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Volume II

APERC
Asia Pacific Energy Research Centre

APEC ENERGY DEMAND AND SUPPLY OUTLOOK

7TH EDITION

VOLUME II

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FOREWORD

The first *APEC Energy Demand and Supply Outlook* was published more than 20 years ago, in September 1998, when the Asia Pacific Energy Research Centre (APERC) was just two years old. Over these past two decades, the Outlook has evolved to present data and analysis through periods of unprecedented growth and rapid change in the energy sector of the Asia-Pacific Economic Cooperation (APEC) region.

Today, the global energy sector is undergoing a rapid transformation as it moves toward more sustainable and lower-carbon systems. The *APEC Energy Demand and Supply Outlook*, 7th Edition highlights the reality that energy choices made in the APEC region will have impacts on energy security and environmental sustainability on the global level. This report examines the gaps between the region's shared goals and current trajectories of APEC economies individually and collectively. Importantly, through scenario modelling, it lays out pathways that can deliver on these goals.

The Business-as-Usual (BAU) scenario illustrates the development pathway that APEC is currently on, which meets the APEC aspirational goal of reducing energy intensity by but falls short of APEC's goal to double the share of renewables in the energy system. The BAU also shows APEC economies failing to meet their Nationally Determined Contribution (NDC) targets under the Paris Climate Agreement.

Recognising the enormity of the challenge ahead for APEC economies, APERC asked *'what will it take?'*. To answer this question, it then modelled two alternative pathways—the APEC Target (TGT) and 2-Degree Celsius (2DC) scenarios—that reveal ways for APEC economies to simultaneously meet their development and sustainability goals.

The primary aim of this Outlook is to support APEC economies in achieving their stated energy goals as they continue to develop and grow. It also aims to serve as a point of reference for those wishing to become more informed about recent energy trends in the APEC region. To that end, the report includes two volumes: Volume I explores key risks and opportunities facing the APEC region as a whole while Volume II presents 21 economy-specific outlooks.

I am pleased to present this Outlook, thanks to the hard work and collaboration by the APERC research team, under the leadership of Mr. James Kendell and Dr. Melissa Lott, and with contributions from experts across the 21 APEC economies and beyond.

Dr. Kazutomo IRIE

President

Asia Pacific Energy Research Centre (APERC)

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SCENARIOS AND STRUCTURE

SCENARIO MODELLING TO SUPPORT DECISION MAKING

To explore the potential implications of the energy transition in APEC economies, the 7th edition of the *APEC Energy Demand and Supply Outlook* examines three scenarios (Table I). The Business-as-Usual (BAU) Scenario is based on key energy demand and supply assumptions that reflect current trends and relevant polices already in place or planned. It provides a baseline against which other scenarios can be compared.

To investigate how specific targets or goals might be achieved, two alternatives analyse different possible trajectories. The APEC Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals, set by APEC Ministers and Leaders, to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level) (APEC EWG, 2018).

The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of further reducing energy intensity, expanding renewables deployment and curbing carbon dioxide (CO_2) emissions. Modelling for the 2DC is underpinned by targets for energy sector emissions reduction that would provide at least a 50% chance of limiting the global average temperature increase to 2°C by 2050. The 2DC is aligned with both APEC aspirational goals as well as global commitments set in the agreement reached in Paris in 2015 during the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the COP21 Paris Agreement.

These alternative scenarios illustrate how the region could meet such goals while also highlighting the opportunities and risks associated with delayed action. As both alternative scenarios require substantial additional investment, the *7th Edition* modelling investigates capital investments and the energy savings incurred through reductions and shifts in energy consumption. Importantly, both scenarios show that on an APEC-wide basis, additional capital costs are more than offset by demand-side savings through reduced fuel costs.

To both improve the usability of these tools and enhance the insights that can be drawn from scenario results, APERC made updates to the modelling suite since the 6th Edition (Box I). All scenarios are explored with a time horizon to 2050, whereas the 6th edition of this Outlook included analysis to 2040.

Table I • Outlook scenarios overview

	Business-as-Usual (BAU)	APEC Target (TGT)	2-Degrees Celsius (2DC)
Definition	Recent trends and current policies.	Enhanced efficiency measures and accelerated adoption of modern renewables to achieve APEC aspirational goals.	Development of low-carbon energy systems to provide a 50% chance of limiting average global temperature increase to 2°C.
Purpose	Illustrates the likely future energy systems if no significant changes occur. Provides a baseline for comparison with and decision making in relation to the alternative scenarios.	Outlines a pathway to simultaneously achieve the APEC aspirational goals to reduce energy intensity and double the share of modern renewables in the energy system, including in electricity generation.	Explores the degree of additional ambition needed to support development of low-carbon energy systems.
Limitations	Assumes that recent trends largely remain consistent in coming years. APEC aspirational goal for doubling renewables is not met.	Greenhouse gas emissions are not constrained.	Does not achieve targets under COP21 Paris Agreement to keep global temperature rise to 'well below 2°C' or to reach net-zero emissions.

STRUCTURE OF THE 7TH EDITION

As was done in the 6th edition of the *APEC Energy Demand and Supply Outlook*, the 7th edition comprises two volumes. Volume I focuses on major energy trends and projections for APEC overall. Volume II is a compendium of energy outlooks for each of the 21 APEC economies.

Volume I includes three parts. Part 1 examines the outlook for energy demand (Chapter 2), the electricity sector (Chapter 3) and energy supply (Chapter 4) in the BAU Scenario, which reflects existing policies and largely assumes that recent trends continue. Part 2 explores two alternative energy sector development pathways, namely the TGT Scenario (Chapter 5) and 2DC Scenario (Chapter 6). The potential implications of these scenarios are investigated in Part 3 with regards to energy investments (Chapter 7), energy security (Chapter 8) and energy trade (Chapter 9). Part 3 concludes with discussion of strategies by which APEC could mitigate climate change (Chapter 10).

Volume II includes a detailed outlook for each of the 21 APEC economies, with each chapter comparing major energy demand and supply trends under all three scenarios. Mirroring Volume I, each chapter then examines the implications of these scenarios in terms of energy investment, security and trade. Each chapter in Volume II concludes with recommendations for future policy action that could support energy security and sustainable development in line with APEC aspirational goals and the COP21 Paris Agreement.

Box I • Model developments incorporated into the *Outlook 7th Edition*

- Model projections have been extended to 2050 in order to capture additional insights on both renewables and emissions trends, particularly in the 2DC Scenario.
- For 11 economies—which represent 95% of APEC energy demand—models now use GDP forecasts from the OECD, enabling more direct comparison of results with other global outlooks.
- The buildings model is primarily activity-driven, allowing for more detailed analysis of the impacts of increasing energy access, fuel switching, technology shifts and social change (e.g. increased teleworking).
- The industry model is now bottom-up, enabling direct analysis of best available technology adoption and structural shifts, as well as explicit accounting of industrial product outputs.
- In the power model, the number of technologies represented was expanded from 19 to 33, and includes two types of energy storage (pumped storage hydro power and batteries) as well as combined heat and power facilities. Daily load curves are included, allowing the model to capture variability in supply and demand while also providing additional insights on the impacts of renewables integration.
- The transport model includes activity-based analysis for both passenger and freight transport, allowing for improved understanding of mode shifting. Light- and heavy-duty vehicle technologies were disaggregated, allowing for detailed analysis of fuel efficiency policies.
- Renewables are distributed among the demand-side and electricity models. Renewable supply potential is included for first- and second-generation biofuels.
- A refinery model was added, including a biorefinery sub-model that explicitly captures the operation of these facilities and evaluates investment and trade potential to 2050.
- A production and trade model was incorporated that captures trade balance dynamics within APEC.
- The investment module was expanded to capture demand-side investment and fuel savings, to complement previous capabilities on supply-side investment.

1. AUSTRALIA

KEY FINDINGS

- **Australia is the sixth-largest energy producer and third-largest energy exporter in the APEC region.** Exports, mainly of coal and natural gas, accounted for 78% of primary energy production in 2016.

- **FED increases modestly in the BAU and the TGT but shrinks in the 2DC.** Improved efficiency, structural changes in the Australian economy and high energy prices all act to slow both population and GDP-led growth.

- **Energy intensity improves by 51% under the BAU, 60% under the TGT and 69% under the 2DC.** Decoupling energy use from economic growth is integral to Australia's CO_2 emissions reduction efforts.

- **Renewable energy resources are outstanding.** Australia's world-class wind and solar resources are projected to contribute to strong renewables growth, especially in the electricity generation sector. Solar generation increases seven-fold in the BAU and nine-fold in the 2DC.

- **Total investment costs are lower in both the TGT and 2DC compared with the BAU,** as marginally higher capital expenditure is outweighed by significantly lower fuel costs.

- **While CO_2 emissions decrease under all three scenarios,** achieving Australia's NDC of reducing CO_2 emissions 26% to 28% from the 2005 level by 2030 is unlikely without additional effort beyond even the 2DC.

ECONOMY AND ENERGY OVERVIEW

Australia is the sixth-largest economy in the world by land area, covering approximately 7.7 million square kilometres (km^2), and the fifth-largest in the Asia-Pacific Economic Cooperation (APEC) region. It lies in the Southern Hemisphere between the Indian and Pacific Oceans and comprises six states and two territories. Most of the population of 24 million lives along the eastern and south-eastern seaboards.

Australia is a globally significant energy producer with huge reserves of coal, natural gas and uranium, and outstanding wind and solar resources. Energy production and exports have been significant drivers of gross domestic product (GDP) and trade growth over the past decade. This has mostly been due to demand growth from other APEC economies, primarily China, Japan and Korea. While production continues to increase, particularly as liquefied natural gas (LNG) projects are finalised in coming years, the explosive growth of the past decade is unlikely to be repeated.

The Australian economy has maintained a robust compound annual growth rate (CAGR) of 2.9% between 2000 and 2016 (Table 1.1) and is the only developed economy in APEC to have recorded uninterrupted annual economic growth over that period (Austrade, 2018). This has occurred during a time of ongoing long-term structural change in the economy. Service sectors such as tourism and education, as well as financial services, continue to grow in importance relative to manufacturing sectors such as oil refining, iron and steel production, and aluminium smelting. Strong population growth and resource extraction (of iron ore, copper, gold, uranium, coal, natural gas and oil) are also significant components of the Australian economy and have underpinned much of the recent GDP growth.

Table 1.1 • Australia: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	723	975	1 149	1 305	1 792	2 348	2 959
Population (million)	19	22	24	25	28	31	33
GDP per capita (2016 USD PPP)	37 920	44 065	47 643	51 401	63 459	76 308	89 159
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	111	129	131	140	150	151	152
TPES per capita (toe)	5.8	5.8	5.4	5.5	5.3	4.9	4.6
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	153	133	114	108	84	64	51
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	70	77	81	84	91	98	103
FED per capita (toe)	3.6	3.5	3.4	3.3	3.2	3.2	3.1
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	96	79	71	64	51	42	35
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	335	386	376	399	412	387	367
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

Australia has enormous coal, natural gas and raw uranium reserves, all of which underpin large exports and have traditionally ensured domestic energy security of those fuels (Table 1.2). Thermal and metallurgical coal supplies, mainly located in the eastern states, are the fifth-largest in the world and amounted to 68 310 million tonnes (Mt) in 2017 (45 540 Mtoe). Lignite reserves in Victoria, while not exported, are the second-largest in the world at 76 508 Mt (25 503 Mtoe). Australia's natural gas reserves of 3.6 trillion cubic metres (tcm) (3 095 Mtoe) are spread around the economy, with the largest found offshore Western and Northern Australia and in Queensland coal seams. Oil reserves are less significant and a considerable amount of domestic production is of condensate and liquefied petroleum gas associated with natural gas fields.

Table 1.2 • Australia: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	144 818	301	14	3	3
Oil (billion bbl) [a]	4	32	0.24	26	7
Natural gas (tcm) [a]	3.6	32	1.9	12	4
Uranium (tU) [b]	1 269 800	219	33	1	1

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. tU = tonnes of uranium. a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kgU.
Sources: For coal, oil and natural gas, BP (2018). For uranium, NEA (2018).

Australia's solar resources are world-class and comprise hundreds of thousands of square kilometres of highly irradiated, lightly populated land (Geoscience Australia, 2018a). Wind resources in the south, south-west and south-east are also outstanding and benefit from the 'roaring forties'—the powerful winds that circumnavigate the Southern Hemisphere. Wave energy resources are also exceptional in the south, south-west and south-east, while northern Australia has significant tidal potential. As the world's driest inhabited continent, there are limited prospects for further hydro development, except as pumped storage.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Australian energy policy has become increasingly politicised since the last edition of the Outlook. Agreement within and across government as to the challenges posed by climate change, and the best way to achieve Australia's greenhouse gas (GHG) emissions reduction targets, has become increasingly difficult to find. This situation has led to considerable uncertainty in a number of key areas of energy policy and was brought to a head in late 2016 when South Australia experienced a rare 'system black' event—the total shutdown of power supply to the grid.

The federal government's response was to establish the *Independent Review into the Future Security of the Electricity Market* (Environment, 2018a). The key issue tackled by the Review surrounds the energy trilemma: the need to deliver energy securely, affordably and sustainably. The review made over 40 recommendations, including that a clean energy target be introduced. Most of the recommendations have been accepted and are in the process of being implemented. The government's energy security board (the establishment of which was one of the first recommendations of the Review to be implemented) proposed that a National Energy Guarantee (NEG), rather than a clean energy target, be set up to reduce GHG emissions. Following a change of leadership in late 2018, the Australian government shelved the NEG and has declared its intention to focus instead on lowering power prices.

Recent years have also seen more active policy-making by state and territory governments. South Australia has begun directly intervening in the energy market by funding natural gas, diesel and battery peaking capacity, and establishing a 'virtual power plant' (solar rooftop and battery storage controlled by the market operator) (South Australia, 2018). In Victoria, the state government has established a Renewable Energy Target (RET) of 40% by 2025, with zero emissions by 2050 (Victoria, 2018). Queensland's RET is 50% by 2030 with zero emissions by 2050 (Queensland, 2018) and the Australian Capital Territory's RET is 100% by 2020, with zero emissions by 2050 (ACT, 2018). These policies will likely improve energy sustainability and renewables penetration, but may also place strain on the highly integrated east coast system.

Eastern Australian natural gas markets are also undergoing a period of profound change as new LNG supply capacity in Queensland links domestic and international markets for the first time. Security of supply concerns led to the development of the Australian Domestic Gas Security Mechanism (ADGSM) in 2017. The mechanism allows the government to limit the exports of LNG producers if there is a supply shortfall in the domestic market (Industry, 2018a). The Australian Energy Market Operator forecasts that sufficient natural gas will be available for the east coast market in 2019 and beyond, but highlights the fine balance of the market and its susceptibility to shortages as a result of weather-driven demand spikes (AEMO, 2018).

Despite the uncertainty in electricity and natural gas markets, renewable energy continues to expand, assisted by the large-scale RET, which mandates an additional 33 terawatt-hours (TWh) of renewable electricity generation by 2020 (Environment, 2018b). When combined with the small-scale scheme [1] and existing renewables generation, the government expects the RET to lead to around 24% of Australia's electricity being generated from renewable sources in 2020. The Australian solar industry had a banner year in 2017 as annual residential solar photovoltaic (PV) installations surged to 1.0 gigawatts (GW), reaching 6.4 GW in total, despite the reduction or abolishment of most feed-in tariffs (AEC, 2018). Utility-scale solar PV has also been gaining momentum as capital costs fall and wholesale electricity prices, driven by rising natural gas prices, remain high. The national electricity market now has more than 2.0 GW of installed utility-scale solar PV, with another 1.7 GW of projects under construction or committed (CER, 2018). The National Energy Productivity Plan (NEPP), released in 2015, aims to increase Australia's energy productivity by 40% during the period 2015-30 (Environment, 2018c) but relies more on existing policies and structural changes in the economy than on funding for ambitious new energy efficiency goals.[2]

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy assumptions and projections for Australia under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 1.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

[1] The small-scale renewable energy scheme creates a financial incentive for individuals and small businesses to install eligible small-scale renewable energy systems such as solar PV.

[2] Energy productivity refers to the amount of energy consumed in the economy relative to GDP. As such, structural changes in the Australian economy, such as growth in the services sectors relative to industrial sectors, is a key driver of improved energy productivity. Energy efficiency is also an important component of energy productivity.

Table 1.3 • Australia: Key assumptions and policy drivers under the BAU

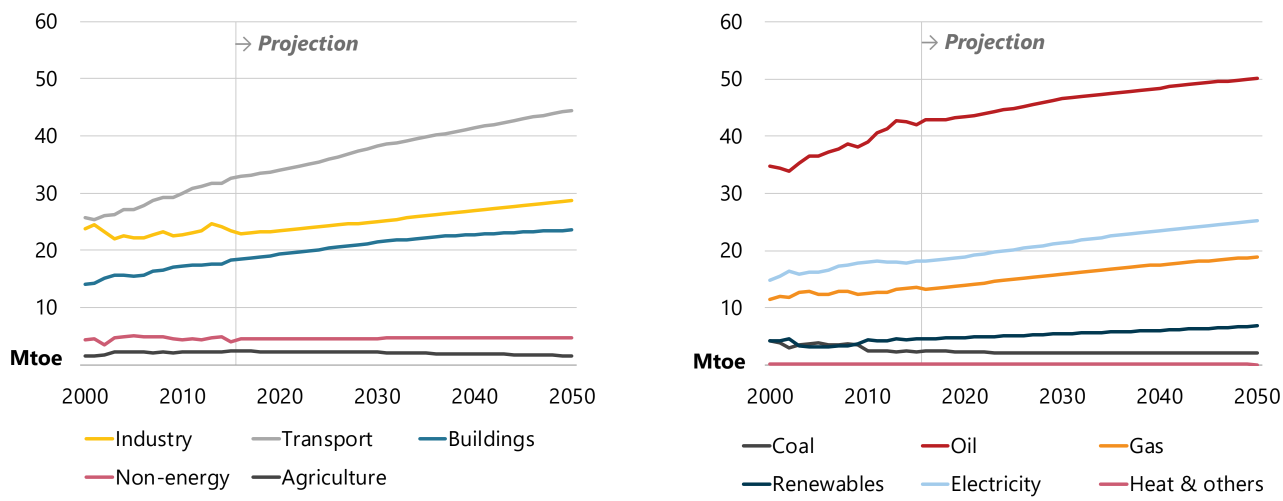
Buildings	Minimum energy performance standards and labelling maintained at current levels. Building envelopes improve moderately.
Industry	No new industry policy.
Transport	Labelling and reliance on international standards to drive improved efficiency. Market-determined deployment of EVs.
Energy supply mix	Continued growth in natural gas and coal production underpinned by large reserves and global demand. No new oil reserves found.
Power mix	East coast natural gas reserves are sufficient to support new generation post-2025. No nuclear or new coal-fired power plants. Snowy Hydro 2.0 not built under the BAU.
Renewables	Strong growth in solar and wind, driven by the RET and cost competitiveness.
Energy security	Implementing a phased return to compliance with IEA stockholding obligation, including through a pilot purchase of up to 0.40 Mtoe of oil tickets.
Climate change	Economy works towards NDC of 26% to 28% below the 2005 level by 2030 (but does not achieve it).

Notes: EVs = electric vehicles. IEA = International Energy Agency. NDC = Nationally Determined Contributions. RET = Renewable Energy Target. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

As the Australian economy has grown consistently over the past 25 years, so too has final energy demand (FED). The buildings and transport sectors have been the main drivers of this growth, which like GDP, is closely aligned with a growing population. These trends are projected to continue for both sectors, though more slowly than the historical rate owing to efficiency improvements throughout the Outlook period (2016-50) (Figure 1.1). Industrial energy demand has been almost unchanged since 2000, as the expansion of the mining sector has largely compensated for shutdowns and reduced demand in the iron and steel sector. Over the Outlook period, however, demand increases gently, mainly in less trade-exposed sectors. Growth in the agriculture sector has been modest in recent years, but it decreases slightly to 2050 under the BAU, as improved efficiency (mainly of tractors) offsets some increased activity.

Figure 1.1 • Australia: Final energy demand by sector and fuel, 2000-50

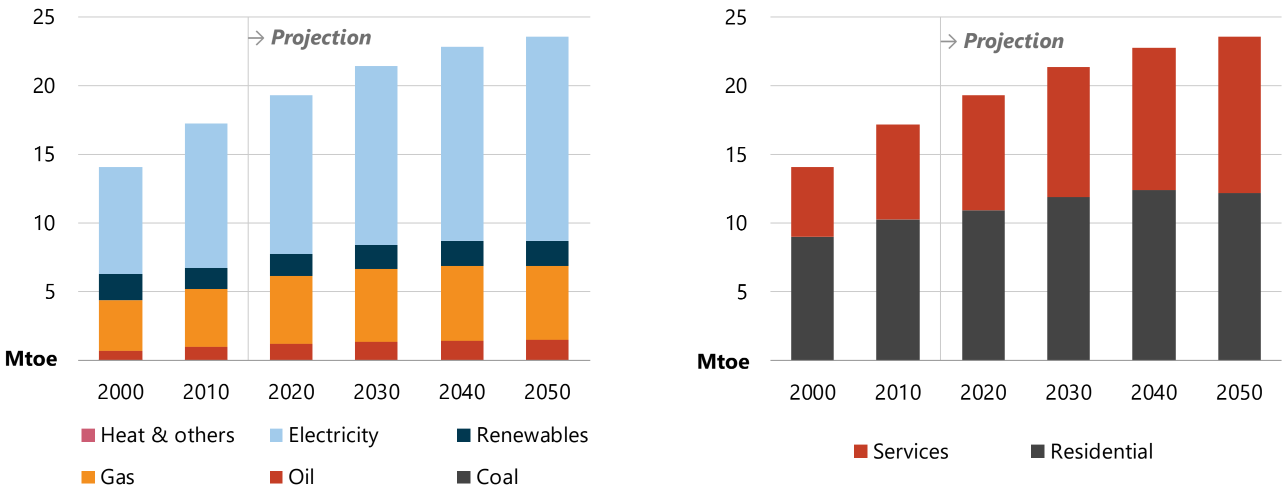


Sources: APERC analysis and IEA (2018a).

BUILDINGS: STEADY DEMAND GROWTH

Energy demand in the two buildings subsectors (residential and services) continues to rise under the BAU, at a CAGR of 0.73% over the Outlook period, despite high natural gas and electricity prices (due in part to policy and political issues discussed earlier) and continued energy efficiency improvements (Figure 1.2). Strong population and GDP growth, and structural shifts in the economy, away from industry and towards services, compensate for these deflationary effects.

Figure 1.2 • Australia: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Electricity accounted for 59% of FED in the buildings sector in 2016, but the share increases to 63% in 2050 under the BAU, growing at a CAGR of 0.92%. The residential subsector accounted for 57% of buildings FED in 2016 but loses share slightly to services (falling to 52% by 2050) due to ongoing structural changes in the Australian economy over the Outlook period.

Residential subsector demand, which has been rising steadily, continues this trend until 2040 when it peaks at 12 Mtoe. By the end of the Outlook period demand tails off slightly as the effects of efficiency improvements outweigh population growth. The number of households increases from 9.2 million in 2016 to 14 million in 2050, at a 1.2% CAGR (slightly higher than the population CAGR of 0.94% over the same period because of decreasing household size[3]). Floor area per household increases slightly throughout the projection period, reaching an average of 195 square metres (m^2) in 2050 (from 187 m^2 in 2016) as apartments account for a larger share of the residential stock, which dampens the effects of growing stand-alone house size.

In the medium term, space cooling becomes the fastest-growing residential end-use as air conditioning penetration rates continue to rise. Energy use for space cooling, therefore, increases 48% by 2030, and then rises more modestly for the remainder of the Outlook period. Water and space heating energy use also expands rapidly in the medium term before flattening around 2030 as saturation and improved efficiency offset continued growth in household numbers and house size. Apart from some expansion in electricity (increasing from 48% to 54%), which largely comes at the cost of gas, most fuel types maintain the same shares over the Outlook period. Renewables remain flat in space heating (as electricity and natural gas continue to be promoted

[3] In terms of people per dwelling.

over biomass to improve air quality), but their share increases more strongly in water heating with further deployment of solar thermal water heaters.[4]

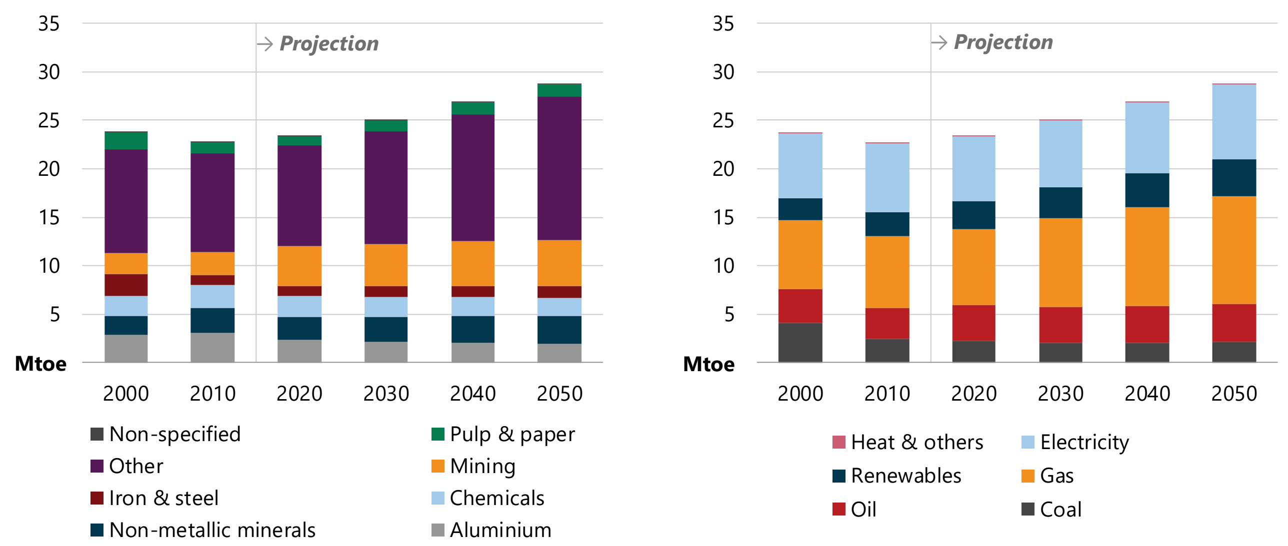
Under the BAU, energy demand in the services subsector rises at a CAGR of 1.1% over the Outlook period and peaks at 11 Mtoe in 2050. Service floor area increases more strongly (75%) than energy demand (44%) in the period 2016-50 due to efficiency improvements. This is most evident in space heating, where energy demand rises slowly (CAGR of 0.33%), especially in the latter half of the Outlook period.

Services subsector end-uses follow similar trends to the residential sector. Energy demand for space cooling, as well as for space and water heating, rises in the medium term before flattening around 2030 owing to efficiency improvements. The largest growth is in the 'other' subsector, which includes appliances and electronics such as computers, which become more pervasive in the sector. No significant changes in the fuel mix are projected for the services subsector, and electricity remains dominant with around 73% of FED in both 2016 and 2050.

INDUSTRY: MODEST 'OTHER' GROWTH

Energy demand in industry has increased marginally over the past decade, mainly due to growth in the mining subsector driven by the mining boom of 2011-14. The associated appreciation of the Australian dollar, however, adversely affected a number of other trade-exposed industries (The Treasury, 2017). A symbolic example of this was the shutdown of Holden's Elizabeth plant in South Australia—the last car manufacturing operation in Australia—in 2017, after 54 years in business. Industry sector energy demand continues to increase modestly over the Outlook period as mining and less trade-exposed sectors, such as non-metallic minerals and food processing (categorised in the 'other' subsector), move with the economy (Figure 1.3).

Figure 1.3 • Australia: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy demand in the mining subsector has doubled in the past decade, from 2.0 Mtoe in 2006 to 4.0 Mtoe in 2016. This growth is mainly the result of enormous expansion in iron ore production capacity in Western Australia, which in 2017 produced more iron ore than the next three-largest producers—Brazil, India and China—combined (Western Australia, 2018). This once-in-a-lifetime growth, almost entirely to supply explosive demand from China, has resulted in oil and electricity use growing rapidly to supply trucks, railways, mining equipment

[4] Solar PV is modelled in the electricity sector, so strong growth in that fuel type is reflected in increased electricity demand rather than for renewables in residential buildings.

and off-grid generation. Mining energy demand grows more modestly over the Outlook period, however (reaching 4.8 Mtoe in 2050), as production stabilises.

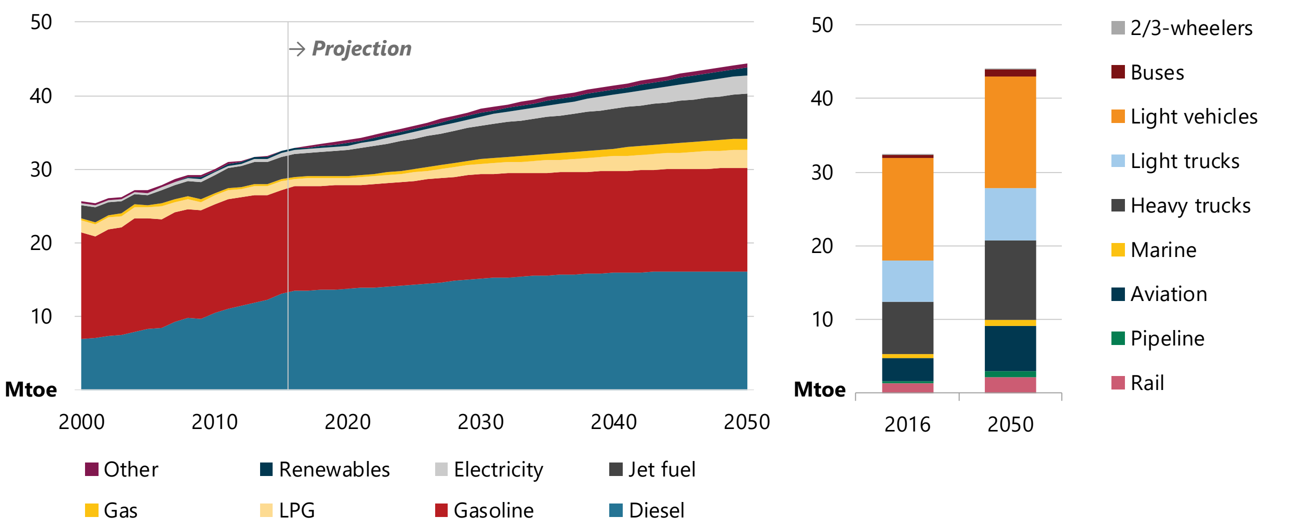
Energy demand rises steadily in the non-metallic minerals (0.83% CAGR), iron and steel (0.88% CAGR), pulp and paper (0.88% CAGR), and other subsectors (1.2% CAGR) over the Outlook period, in line with economic growth. Demand in the non-metallic minerals and iron and steel subsectors in particular rise with expanding floor area in both residential and services buildings. Energy demand in aluminium and chemicals falls in the face of stiff competition from abroad and rising energy costs at home.

Oil demand has increased steadily in recent years because diesel is the fuel of choice for off-grid mining operations. The trend does not continue under the BAU, however, as mining sector activity slows over the Outlook period. Demand growth is modest for natural gas (1.3% CAGR) and electricity (0.43% CAGR), and they are used mainly in the 'other' subsector.

TRANSPORT: STEADY GROWTH, PARTICULARLY FROM AVIATION

Domestic transport is Australia's largest FED sector, accounting for 41% of total demand (33 Mtoe) in 2016. Demand continues to increase over the Outlook period, peaking at 44 Mtoe in 2050 despite improvements in conventional engine efficiency and significant penetration of hybrid and electric vehicles in the road fleet. Diesel and gasoline shrink from a combined 84% of domestic transport energy use in 2016 to 68% in 2050, while jet fuel expands from 9.5% to 14% over the same period (Figure 1.4).

Figure 1.4 • Australia: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy demand in road transport grows moderately, as stock expansion (driven mainly by population growth) outweighs improved efficiency. Under the BAU, average passenger vehicle fuel efficiency improves from 2.0 megajoules per passenger kilometre (MJ per pkm) to 1.4 MJ per pkm, and freight average efficiency rises from 0.63 MJ per tonne-km (tkm) to 0.53 MJ per tkm. Australia has labelling standards (the Green Vehicle Guide) and emissions standards but lacks vehicle efficiency standards. It is therefore up to Japan, Korea, the United States and Europe (among others) to continue pushing international manufacturers to improve the efficiency of cars that will ultimately be sold in Australia.

Jet fuel use almost doubles over the Outlook period, as Australia's enormous land mass and dispersed but large cities lend themselves most to air travel (as opposed to high-speed rail, for example). While fuel switching is unlikely under the BAU, efficiency does improve (from 1.6 MJ per pkm to 1.4 MJ per pkm in passenger air travel). This is not enough, however, to compensate for the doubling of passenger air kilometres flown (71 billion km to 165 billion km) over the Outlook period.

Australian governments are investing significantly in transport infrastructure to alleviate the congestion resulting from strong population growth. A number of new rail projects expanding the metro systems in Melbourne (the AUD 11 billion [USD 7.9 billion][5] Metro Tunnel), Sydney (the AUD 8.3 billion [USD 5.7 billion] Metro Northwest) and Perth (the AUD 2.0 billion [USD 1.4 billion] Metronet) are currently under construction (Infrastructure Australia, 2018). A significant upgrade to Australia's freight-handling inland rail network (the AUD 10 billion [USD 7.2 billion] Inland Rail) is also under construction, which underpins a 58% increase in the use of oil products in the rail sector through the Outlook (inter-city train lines are generally not electrified in Australia because of the long distances).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Energy demand in Australia's transformation sector has grown steadily since 2000 as energy industry own-use for oil and gas extraction and coal mining have compensated for refinery closures. Fuel supply for electricity generation rose steadily in the decade from 2000-10 but peaked in 2011 as residential demand fell and more efficient natural gas and renewables entered the generation mix. Total primary energy supply (TPES), trade and production are dominated by fossil fuels, a trend that continues under the BAU. However, the fuel mix changes as the natural gas share increases against coal over the Outlook period.

ENERGY INDUSTRY OWN-USE: REFINING SLOWS AS OIL AND GAS DEMAND INCREASES

Energy use in the refinery sector has fallen sharply in recent years with the shutdown of the Clyde refinery in 2011, Kurnell refinery in 2012 and Bulwer Island refinery in 2014. Australia has four remaining refineries, the newest of which was commissioned in 1965. The economy now imports a larger proportion of refined products directly instead of refining predominantly imported crude oil. This trend, combined with increased demand in mining and transport, has added to Australia's net imports of petroleum products under the International Energy Agency (IEA) oil stockholding methodology.[6] Refinery inflows and energy own-use stabilise at 22 Mtoe (much below the high of 39 Mtoe recorded in 1998) and 1.4 Mtoe over the Outlook period, as petroleum product imports grow with demand.

Energy industry own-use grew strongly (4.7% CAGR) during the period 2000-16 as the coal and natural gas sectors expanded rapidly in support of Australia's escalating energy exports. This growth continues under the BAU as energy use for oil and gas extraction increases 34% in 2016-25 (when seven new LNG projects finish commissioning); it then stabilises over the remainder of the Outlook period.

POWER SECTOR: LARGE CAPACITY GROWTH IN RENEWABLES

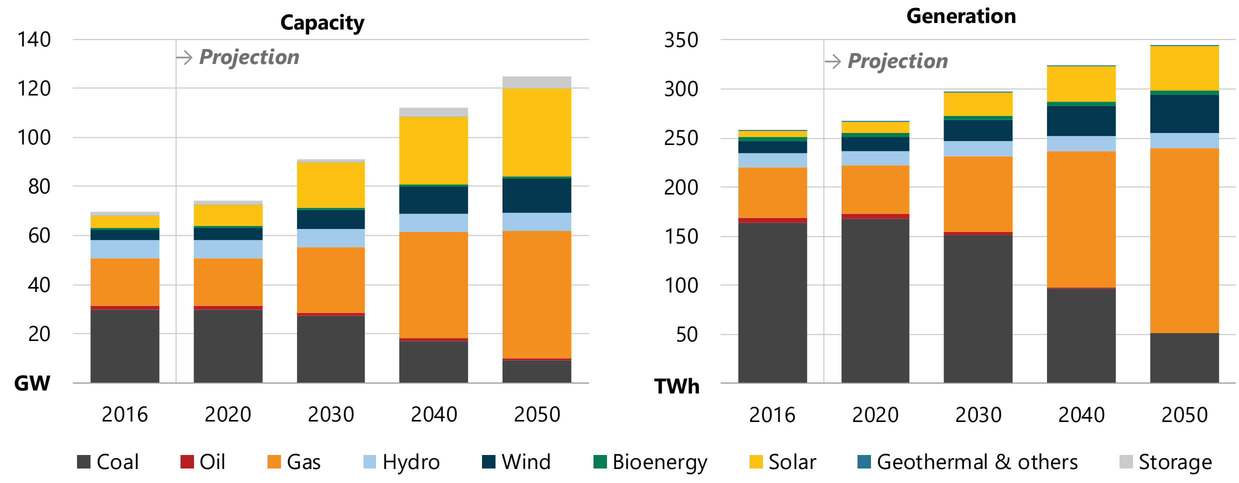
The National Electricity Market (NEM), the interconnected network spanning the eastern and southern states (Queensland, New South Wales, the Australian Capital Territory, Victoria, Tasmania and South Australia), accounts for 80% of the electricity produced in Australia. The remainder is generated in the South West

[5] All conversions in this chapter are at AUD 0.72 = USD 1, the exchange rate on 17 December 2018.
[6] As a member of the IEA, Australia is obliged to hold emergency stocks equivalent to 90 days of net imports. See the energy security and trade section of this chapter for further information.

Interconnected System (SWIS, based around Perth in Western Australia), the North West Interconnected System (NWIS, based around the mining operations in the Pilbara), the Darwin-Katherine Interconnected System (DKIS, based in the Northern Territory) and off-grid mining operations.

The NEM has historically been highly dependent on coal, reflecting plentiful resources in the eastern states. Enormous lignite reserves in Victoria's Latrobe Valley and thermal coal in the Hunter Valley in New South Wales and Surat-Bowen Basins in Queensland support a large number of aging subcritical thermal power plants in Australia's three most populous states (Figure 1.5). The SWIS, NWIS and DKIS rely more on natural gas, supported by Western Australia's domestic natural gas reservation policy, and petroleum products.

Figure 1.5 • Australia: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

Natural gas-fired power generation doubled over the past decade driven by the Queensland Gas Scheme,[7] new technologies opening up coal seam gas (CSG) reserves and the development of huge offshore discoveries in Western Australia. Under the BAU, this trend does not continue in the near term given high prices and market tightness. Post-2025, natural gas generation begins to rise again, however, as aging coal-fired plants begin to shut down and new high-efficiency combined-cycle natural gas-fired plants replace them.

Electricity generation from renewable energy resources in Australia has historically been dominated by hydropower, but this has been changing in recent years. From 2010 to 2016, wind generation more than doubled and solar increased more than fifteen-fold. Wind power capacity continues to increase significantly, at a CAGR of 3.5% over the Outlook period, supported by the RET and falling costs. Solar capacity increases even more strongly, at a CAGR of 6.0%, as robust recent growth in residential PV is joined by an increasing amount of commercial and utility-scale PV, and solar thermal generation. These capacity additions result in renewables accounting for 30% of electricity generation in 2050, compared with 14% in 2016.

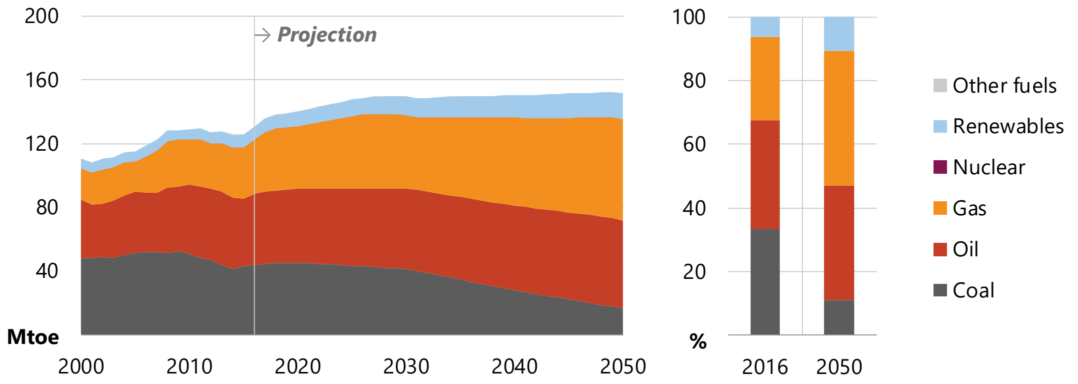
TOTAL PRIMARY ENERGY SUPPLY: FOSSIL FUELS REMAIN ON TOP

Australia's TPES is dominated by fossil fuels, which accounted for 94% of the total in 2016. Oil overtook coal in 2014 to become the largest source of TPES for the first time in over two decades and now accounts for a 34% share. This shift was driven by the growth of natural gas (4.0% CAGR over the last decade), which has been displacing coal in power generation, to reach 26% of TPES in 2016. Renewables use has expanded at a CAGR of

[7] The Queensland Gas Scheme commenced in 2005 and required electricity retailers to source 15% of the electricity they sold or used in Queensland from gas-fired generation. The scheme was discontinued in 2013.

2.2% since 2006, to reach 6.3% of TPES in 2016, as residential-scale solar PV and utility-scale wind power shares increased in the electricity sector (Figure 1.6).

Figure 1.6 • Australia: Total primary energy supply by fuel, 2000-50



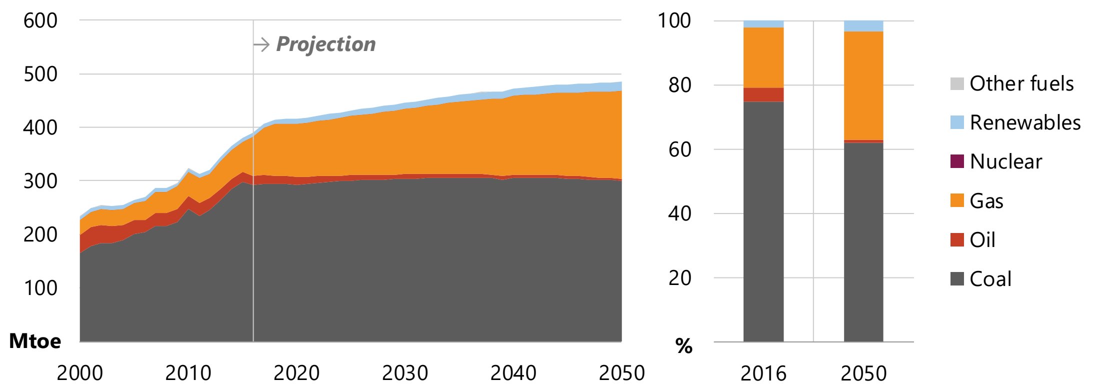
Sources: APERC analysis and IEA (2018a).

Natural gas expands to become dominant in the fuel mix from 2037 onwards (reaching 42% in 2050). This growth is driven in the short term by new LNG plants coming online, and in the medium to long term by the replacement of aging coal plants with new combined-cycle natural gas-fired power stations. Oil retains its share of TPES as it remains dominant in transport. Renewables increase to 11% of the energy mix in 2050 as residential and utility-scale solar and wind continue to expand.

ENERGY PRODUCTION AND TRADE: CONTINUED GROWTH DRIVEN BY APEC DEMAND

Australian energy production increased by two-thirds in 2000-16, largely as a result of expanding coal production (mostly metallurgical), which supported growing exports to other APEC economies, mainly China (Figure 1.7). Natural gas production has also expanded rapidly in recent years as Australia increased its share of Japan's LNG imports and met growing demand from China and India. Oil production has shrunk, however, as conventional fields mature, and it does not return to previous levels over the Outlook period even though the production of associated liquids at large offshore natural gas projects increases to 2020. Australia also produces and exports a significant amount of raw uranium (7 000 tonnes in 2017), making it the third-largest producer in the world (Industry, 2018b) (however, statistics in this chapter cover only enriched uranium). Although renewable energy production is expanding, it has historically been dwarfed by fossil fuels.

Figure 1.7 • Australia: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Australian energy production and trade are dominated by coal over the Outlook period, with a moderate increase until 2040 in response to growing demand in APEC export markets. Growth in production of metallurgical coal, 95% of which is exported, exceeds shrinking thermal coal production. Natural gas becomes increasingly important, more than doubling from 73 Mtoe in 2016 to 164 Mtoe in 2050, also to support increasing exports. Oil production continues to decline as mature fields are depleted. Although renewables expand significantly to overtake oil production around 2026, the share remains small (2.1% in 2016 to 3.4% in 2050) compared with coal and natural gas.

Box 1.1 • Australia: Solar power

Australia has a long history with solar power, from the Commonwealth Science and Industrial Research Organisation's development of the world's first solar hot water systems in the 1950s, to the 1989 breakthrough at the University of New South Wales by researchers who were the first to achieve 20% efficiency rates in PV panels. Australia now has one of the world's leading uptake rates of household PV systems at 20% nationally, and over 30% in South Australia (IEA, 2018b; APVI, 2018).

Australia's success with solar PV results from a number of factors, including:

- Outstanding solar resources. Australia has the best solar irradiance per square metre of any continent and consequently some of the best solar energy resources (Geoscience Australia, 2018b).
- Rising retail electricity costs. Electricity costs for households have more than doubled over the past decade, far exceeding inflation (ABS, 2018).
- Falling system costs. Average prices for wholesale modules have fallen from AUD 3.2 (USD 2.3) per watt (W) in 2010 to AUD 0.80 (USD 0.57) per W in 2015, which has contributed to installation costs for residential systems (smaller than 10 000 W) falling from AUD 6.0 (USD 4.3) per W to AUD 2.5 (USD 1.8) per W over the same period (IEA, 2018b).
- Strong government support for the sector. The federally administered small- and large-scale renewable energy targets coupled with financial assistance from the Australian Renewable Energy Agency and the Clean Energy Finance Corporation have combined with state-based feed-in tariffs and renewable energy goals.

These factors contributed to the deployment of 7.2 GW of solar PV in Australia by 2017, the fourth-largest capacity in APEC (IEA, 2018b). Since the first is not replicable and the second is not desirable, active government support for the sector, including to reduce costs, could help achieve the APEC-wide goal of doubling the share of renewables by 2030.

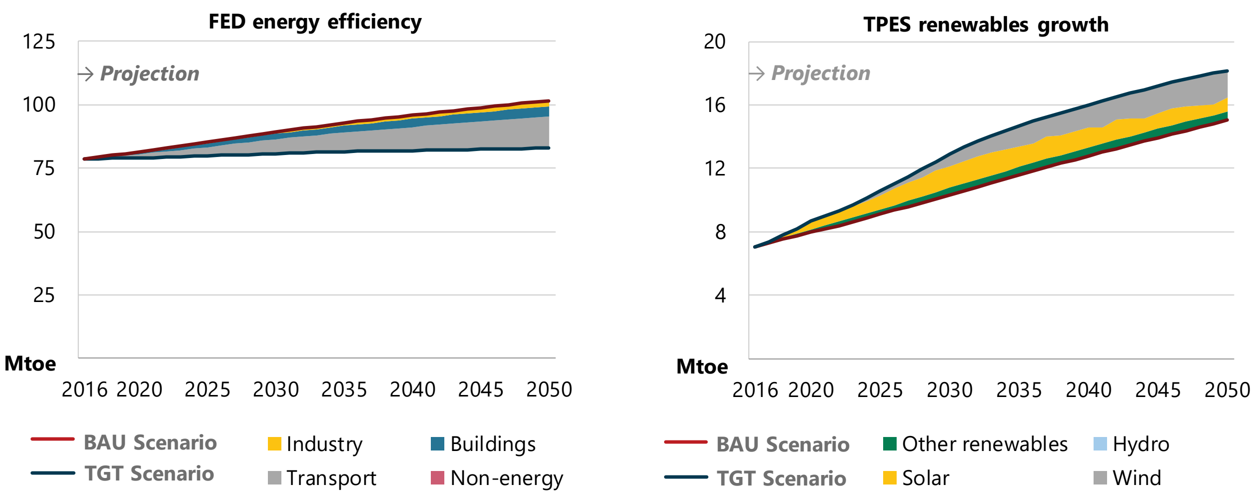
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to reflect Australia's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The APEC Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 18% lower and CO_2 emissions are 21% lower in the TGT by 2050. Under the 2DC, Australia's FED is 36% lower and CO_2 emissions are 60% lower in 2050. The share of renewables in TPES is 43% higher in the TGT and 109% higher in the 2DC by 2050, compared with the BAU.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. The assumptions required to achieve the TGT consist of numerous sectoral-level policy changes, such as more stringent fuel efficiency regulations in the transport sector and higher building and appliance standards. An increase in renewables use is achieved through stronger government support that reduces deployment costs (Figure 1.8). With appropriate policy support, all of these assumptions are realistic and achievable in Australia without radical lifestyle or economic changes.

Figure 1.8 • Australia: Energy efficiency and renewables development, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Source: APERC analysis and IEA (2018a).

Improved energy efficiency in the TGT is achieved mainly in transport and buildings and results in FED decreasing by 19 Mtoe in 2050, compared with the BAU. Improved fuel efficiency, as a result of stronger fuel economy regulations, and better public transport and infrastructure result in a 12 Mtoe reduction in transport by 2050, compared with the BAU. In buildings, higher efficiency owing to stronger building and electric appliance regulations are the key drivers of a 4.1 Mtoe improvement by 2050. Industry demand is only 2.2 Mtoe lower in 2050 under the TGT, as most industrial processes are already utilising best available technologies (BATs). Cumulative improvements in the TGT amount to a 345 Mtoe energy demand reduction over the Outlook period compared with the BAU.

In the TGT, 3.2 Mtoe more renewables are deployed in 2050 (of 19 Mtoe total) than in the BAU, mainly in the electricity sector. More government support and implicitly lower cost assumptions result in an additional 1.7 Mtoe of wind and 0.90 Mtoe of solar PV. Combined with the lower electricity demand in this scenario (as a result of greater energy efficiency improvements), this increase in wind and solar PV results in renewables accounting for 42% of the electricity mix in 2050 compared with 30% in the BAU. Cumulatively, an additional 83 Mtoe of renewables are deployed over the Outlook period (out of 515 Mtoe total) in the TGT compared with the BAU.

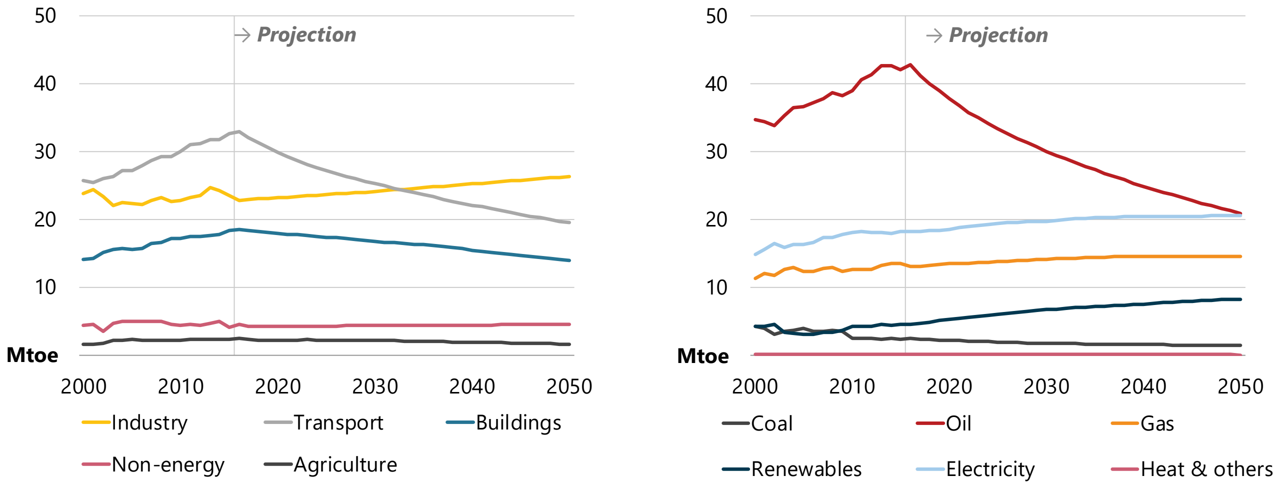
TWO-DEGREES CELCIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Australia will have to undergo varying levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

The most effective means of reducing carbon dioxide (CO_2) emissions in Australia's FED sectors is through energy efficiency improvements in transport and buildings. Decarbonisation of industry and non-energy sectors is challenging, as fossil fuels are a vital component of many industrial processes, especially in the aluminium, iron and steel, and chemical and petrochemical subsectors. The 2DC results in FED shrinking over the Outlook to 66 Mtoe in 2050 (from 81 Mtoe in 2016), compared with 103 Mtoe in the BAU (Figure 1.9).

Figure 1.9 • Australia: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy demand for domestic transport declines by 41% over the Outlook period, falling from 33 Mtoe in 2016 to 19 Mtoe in 2050. The transport pathway is mirrored by oil demand in FED, which also falls steadily to 2050. Significant changes in the composition and efficiency of the vehicle fleet and a decrease in tonne and passenger kilometres are instrumental to this projection. The light-duty vehicle (LDV) stock expands from 14 million to 19 million, slightly less than in the BAU, but with more than 16 million technologically advanced vehicles by 2050. Battery electric vehicles expand particularly rapidly to account for 57% of total LDVs in 2050. This projection is dependent on strong support at all levels of government as well as continued cost reductions in existing technologies. Other transport subsectors such as aviation and heavy-duty trucks are much more challenging to decarbonise, so require aggressive efficiency improvements, improved capacity factors and significant modal shifts (from road to rail, for example).

FED in the buildings sector has the second-largest decrease, shrinking from 18 Mtoe in 2016 to 14 Mtoe in 2050. There is also a significant change in the energy mix as the share of oil falls by almost a half and natural gas decreases by almost two-thirds while renewables more than double. This transformation results from improved building envelopes, which significantly cut energy demand for space heating and reduces growth in space cooling. Increased deployment of renewables is mainly in the form of solar-powered water heating in the residential sector and some advanced biofuels and geothermal (solar PV is modelled in the electricity sector).

Under the 2DC, industrial energy demand decreases moderately, as most subsectors have already adopted BATs and fossil fuels are integral to many industrial processes. Improved recycle rates in iron and steel and clinker-to-cement ratios in non-metallic minerals surpass the levels achieved in the TGT. Renewables use increases slightly as advanced biomass is deployed in all sectors to substitute for coal and natural gas. Restricted deployment of coal and natural gas with carbon capture and storage (CCS) is assumed to limit CO_2 emissions from subsectors with limited fuel switching opportunities by 2050 (e.g. chemical and petrochemical).

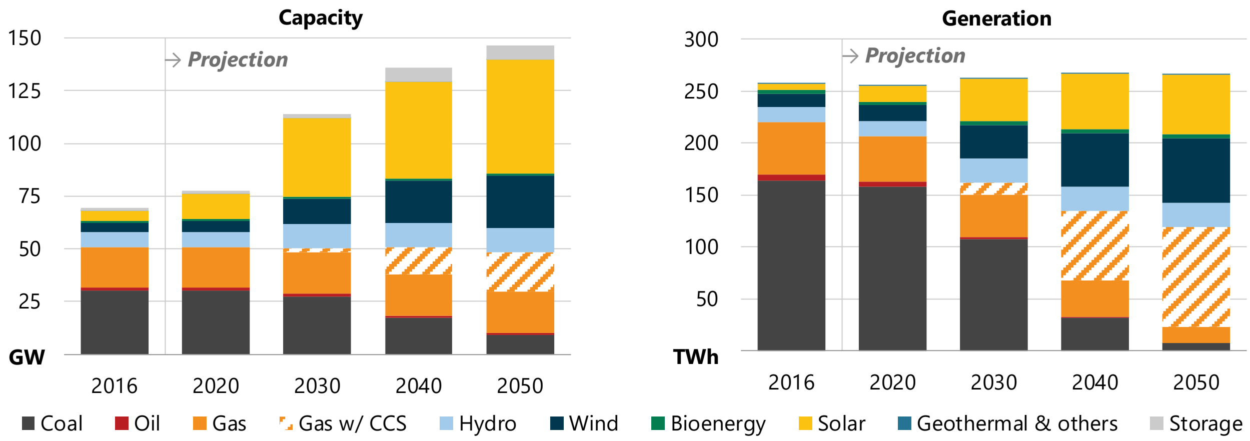
TRANSFORMATION AND SUPPLY IN THE 2DC

Decarbonisation of the refinery and energy industry own-use sectors is particularly difficult, for reasons similar to those of many industrial subsectors. Substituting fossil fuel use in the coal mining and oil and gas subsectors is generally neither practical nor financially viable. As such, no renewables are projected to be deployed in these or the refinery sectors even in the 2DC. Improved efficiency combined with significantly lower production of coal and slightly lower natural gas production by 2050 are the main reasons for energy industry own-use decreasing slightly over the projection period (compared with a 4.5 Mtoe increase in the BAU). As Australia remains a net petroleum product importer throughout the Outlook period, refinery production and energy use remain unchanged in all scenarios.

In contrast to other transformation sectors, electricity undergoes fundamental changes under the 2DC as coal is almost entirely eliminated from the fuel mix by 2050. Total electricity generation increases slightly, from 257 TWh in 2016 to 266 TWh in 2050 (compared with 344 TWh in the BAU). This decrease in comparison with the BAU results mainly from lower buildings electricity demand, which is partially offset by a doubling in electricity demand from transport.

In power generation, the fuel mix changes significantly under the 2DC compared with both the BAU and TGT as a transformative quantity of solar PV is deployed. Solar capacity increases eleven-fold over the Outlook period, reaching 54 GW in 2050 (to account for 37% of total power capacity). Wind capacity also expands strongly, to 25 GW in 2050. Due to the lower capacity factors compared with fossil fuels, however, solar accounts for only 22% of total electricity generation in 2050, and wind for 23%. Renewables overall increase to 55% of total generation by 2050 (Figure 1.10). Expansion in these two generation technologies results from a carbon constraint placed on the sector, which acts like an implicit average CO_2 price of USD 150 per tonne in the 2040s, as well as from the relative cost competitiveness of solar and wind against fossil fuel technologies.

Figure 1.10 • Australia: Power capacity and electricity generation in the 2DC by fuel, 2016-50

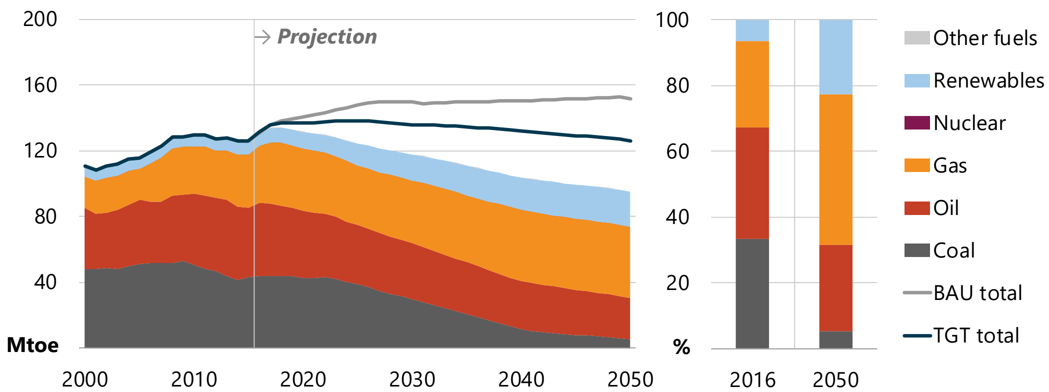


Note: CCS= carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

CCS is integral to decarbonise Australia's fossil fuel-intensive electricity sector, particularly later in the Outlook period. In Australia, CCS is assumed to become viable from 2030 onwards, by which point coal is mostly phased out. Combined-cycle natural gas turbines, both new and existing, are therefore the main recipients of CCS, which reaches 19 GW of capacity in 2050. Nuclear energy is assumed to be unavailable over the Outlook period for socio-political reasons, despite Australia's enormous uranium reserves, and stable geology and institutional systems.

Under the 2DC, TPES is transformed as coal nearly disappears, similar to the electricity sector. The share of oil in the fuel mix also decreases as natural gas becomes dominant, accounting for 45% of TPES in 2050 (compared with 26% in 2016). Renewables more than triple over the Outlook period to 22% in 2050 (Figure 1.11). The drastic fall in coal results from power sector decarbonisation, as natural gas with CCS becomes the dominant source for electricity generation. Similarly, the majority of renewables growth occurs in the electricity sector. The fall in oil can be attributed to transport as efficiency improves and a more technologically advanced vehicle fleet, including hybrid and battery electric vehicles, is deployed.

Figure 1.11 • Australia: Total primary energy supply in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Australia's primary energy production and net trade are completely dominated by fossil fuels, which in 2016 accounted for 98% of total production (390 Mtoe). The 2DC results in significantly lower demand for fossil fuels both in Australia and around the world, reducing Australia's energy production and trade, particularly of coal. Natural gas production continues to rise to 2030 but flattens over the remainder of the Outlook period.

Australian exports are projected to fall from 309 Mtoe in 2016 to 171 Mtoe in 2050, with coal exports decreasing by more than half. Crude oil imports are relatively flat in the 2DC as refineries continue to operate just below current capacity (23 Mt per year). Petroleum product imports are most impacted by lower demand in 2050, falling to 11 Mtoe from 27 Mtoe in 2016.

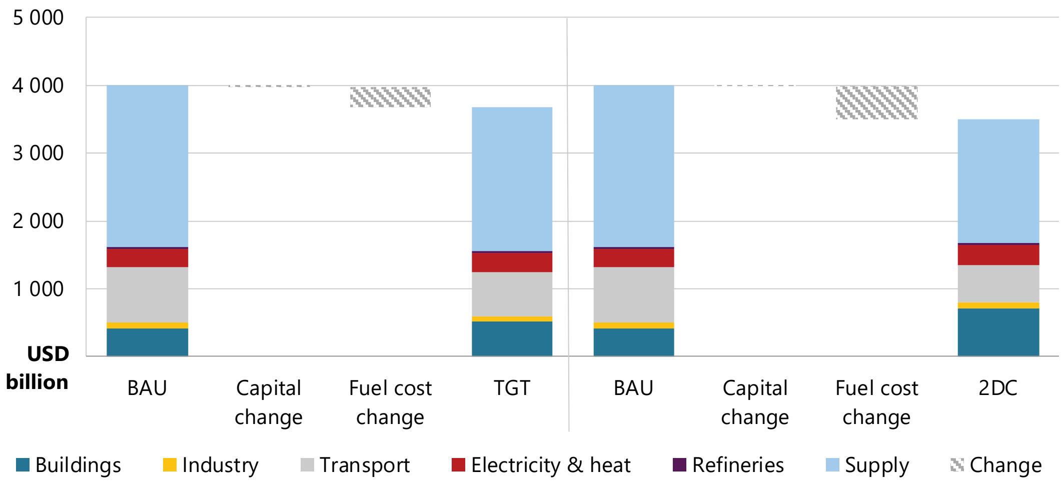
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The *APERC Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[8]

Australian energy investment over the Outlook period amounts to USD 4.0 trillion in the BAU and is dominated by capital spending on energy supply (USD 2.2 trillion). Natural gas is the main source of this expenditure in both the short term, as under-construction LNG projects are finished, and the long term, as CSG wells are drilled and new offshore resources are developed to meet growing domestic demand and exports (Figure 1.12). Fuel costs amount to USD 1.3 trillion, mostly for transport (53%) and buildings (19%).

Figure 1.12 • Australia: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

[8] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

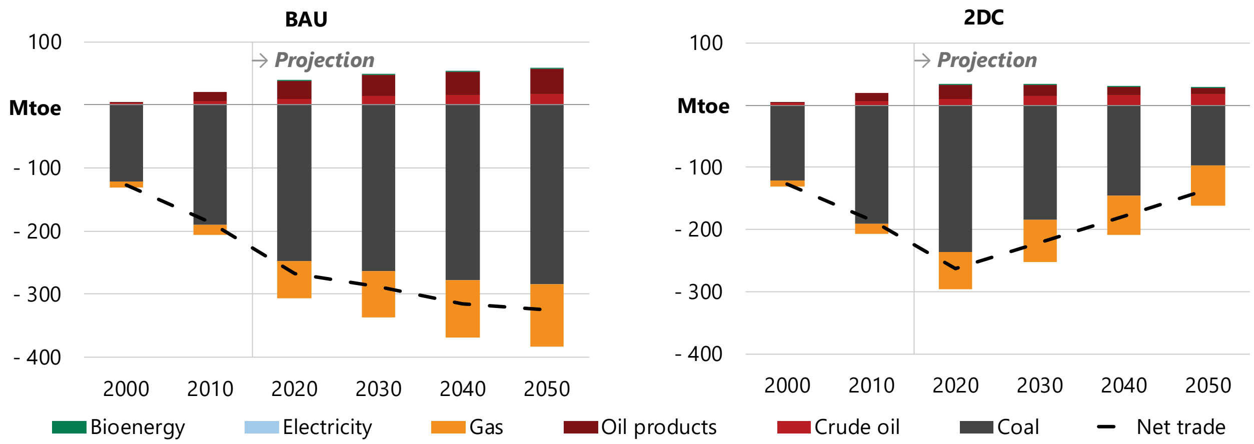
Total energy investments in both the TGT (USD 3.7 trillion) and the 2DC (USD 3.5 trillion) are significantly lower than in the BAU (USD 4.0 trillion) as fuel cost savings outweigh higher capital costs. Increased capital expenditure on buildings and electricity capacity in the TGT and 2DC is offset by significantly lower spending on supply, due to less domestic and international demand for fossil fuels. Increased buildings capital expenditure goes mainly towards improved heating, ventilation and air conditioning (HVAC), and electric appliances, all of which reduce energy demand (but the resulting cost savings are not sufficient to compensate for the increased capital costs). Higher retirement rates for coal-fired power plants, and their replacement with high-efficiency natural gas-fired plants and renewables, account for much of the investment in electricity generation under both the TGT and the 2DC. Additionally, CCS in the 2DC adds to capital costs without reducing fuel costs but significantly reduces emissions. Total transport expenditure decreases noticeably in all three scenarios, with higher capital spending on electric vehicle infrastructure, faster stock turnover and more efficient internal combustion engine vehicles in the TGT and 2DC more than offset by significantly lower fuel expenditures.

ENERGY TRADE AND SECURITY

Australia's extensive reserves and geographic proximity to Asia underpin huge exports of coal and natural gas, mainly to other APEC economies. In 2016, 252 Mtoe of coal and 43 Mtoe of natural gas were exported. These volumes increase to 283 Mtoe of coal and 103 Mtoe of natural gas in 2050 under the BAU (Figure 1.13). Exports in the 2DC are significantly lower, at 97 Mtoe of coal and 69 Mtoe of natural gas in 2050, given lower regional demand associated with a coordinated global effort to reduce CO_2 emissions.

Australia is also a large importer of refined petroleum products, which are increasingly being purchased from other APEC economies rather than produced in Australian refineries. This change is occurring for a number of reasons, including declining domestic crude oil production, high Australian costs, the economies of scale being achieved by enormous regional refineries and relatively low shipping costs.

Figure 1.13 • Australia: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Security of supply has become a growing issue in Australian natural gas and electricity markets in recent years. Rapidly expanding east coast LNG exports have placed a strain on domestic natural gas markets and resulted in huge price increases (Environment, 2018d). Some producers have found it more profitable to shut down their natural gas-fired power plants and sell their contracted gas to LNG exporters than to continue operating. This has, in turn, created security of supply concerns in electricity markets, particularly during summer months when natural gas provides a significant amount of peaking capacity. Recent legislative changes (the ADGSM) requiring producers to supply the domestic market before selling gas for export appear to have had a more significant effect on prices than the bans on fracking (the technology that underpins CSG development) enacted in response to significant public pressure in New South Wales and Victoria.

Australia has been non-compliant with the IEA's treaty obligation to have oil stocks equivalent to 90 days of the previous calendar year's average daily net imports, since 2012 (IEA, 2018c). Falling domestic crude oil production (reflected in the low crude oil self-sufficiency rate and reserve gaps in Table 1.4), along with rising product demand and imports, are responsible for this non-compliance. As a result, the economy's net imports have increased under the IEA statistical methodology, while demand-cover stock levels have remained relatively stable. The Australian government does not have public stockholdings or place minimum stockholding obligations on the oil industry. In 2016, however, the government proposed a phased plan to return to compliance, with Phase 1 involving the purchase of tickets equivalent to up to 400 kilotonnes in the 2018-19 and 2019-20 financial years and the launch of a mandatory industry reporting scheme for petroleum statistics in January 2018.[9] The government is currently developing Phase 2, targeting a long-term and least-cost approach to returning to full compliance by 2026.

A liquid fuel security assessment, which assesses the human and environmental threats to adequate, reliable and affordable energy delivery, is also currently being undertaken by the federal government and is scheduled for release in mid-2019 (Environment, 2018e). The outcomes of this assessment will inform the development of Phase 2 of the compliance plan and will also contribute to a broader National Energy Security Assessment (NESA) that considers electricity and natural gas, to be released in mid-2019. This NESA, the first since 2011, is vital to shaping Australia's energy security policy for the next decade.

Table 1.4 • Australia: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	79	72	74	77	67	71	77
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Crude oil self-sufficiency (%)	79	37	37	37	20	20	20
Primary energy supply diversity (HHI)	0.29	0.29	0.27	0.26	0.32	0.29	0.31
Coal reserve gap (%)	0.29	4.4	4.2	3.9	10	9.1	7.0
Gas reserve gap (%)	2.0	52	51	50	152	143	125
Crude oil reserve gap (%)	11	118	118	118	194	194	194

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook period as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

The Australian way of life is highly energy-intensive—Australia's per-capita TPES and FED were among the highest in APEC in 2016. As the driest inhabited continent, Australia is also particularly vulnerable to climate change and has been experiencing increasingly frequent and severe heatwaves and bushfire seasons in recent years (BOM, 2016). Despite this, climate change policy has undergone significant changes in the past decade,

[9] Tickets refer to stockholding arrangements under which a seller agrees to hold an amount of oil on behalf of a buyer in return for an agreed fee. The buyer can take delivery by purchasing the oil at market price in times of crises, according to the contractual conditions (IEA, 2018d).

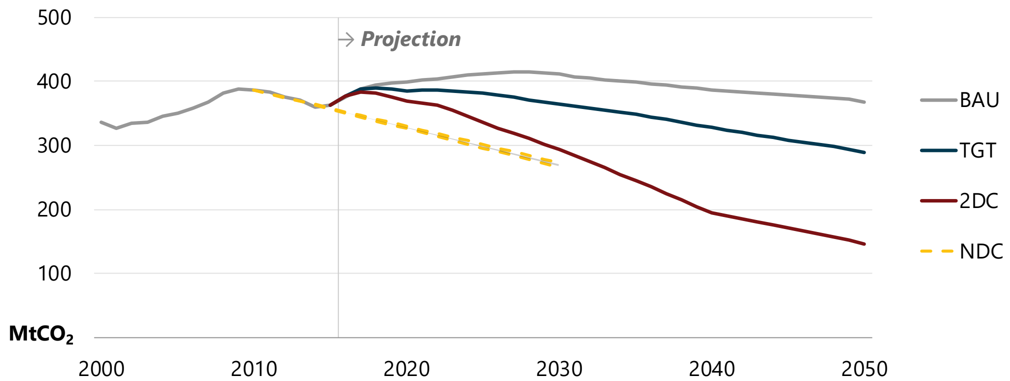
with the introduction and later abolishment of a carbon price system, followed by the proposed and then abandoned NEG.

Following the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in 2015, Australia committed to a nationally determined contribution (NDC) of a 26% to 28% reduction of the 2005 economy-wide emissions level by 2030.[10] An Emissions Reduction Fund is the current government's principal program to meet the NDC. The fund has three components—crediting, purchasing and safeguarding emissions reductions—and is operated as a reverse auction by the Clean Energy Regulator, which has AUD 2.6 billion (USD 1.7 billion) to purchase emissions reductions on eligible carbon reduction projects. Between 2014, the year it was established, and 2018, the government purchased 192 Mt of carbon abatement at an average cost of AUD 12 (USD 8.6) per tonne (Environment, 2017). Almost all of this abatement has been in vegetation, waste and fire management, and less than 1.0% in energy-related sectors.

The RET, set at 33 TWh by 2020, remains the government's strongest support for decarbonisation in the energy sector. However, it has become clear in recent years that regardless of the RET, the market has little appetite for new-build fossil fuels, particularly coal-fired generation. Government-funded organisations such as the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC) have also been instrumental in renewable energy development.

These policies are not sufficient to move Australia towards a 2DC pathway. Aggressive decarbonisation of the power sector through renewables and CCS, combined with strong efficiency gains in transport and buildings, is required to drive down emissions sufficiently. Energy use in the industry and refinery sectors does not increase strongly, if at all, so despite the lack of decarbonisation, these sectors do not contribute to higher emissions. Energy use in the agriculture and energy own-use sectors increase significantly, however, and are also difficult to decarbonise, so emissions increase to 2050.

Figure 1.14 • Australia: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

Energy sector CO_2 emissions decrease marginally over the Outlook period in the BAU and shrink by 24% in the TGT and 62% in the 2DC (Figure 1.14). Cumulatively, the 2DC results in 4 553 Mt less CO_2 emissions than in the BAU. Assessing Australia's progress in achieving its NDC is difficult since a large amount of Australia's CO_2

[10] Gases covered are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride. Sectors covered are energy, industrial processes and product use, agriculture, land use, land-use change and forestry (LULUCF) and waste.

emissions reduction comes from LULUCF (Environment, 2018f). Assuming that Australia also reduces energy sector emissions by 26% to 28%, the NDC would not be achieved by 2030 in any of the three scenarios.

OPPORTUNITIES FOR POLICY ACTION

With structural changes in the Australian economy and supporting policies, energy efficiency increases 45% from the 2005 level by 2035 under all three scenarios. Renewables, however, do not double from the 2010 level in the BAU scenario but do by 2030 in the TGT and by 2026 in the 2DC. Most significantly, however, Australia's NDC of a 26% to 28% reduction in emissions is not achieved in the energy sector between 2005 and 2030.

Despite the strong improvement over the Outlook period, Australia can do more to raise energy efficiency, especially in transport. Introducing vehicle fuel efficiency standards, which is under discussion at the Ministerial Forum, should be undertaken as soon as possible. More support for technologically advanced vehicle types such as hybrid and battery electric, and expanding the use of public transport, which lags far behind roads in public spending, would also help. In the buildings sector, more stringent regulations to improve building envelopes, reduce floor area and support businesses to improve efficiency would help achieve the NEPP.

Leveraging Australia's strong solar potential to develop and implement world-leading integration of variable renewable energy could help meet emissions reduction goals and spur economic growth. Increasing support for ARENA, which is funded until 2022, and the CEFC, which received the last of its government funding in 2018, could contribute to this. In light of the failed development of the NEG, extending and expanding the RET beyond 2020 would continue to provide some support for electricity sector decarbonisation. Including a mechanism to properly value storage (such as a capacity market, for example) would also help manage the changing load profiles resulting from high solar penetration rates.

Further reform of the natural gas sector would improve energy security, reduce Australia's CO_2 emissions and help integrate expanding variable wind and solar generation. While relaxing state-based moratoria on CSG development and introducing greater incentives for gas companies to develop leases may result in additional supply, they will not resolve market issues. Queensland's three LNG projects are currently operating below capacity, and any new production will likely increase exports before raising domestic market supplies; continued enforcement of the ADGSM would help mitigate this effect. Additionally, proposals being discussed by the Queensland government to introduce limited forms of reservation policy to ensure that new developments supply the domestic market before being exported would also help. More support for CCS is integral to electricity sector decarbonisation under the 2DC, as closed-cycle gas turbines with CCS meet a significant portion of Australia's electricity demand to 2050.

Finally, a renewed focus on inter-jurisdictional agreement (through the Council of Australian Governments) and policy stability at the federal level should be of paramount importance. Creating certainty for electricity market participants would improve energy security, sustainability and affordability by supporting the development of new generation capacity and assisting the transition away from baseload lignite and thermal coal.

2. BRUNEI DARUSSALAM

KEY FINDINGS

- **With a new refinery becoming operational in 2019, petroleum products become Brunei Darussalam's primary export by 2020, overtaking crude oil and LNG.** The refinery also boosts liquid fuel supply competition in south-east Asia.

- **Significant domestic natural gas reserves underpin self-sufficiency over the Outlook period,** even though crude oil imports will be needed to feed the new refinery beyond 2020.

- **Throughout the Outlook period, the largest energy demand comes from the non-energy sector.** However, the sector with the greatest potential for energy savings in the TGT and 2DC is domestic transport, which could be realised by promoting public transportation.

- **With an additional 277 MW of wind capacity and 158 MW of solar in the 2DC compared to BAU, the share of renewables in power generation increases to 38% by 2050 (compared with 0.08% in the BAU).** However, natural gas (with CCS in the 2DC) remains the dominant fuel for power generation in all scenarios.

- **In 2050, energy-related CO_2 emissions compared to the BAU decrease 16% for the TGT and 49% for the 2DC.** Higher efficiency in power production, domestic transport and buildings are the key drivers of this reduction.

- **Cumulative energy investments are 7-8% lower in the 2DC and the TGT compared to the BAU;** fuel savings in the supply and transport sectors outweigh additional capital expenditure on electricity and buildings.

ECONOMY AND ENERGY OVERVIEW

Brunei Darussalam is located on the northern coast of Borneo in south-east Asia. It consists of two unconnected areas surrounded by the Malaysian state of Sarawak, and faces the South China Sea to the north. Within the Asia-Pacific Economic Cooperation (APEC), it is one of the smallest economies geographically with a total land area of 5 765 square kilometres, which is divided into four districts.

The discovery of oil in 1929 enabled Brunei Darussalam to become a regionally significant supplier of crude oil; more recently, it has become an important producer of liquefied natural gas (LNG), which it exports to south-east Asia. Revenue from these fossil fuel sales is essential to the economy, accounting for more than half of gross value added and financing the economy's development programs (MFE, 2018).

With a population of 423 000 in 2016 and per-capita gross domestic product (GDP) of USD 76 633 (Table 2.1), Brunei Darussalam is one of the wealthiest economies in south-east Asia. However, the 2014 global drop in oil prices and continued energy price uncertainty have significantly affected the economy's GDP. Like other oil- and gas-dependent economies, Brunei Darussalam faces challenges in diversifying its economy, which has led the government to introduce initiatives and efforts to attract new foreign direct investment (FDI).

Table 2.1 • Brunei Darussalam: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	29	33	32	35	39	42	45
Population (million)	0.33	0.39	0.42	0.45	0.49	0.52	0.54
GDP per capita (2016 USD PPP)	87 609	85 874	76 633	77 959	79 881	81 720	84 318
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	2.4	3.2	3.2	4.3	4.4	4.1	4.2
TPES per capita (toe)	7.3	8.2	7.6	9.7	9.0	8.0	7.8
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	82.83	95.96	99.58	124.97	112.74	97.36	91.99
APEC TPES per GDP (toe per 2016 USD million PPP)	167.53	146.67	123.30	110.52	84.98	67.18	56.08
Final energy demand (Mtoe)	0.6	1.3	1.5	1.5	1.7	1.8	1.9
FED per capita (toe)	1.7	3.3	3.4	3.4	3.4	3.4	3.5
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	19.71	38.23	44.82	43.70	42.82	41.89	41.69
APEC FED per GDP (toe per 2016 USD million PPP)	111.99	95.37	82.87	74.06	56.86	44.91	37.62
Energy-related CO_2 emissions ($MtCO_2$)	4.9	6.8	6.6	8.8	9.0	8.5	8.6
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

Oil and natural gas are Brunei Darussalam's main energy resources; as such, energy policies and plans focus on their development and utilisation. Crude oil, LNG and methanol exports generate most of the government's revenue. In 2016, proved oil reserves were estimated at 1.1 billion tonnes and gas at 0.27 trillion cubic metres.

At current production levels, these proved reserves are sufficient for another 22 years for gas, and 27 years for oil (Table 2.2).

Table 2.2 • Brunei Darussalam: Energy reserves and production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Oil (billion bbl) [a]	1.1	27	0.06	41	11
Natural gas (tcm) [a]	0.3	22	0.14	36	10

Notes: bbl = barrels. tcm = trillion cubic metres Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions.
Source: BP (2018).

Coal reserves include bituminous and sub-bituminous types, as well as a low-quality lignite. To decide on a strategy to use coal as an alternative energy source, the government would require a reliable indication of economically viable deposits; however, currently available technical information and data are insufficient to evaluate reserves.

Currently, Brunei Darussalam produces about 1 700 MWh of solar energy per year, which is the only renewable energy source that has been developed even though there is significant solar irradiation and bioenergy potential. The government has set a target to increase the share of renewable energy in total power generation to 2.7% by 2017 and 10% by 2035 (MEMI, 2014).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Brunei Darussalam's economy is among the most reliant on revenues from crude oil and LNG exports in the APEC region, and is therefore the most influenced by energy price fluctuations. A primary goal, therefore, is to diversify the economy. Various options have been explored including exporting methanol and downstream oil and gas products, as well as developing non-energy industries. Five key areas targeted by the government are: halal manufacturing, information technology, business services, tourism, and downstream oil and gas. The government is also promoting FDI and private-sector investment.

Despite greater economic diversification, the oil and gas sector is expected to remain a core pillar of Brunei Darussalam's economy. In 2017, Brunei Shell Petroleum Company Sdn Bhd (BSP), the economy's largest oil and gas producer, made the largest onshore oil and gas discovery in 37 years with its Layang-Layang well. This discovery has the potential to generate revenue equivalent to about 15% of the state budget (RTB News, 2017).

As part of a pioneering demonstration project for a global hydrogen supply chain,[11] Brunei Darussalam started building its first hydrogenation plant in 2018 in the Sungai Liang Industrial Park. The project aims to supply 210 tonnes of hydrogen to Japan in 2020, and could eventually lead to hydrogen use in Brunei Darussalam for fuel cell vehicles and/or power generation. Novel low-carbon technologies, such as those based on hydrogen, help to address the economy's energy security concerns while also supporting long-term environmental commitments (NEDO, 2017).

[11] The Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD), established by an association of four Japanese companies (Mitsubishi, Nippon Yusen, Chiyoda and Mitsui), initiated this demonstration project to realise Japan's goal to develop global hydrogen transport and supply technologies for full-scale hydrogen power generation by 2030.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Brunei Darussalam under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 2.3). Definitions used in this Outlook may differ from the government targets and goals published in the 2014 Energy White Paper (EWP).

Table 2.3 • Brunei Darussalam: Key assumptions and policy drivers under the BAU

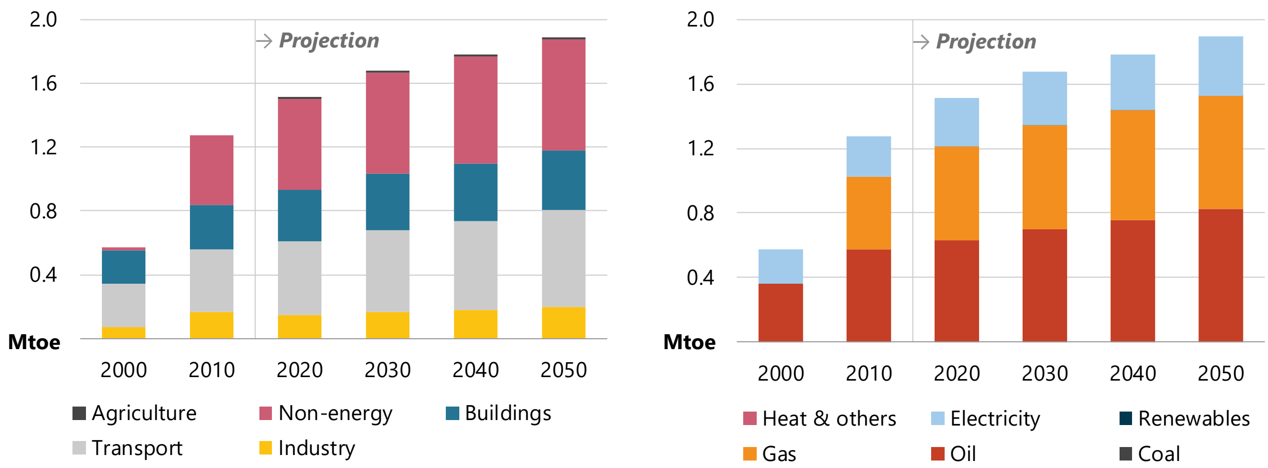
Buildings	Standards and labelling programs instituted.
Transport	Modest deployment of hybrid and electric vehicles.
Energy supply mix	Oil and gas production increases to 11 Mtoe by 2035, and decreases thereafter.
Power mix	Natural gas remains the dominant fuel source for power generation.
Renewables	Solar capacity expands to 5 MW by 2050. Installed capacity of waste-to-energy facilities expands to 20 MW by 2035.
Energy security	Energy self-sufficiency is attained. Renewables target share not reached.
Climate change	Goal of 63% energy consumption reduction by 2035 (relative to 2009) not achieved.

Notes: Mtoe = million tonnes of oil equivalent. MW = megawatts. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Brunei Darussalam's final energy demand (FED) grew 7.9% per year from 2005 to 2016, significantly outpacing GDP annual growth of 0.03%. With slowing population growth, the rate of energy demand increase is projected to slow over the Outlook period (2016-50). It rises at a compound annual growth rate (CAGR) of 0.77% in the BAU Scenario, from 1.5 million tonnes of oil equivalent (Mtoe) in 2016 to 1.9 Mtoe in 2050 (Figure 2.1). The shares of each fuel in FED remain largely unchanged throughout the projection. Oil is the dominant fuel, accounting for 43% of energy demand in 2016 and 44% in 2050 (0.62 Mtoe to 0.83 Mtoe). In 2050, natural gas has a 37% share (0.70 Mtoe) and electricity a 20% share (0.37 Mtoe). Renewables use remains minor through the Outlook, accounting for only 0.03% of FED in 2050.

Figure 2.1 • Brunei Darussalam: Final energy demand by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

The shares by sector are also stable. The non-energy sector, with its various downstream projects such as aluminium derivatives and propylene production, maintains the largest share of demand (38% in 2016 and 37% in 2050). Historically, the sector became the dominant source of demand in 2010, when an export-oriented methanol plant came online (the share dropped from 35% in 2010 to 18% when the plant briefly stopped operations in 2013, then climbed back to 38% the following year). Domestic transport has the second largest slice (31% in 2016 and 32% in 2050), followed by buildings and industry. The agriculture sector continues to have the lowest energy demand as Brunei Darussalam imports most of its agriculture products.

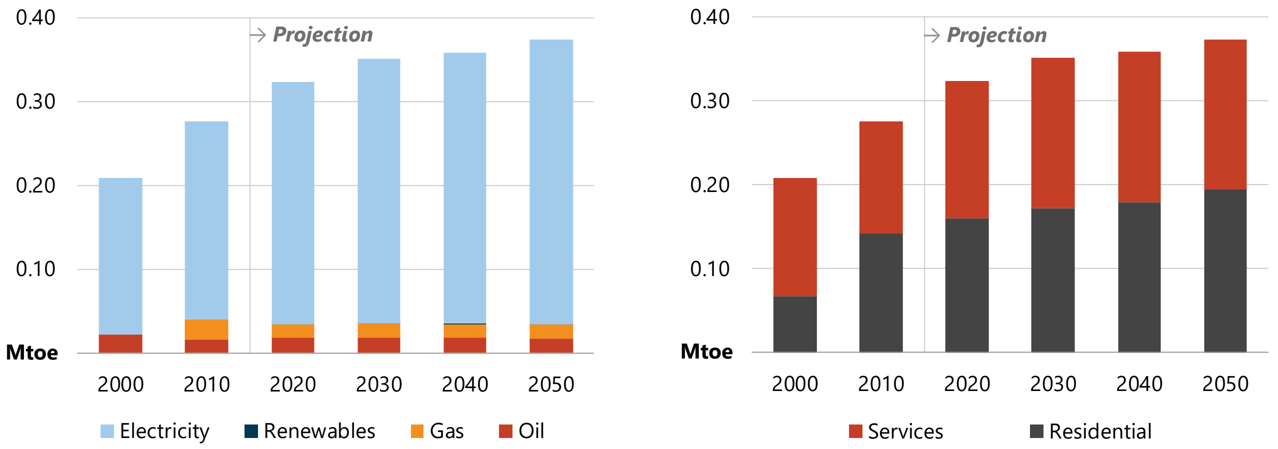
BUILDINGS: SPACE COOLING ACCOUNTS FOR THE MAJORITY OF ENERGY DEMAND

In the past, residential electricity tariffs in Brunei Darussalam were regressive, with relatively low cost at higher levels of consumption and were not structured to incentivise energy efficiency. To discourage wasteful energy use, new progressive tariffs were introduced in January 2012, with the average cost per kWh rising as consumption increases (DES, 2018). However, over-consumption remains an ongoing issue as electricity prices are still heavily subsidised by the government, which makes it difficult to financially incentivise energy conservation and efficiency (APEC, 2013).

Space cooling accounts for a large portion of electricity consumed in buildings, reflecting the economy's tropical climate and relatively affordable electricity. On a per-capita basis, Brunei Darussalam's electricity consumption in buildings (7 317 kWh per capita) far exceeded that of other developed Asian economies such as Japan and Singapore (both slightly above 4 700 kWh per capita) in 2016.

Buildings sector energy demand in Brunei Darussalam climbs at a CAGR of 0.64% from 2016 to 2050 in the BAU Scenario. This is the result of relatively slow GDP per-capita growth (0.28% CAGR). Throughout the Outlook period, electricity accounts for the largest portion (around 90%) of energy demand in buildings, while shares of both oil and natural gas decline (Figure 2.2).

Figure 2.2 • Brunei Darussalam: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Residential sector energy demand increases 27% over the BAU, from 0.15 Mtoe in 2016 to 0.20 Mtoe in 2050. Space cooling remains the leading residential end-use and grows at a 0.48% CAGR over the Outlook. Cooking (1.4% CAGR) and other energy uses (1.5% CAGR) demand has more rapid growth. Services sector energy demand increases slightly, then gently declines, with the end result of moderate growth (from 0.15 Mtoe in 2016 to 0.18 Mtoe in 2050). With wider use of energy efficient inverter air conditioners, energy demand for space cooling is 4.1% lower in 2050 than in 2030. Similarly, demand is 28% lower for lighting (over the same period) owing to the deployment of more energy efficient technologies (such as LEDs).

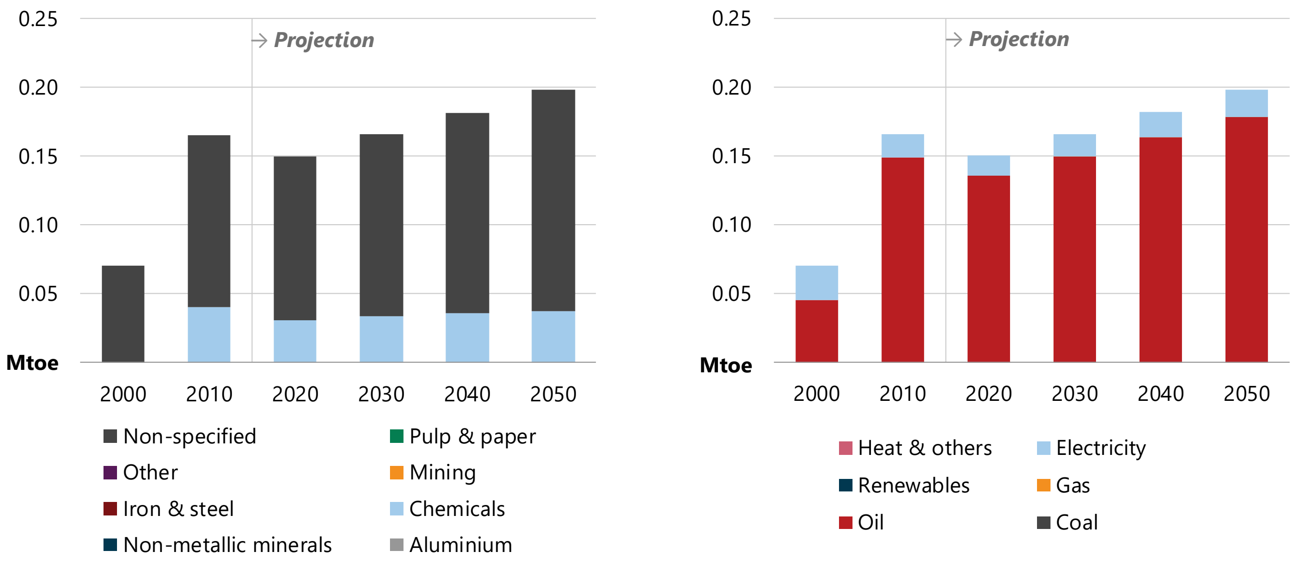
Energy efficiency labelling for buildings is not mandatory, and standards are not fully in place. The government has, however, discussed introducing labelling for domestic appliances on a voluntary basis with a focus on space cooling. Energy efficiency baselines for certain types of public buildings have also been developed (Gov BN, 2015), which could be applied more broadly to further reduce demand growth.

INDUSTRY: STRONG OIL DEPENDENCY

The industry sector has been almost entirely dependent on oil and gas developments, which continue to drive growth under the BAU. The main industry in Brunei Darussalam is petrochemicals, followed by construction, manufacturing, and textiles. Major projects include an ammonia production facility, a marine supply base and a fabrication yard at the new industrial site at Pulau Muara Besar.

In the BAU, industry energy demand grows at a CAGR of 0.94% from 2016 to 2050—from 0.14 Mtoe to 0.20 Mtoe (Figure 2.3). Oil remains the primary energy source in 2050, meeting 90% of industry FED; electricity accounts for the remaining 9.8%.

Figure 2.3 • Brunei Darussalam: Industry final energy demand by subsector and fuel, 2000-50



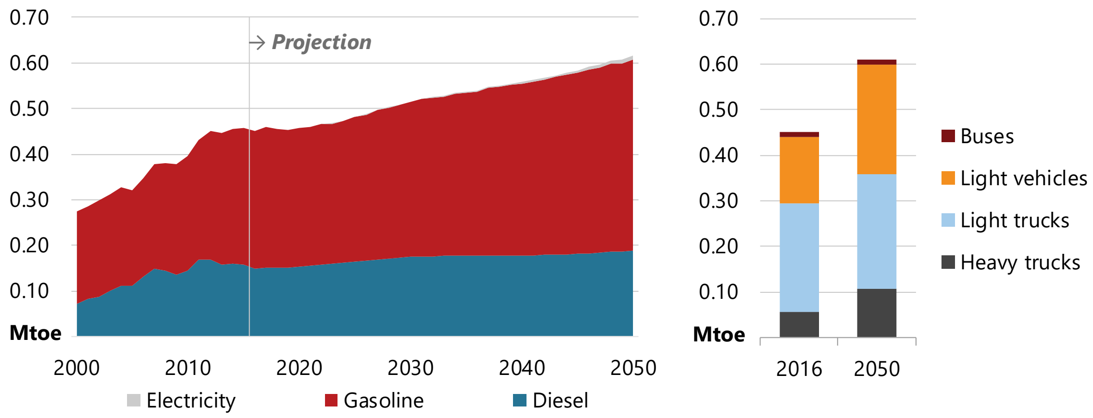
Sources: APERC analysis and IEA (2018a).

TRANSPORT: DEMAND MORE THAN DOUBLES FROM GROWTH IN LIGHT VEHICLE USE

With one car for every 2.8 people, car ownership in the economy is among the highest in the APEC region (MOC, 2014). This is due to low transport fuel prices (in 2013, fuel subsidies were equivalent to over 3% of the economy's GDP) and low vehicle import taxes. A lack of public transport infrastructure also contributes to reliance on private vehicles, a lifestyle that has also been a major driver of transport sector energy consumption.

Throughout the Outlook period, domestic transport demand rises from 0.45 Mtoe to 0.61 Mtoe. This increase comes despite government plans to implement fuel economy regulations for new vehicles with targets similar to those implemented in the European Union. Growth is mainly driven by gasoline use for heavy trucks and light vehicles (Figure 2.4). Development in aviation, buses and rail systems are stagnant due to Brunei Darussalam's small size and population distribution (more than 30% of the population lives in the capital city).

Figure 2.4 • Brunei Darussalam: Domestic transport FED by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

In 2016, road transport accounted for the majority of domestic transport demand, almost all of which was supplied by gasoline and diesel. The situation remains largely the same throughout the Outlook period. Although battery electric vehicles begin to be introduced from 2020, gasoline and diesel still dominate the fuel mix in 2050. Due to the steady pace of GDP and population growth, demand for passenger transport, which was 0.37 Mtoe in 2016, increases to 0.45 Mtoe in 2050. Demand for freight transport was 0.08 Mtoe in 2016, and rises to 0.16 Mtoe in 2050.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Brunei Darussalam's energy transformation landscape changes significantly with the opening of a new export-oriented refinery in 2019. Power generation is highly reliant on gas at present, a trend which continues throughout the BAU, albeit joined by a coal-fired plant dedicated to the new refinery. Oil and gas make up the majority of total primary energy supply (TPES), but production of both decreases due to the decline of domestic resources. The economy remains a net energy exporter, but becomes a crude oil importer after 2020 to feed the new refinery.

ENERGY TRANSFORMATION: NEW REFINERY OPERATIONAL IN 2019

Brunei Darussalam currently produces 6.1 Mtoe of crude oil per year, of which roughly a tenth goes to the Brunei Refinery, the economy's only operating refinery. The BSP-owned refinery has a small capacity of 0.33 Mtoe per year from which it produces three grades of gasoline, liquefied petroleum gas, jet fuel and kerosene—all for domestic consumption. Current capacity has not been able to keep pace with growing domestic demand, however, resulting in imports of some refined products from Singapore and Malaysia.

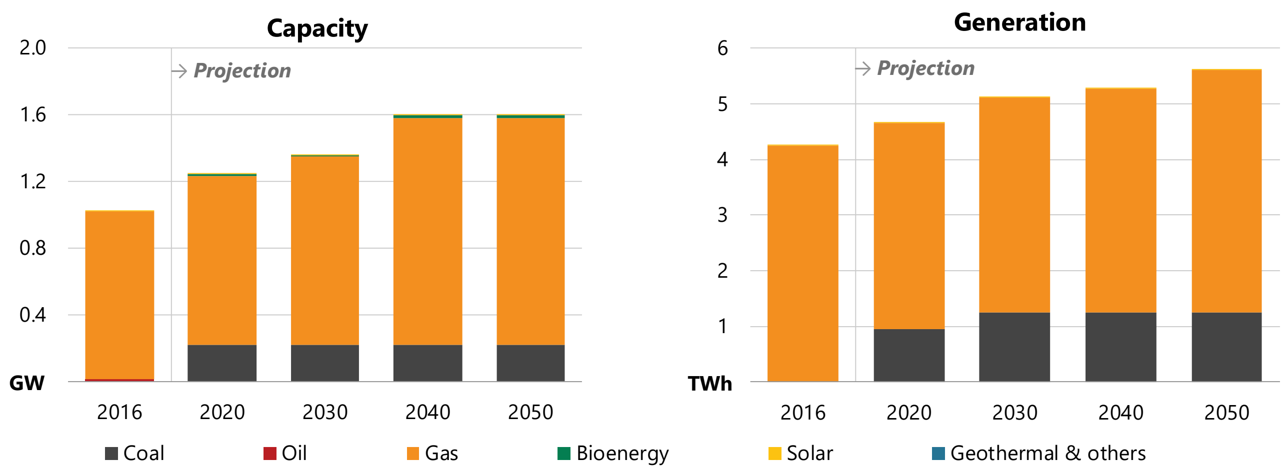
A new export-oriented refinery is scheduled to begin operations in 2019, boosting total refining capacity from 0.43 Mtoe to 9.2 Mtoe per year. This will help to ensure the economy's self-sufficiency in petroleum products. The new refinery is a private-public partnership, owned 70% by the private Chinese company Hengyi Group and 30% by the Brunei Darussalam government (Reuters, 2017). Since new refineries are also coming online in Viet Nam and Malaysia in early 2019, Brunei Darussalam's new refinery is likely to boost competition among suppliers of refined oil products in the region—including with Singapore, which is currently the leading liquid fuel producer in south-east Asia.

POWER SECTOR: HIGH RELIANCE ON NATURAL GAS

Installed power generation capacity in 2016 is largely made up of gas-fired power plants owned by public utilities. Other capacity includes a 12 megawatt (MW) diesel-fired plant and a 1.2 MW solar photovoltaic (PV) demonstration plant. In addition, various companies and industries own facilities for self-production. Together, these sources totalled 1.0 gigawatts and produced 4.3 terawatt-hours (TWh) of electricity in 2016.

Under the BAU, total generation increases at a CAGR of 0.79% to reach 5.6 TWh in 2050. Combined- and open-cycle gas turbines continue to provide more than 70% of generation throughout the Outlook (Figure 2.5). In 2016, gas plants accounted for 99% of electricity generation, but a 220 MW combined heat and power coal plant scheduled to start operations at the new refinery in mid-2019 reduces this share to 80% in 2020. Coal generation keeps rising to 1.3 TWh in 2025, after which it remains largely stable.

Figure 2.5 • Brunei Darussalam: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

The Department of Electrical Services and Berakas Power Management Company have set out plans to increase efficiency in power generation from present levels (23%) to more than 45% (MEMI, 2014). In the BAU, a 12 MW diesel-fired plant and two open-cycle gas turbine power plants (total capacity 210 MW) are decommissioned by 2020, and replaced with combined-cycle gas turbines (CCGTs). These changes result in oil capacity disappearing after 2020 and raise average generation efficiency towards the target of 45%.

Renewable generation in the BAU grows from 1.0 megawatt-hours (MWh) in 2016 and ultimately reaches 4.6 MWh, due to incremental increases in utility solar installations. Renewable power capacity increases to 23 MW in 2035, of which 3.4 MW comes from utility PV and the rest from waste-to-energy plants. Utility solar continues to increase up to 2050, bringing total renewable capacity in 2050 to 26 MW (a 1.6% share).

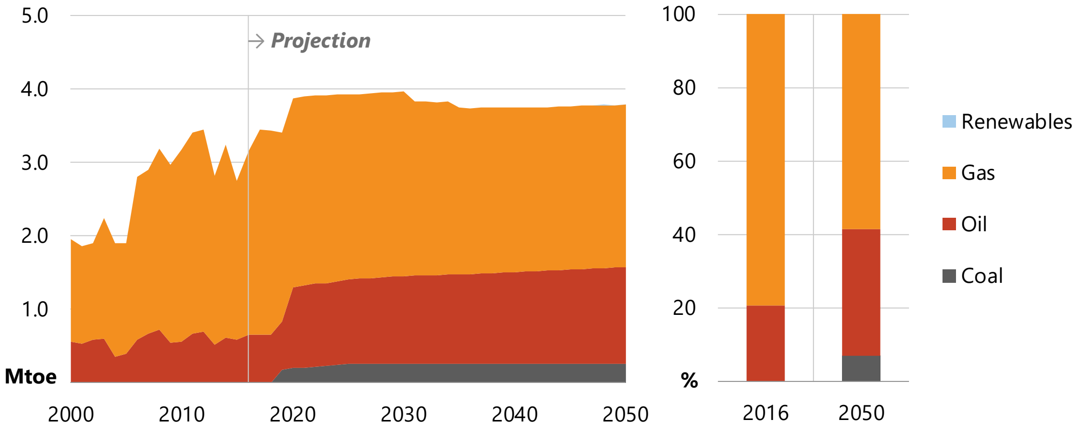
TOTAL PRIMARY ENERGY SUPPLY: NATURAL GAS REMAINS THE LEADING FUEL

Oil and natural gas dominate Brunei Darussalam's TPES. Natural gas is used mainly for electricity generation, producing town gas[12] and as feedstock for downstream industries, while oil is used mostly in refineries. Natural gas accounted for 78% of TPES in 2016 and oil for 20% (Figure 2.6). Under the BAU Scenario, TPES grows at 0.75% CAGR, from 3.2 Mtoe in 2016 to 4.2 Mtoe in 2050. Additional oil required for the new refinery outpaces decreases in natural gas demand due to more efficient power generation (where the government is targeting 45% efficiency from 2020 onwards). The natural gas share in TPES declines to 53% while oil grows to reach 32% by 2050. Coal enters the mix in 2019 with the start-up of a new power station and accounts for 6.3% of TPES in

[12] In Brunei Darussalam, town gas refers to natural gas that is manufactured locally, not necessarily from coal products.

2050, while the share of renewable energy, mainly from solar PV and waste-to-energy sources, increases to only 0.02%.

Figure 2.6 • Brunei Darussalam: Total primary energy supply by fuel, 2000-50

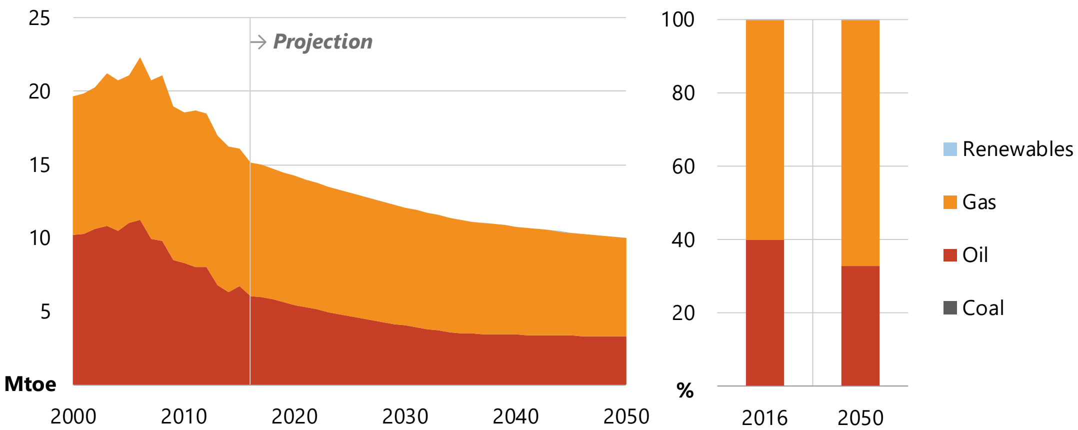


Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: DECLINING FOSSIL FUEL PRODUCTION AFTER 2035

Brunei Darussalam has benefited considerably from oil and natural gas export revenues since the discovery of oil in 1929 and of a giant offshore gas field in 1963; it is currently the fifth-largest oil producer in south-east Asia. After reaching a peak of 22 Mtoe in 2006, oil and gas production declined to 15 Mtoe in 2016 (Figure 2.7). This drop resulted from the decline of remaining reserves, high deferment levels and asset integrity issues (an increasing number of operations-related incidents were affecting production). The economy now aims to boost upstream production by maximising the potential of existing mature fields and venturing into deepwater exploration. The 2014 EWP outlines the government target to attain oil and gas production of 32 Mtoe per year by 2035.

Figure 2.7 • Brunei Darussalam: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

In 2016, production was 40% crude oil and 60% natural gas, with negligible renewables and no coal. The natural gas share is projected to increase to 67% in 2050 and the oil share to decline to 33%, while renewables remains largely unchanged. Total energy production drops from 15 Mtoe to 10 Mtoe during the Outlook period. The decline of oil production (-1.8% CAGR) is due to the natural decline of mature fields and a scarcity of new discoveries (despite the recent success of the Layang-Layang well, which extends Brunei Darussalam's production lifetime).

Hydrocarbon resources account for almost all energy exports and a significant portion of total exports. While Brunei Darussalam remains a net energy exporter throughout the Outlook, the economy becomes a crude oil importer after the new refinery becomes operational in 2019. This is largely compensated for by growth in oil product exports from the same refinery.

ALTERNATIVE SCENARIOS

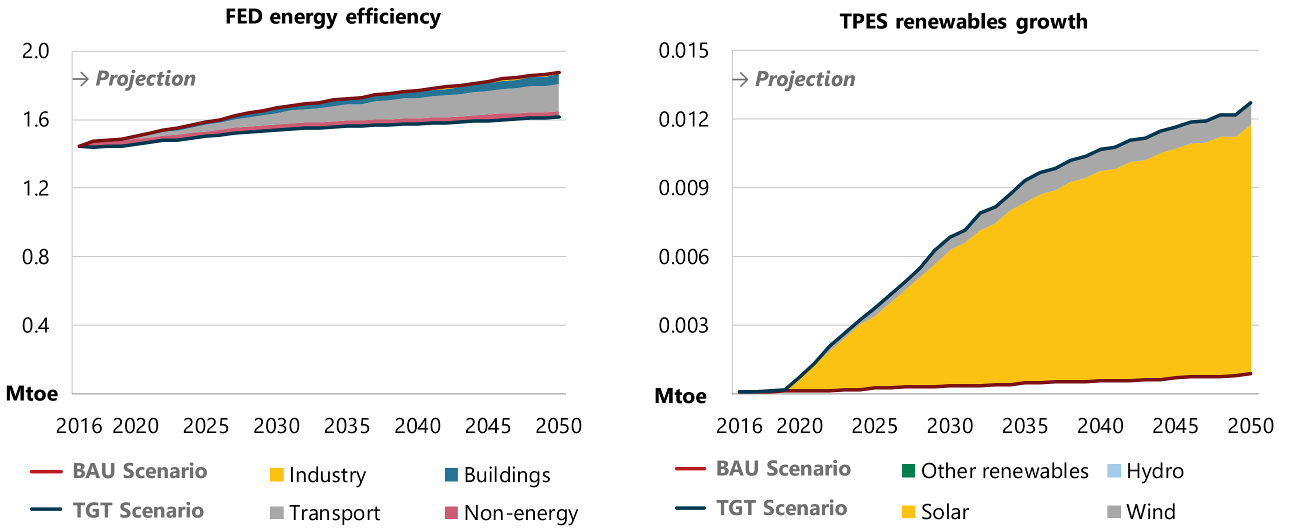
While the BAU Scenario is intended to be representative of Brunei Darussalam's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and carbon dioxide (CO_2) emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Compared with the BAU, FED is 14% lower while CO_2 emissions are 16% lower in the TGT by 2050. Under the 2DC, Brunei Darussalam's FED is 34% lower and CO_2 emissions are 49% lower. The share of renewables in TPES in 2050 is 0.42% in the TGT and 5.5% in the 2DC, compared with 0.021% in the BAU.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. Assumptions under the TGT in Brunei Darussalam reflect numerous sector-level policy changes, such as stricter fuel efficiency regulations in transport and more stringent standards for buildings, equipment and appliances. Stronger government support that implicitly reduces deployment costs also plays a key role in delivering improved energy intensity and boosting the share of renewables under this scenario. In the TGT, energy intensity (measured as final energy in tonnes of oil equivalent [toe] per unit of GDP) in Brunei Darussalam drops from 45 toe per USD million in 2016 to 36 toe per USD million in 2050. As an energy-intensive economy, Brunei Darussalam has already made concerted efforts to promote energy efficiency and less energy-intensive industry activities. The National Energy Efficiency and Conservation Committee (NEECC) currently oversees implementation of energy efficiency and conservation (EEC) action plans in five major sectors: power, commercial, residential, transport and industry.

By sector, the greatest cumulative demand reduction of 15% (2.8 Mtoe) compared with the BAU occurs in domestic transport (Figure 2.8). This drop is primarily the result of greater fuel efficiency in heavy-duty vehicles, increased deployment of electric vehicles (EVs), better urban planning and expanded public transport systems. At present, private car ownership is high and most people rely on private cars; rail service is non-existent and taxi service is limited. Buses are the primary means of public transport and yet more than two-thirds of the population have never used them before (MOC, 2014). The government is discussing plans to create a bus rapid transit system with affordable fares, replace and expand the conventional bus fleet, and increase the number of licensed taxis. If implemented, these measures would increase energy efficiency and spur on demand reductions such as those observed in the TGT.

Figure 2.8 • Brunei Darussalam: Energy efficiency and renewables, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewable growth shows the additional renewables in TPES by type in the TGT compared with the BAU.
Sources: APERC analysis and IEA (2018a).

Buildings provide the second-largest cumulative energy demand reduction under the TGT: 0.88 Mtoe or 7.2% less than under the BAU. This is mainly owing to implementation of legislative measures on EEC and lower consumption by energy-intensive appliances (e.g. air conditioners). The remaining reductions reflect additional measures taken in industry (3.8%) and non-energy use (4.8%).

Renewables in TPES are boosted in the TGT largely due to growth of solar power. Under the TGT in 2050, renewables have a 0.42% share in TPES, mainly composed of solar with a small fraction of wind. This is noticeably higher than the 0.02% share of renewables in the BAU. However, the government's target of 10% renewable sources in the power generation mix by 2035 is not being met in the TGT. The implementation of a number of energy-saving technologies, including a CCGT and cogeneration power plant to improve efficiency in power generation, reduces total gas consumption for electricity generation by 47% in 2050 compared with 2016 levels.

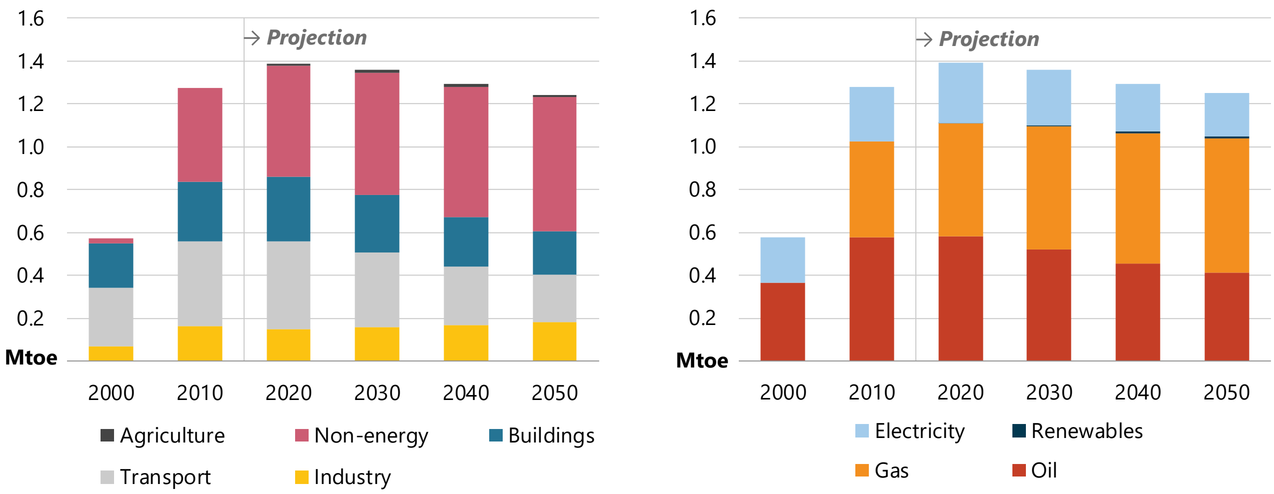
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, all energy sectors in Brunei Darussalam face some degree of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Aggressive energy efficiency measures in the 2DC result in a 0.46% per year decline in Brunei Darussalam's FED over the Outlook, from 1.5 Mtoe in 2016 to 1.2 Mtoe in 2050. Cumulative demand throughout the Outlook period falls the most in transport (38% compared with the BAU), but buildings also show significant declines (26%) (Figure 2.9).

Figure 2.9 • Brunei Darussalam: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

As space cooling accounts for a large proportion of electricity demand in Brunei Darussalam, the 2DC assumes faster implementation of EEC programs, including green building initiatives targeted at new public housing to meet the internationally recognised Building and Construction Authority (BCA) Green Mark standard. Compared with the BAU in 2050, this reduces electricity demand in residences by 41%, and that for residential space cooling by 55%. The 2DC assumes that Brunei Darussalam fully adopts a green building rating system for services buildings, as stated in its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC), in September 2016. This implies using energy efficient inverter air conditioners with a standard minimum temperature as well as more energy efficient lighting (such as LEDs). With the adoption of such measures, services energy consumption in the 2DC drops to 52% below that of the BAU in 2050.

Gasoline and diesel still dominate transport FED under the 2DC, but consumption declines by more than 63% compared with the BAU in 2050. An accelerated shift to more advanced vehicles boosts the hybrid and EV stock in Brunei Darussalam to roughly 200 000 by 2050 (compared with 30 000 in the BAU). This shift results in energy demand per tonne kilometre (TKM) of freight transport falling from 3.0 megajoules (MJ) per TKM in 2016 to 1.5 MJ per TKM in 2050.

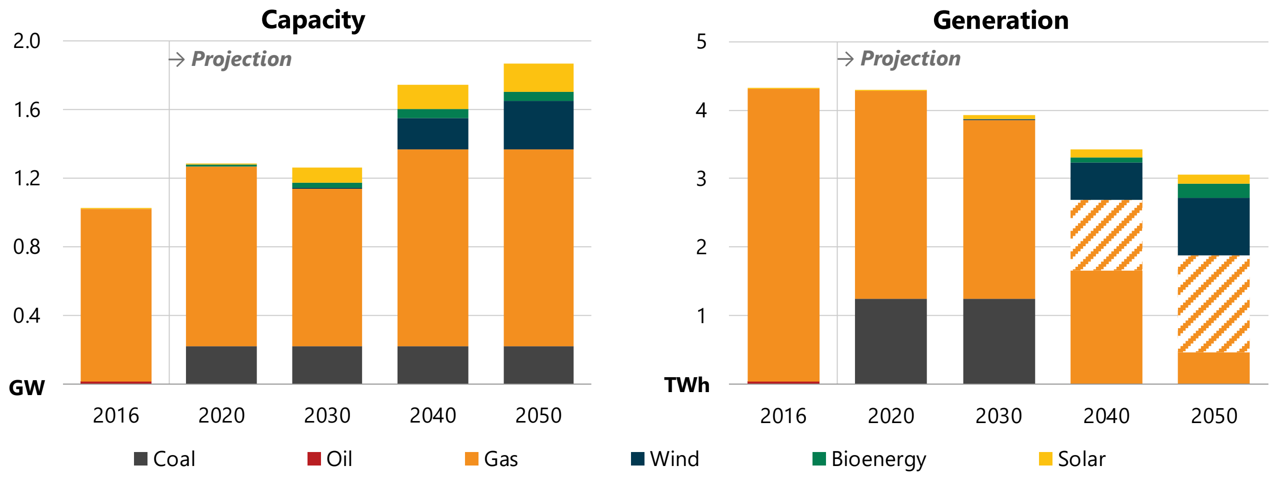
Industry demand increases by 26% between 2016 and 2050 under the 2DC, ultimately reaching 0.18 Mtoe by 2050 (0.016 Mtoe less than the BAU). Both electricity and oil demand grow 26% over the Outlook, compared with 38% growth (again, for both fuels) in the BAU. The shares among industrial subsectors is largely the same across all scenarios, and the heavy reliance on oil persists in the 2DC.

TRANSFORMATION AND SUPPLY IN THE 2DC

The 2DC illustrates the impact renewables could have on the power generation mix and on energy-related CO_2 emissions. To boost solar capacity in this scenario, the government focuses its energy policy on attracting investment. At the same time, it considers providing incentives to citizens, such as feed-in tariffs and net metering systems that allow excess power generated by rooftop panels to be sold to the grid.

Additional solar PV capacity of 158 MW and wind capacity of 277 MW is required in the 2DC compared with the BAU (Figure 2.10) and can be realised if Brunei Darussalam fully utilises large, undeveloped areas of land. Gas with CCS capacity reaches 270 MW in the 2DC (but is absent in the BAU), and accounts for almost half of electricity generation in 2050. Gas generation (including some combined-cycle plants without CCS) accounts for 62% of total generation, with wind supplying 28%, bioenergy 6.5% and solar 4.2%. In 2050, lower demand results in electricity generation dropping 2.6 TWh compared with the BAU.

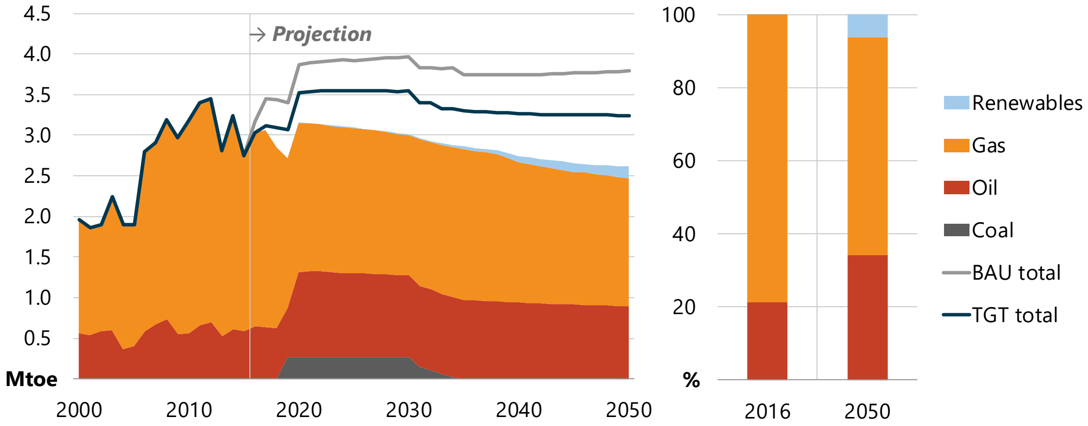
Figure 2.10 • Brunei Darussalam: Power and electricity in the 2DC by fuel, 2016-50



Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

The share of renewable energy in TPES by 2050 is higher in the 2DC (5.5%) than the TGT (0.42%) or the BAU (0.02%). Brunei Darussalam's TPES remains largely fossil fuel-based even under the 2DC, with a marginal increase in the share of gas (to 54%) compared with the BAU (53%) in 2050. Coal disappears by 2050 in the 2DC, compared to a 6.3% share in the BAU (Figure 2.11), while oil also declines, but to a 31% share. The increase of oil supply between 2016 and 2050 in the 2DC is 38%, significantly less than the 102% increase in the BAU. This is primarily due to improved fuel economy in the domestic transport sector. In the same period, the supply of natural gas falls 34% (compared with a 12% decrease in the BAU) as a result of power plants becoming more efficient and renewable generation expanding.

Figure 2.11 • Brunei Darussalam: Total primary energy supply by fuel in the 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

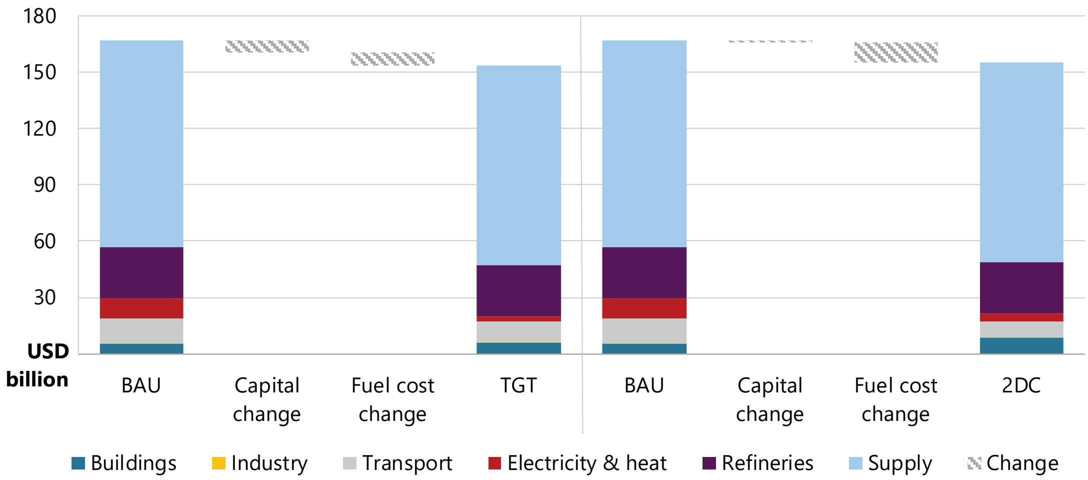
The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[13]

Cumulative energy sector investments required in Brunei Darussalam between 2016 and 2050 under the BAU reaches USD 167 billion (Figure 2.12). With goals to expand refineries and oil and gas production activities (for example exploration in deepwater areas), capital costs take up 76% of total investments (USD 126 billion); and fuel costs account for 24% (USD 40 billion). Within cumulative capital investments, the supply sector requires USD 93 billion, and the refineries sector USD 22 billion, which together amount to a 91% share. A further USD 1.6 billion meets growing transport, buildings and industry energy demand.

There is not much difference in net investments among scenarios. Investment falls by USD 13 billion under the TGT and USD 11 billion under the 2DC compared with the BAU. In both alternative scenarios, the electricity sector and buildings sector require the most additional capital expenditure in order to decarbonise generation and improve building envelopes, mainly. This additional capital cost is larger for the 2DC than the TGT, whereas fuel savings are only marginally larger in the 2DC. Hence, the 2DC adds up to a small net increase in investment when compared with the TGT. Fuel savings are largest in the supply sector for the TGT and in the transport sector for the 2DC. Capital costs for the supply sector and refineries are almost the same throughout scenarios. Since total investment is lower in the TGT and 2DC Scenarios, Brunei Darussalam could consider the potential benefits of taking the pathway that leads not only to savings but also less emissions and a more diversified and efficient energy infrastructure.

[13] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 2.12 • Brunei Darussalam: Energy sector capital and fuel costs, 2016-50

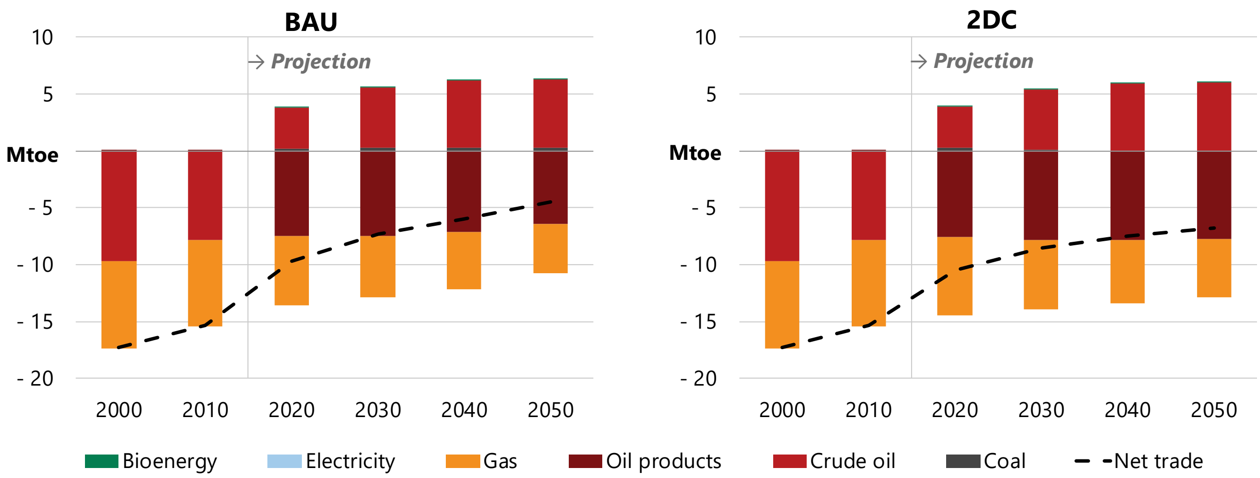


Sources: APERC analysis and IEA (2018a).

ENERGY TRADE AND SECURITY

Brunei Darussalam is currently a net importer of oil products and an exporter of crude oil and natural gas (Figure 2.13). The opening of a new refinery in 2019 is projected to alter this dynamic as imports shift to crude oil, which is eventually exported as oil products. In the short term, this could result in higher competition in regional markets. If refinery capacity continues to exceed demand, however, it may prompt early closures elsewhere in south-east Asia. The volume of crude oil imports and oil product exports do not change drastically among scenarios.

Figure 2.13 • Brunei Darussalam: Net energy import and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Gas exports increase in the 2DC compared with other scenarios, due to domestic demand reductions in the power sector. Brunei Darussalam remains self-sufficient in natural gas throughout the projection. As renewable generation increases through the Outlook period, the economy's Herfindahl-Hirschman Index improves in all three scenarios (from 0.52 in 2016), but is actually lowest in the TGT, at 0.38, because market concentration is aggravated by coal leaving the fuel mix in the 2DC (Table 2.4).

Table 2.4 • Brunei Darussalam: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	88	100	100	100	100	100	100
Coal self-sufficiency (%)	0	0	0	0	0	0	0
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Crude oil self-sufficiency (%)	100	46	46	46	38	38	38
Primary energy supply diversity (HHI)	0.52	0.40	0.39	0.37	0.39	0.38	0.41
Coal reserve gap (%)	0	0	0	0	0	0	0
Gas reserve gap (%)	4	61	61	61	130	130	130
Crude oil reserve gap (%)	4	52	52	52	99	99	99

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

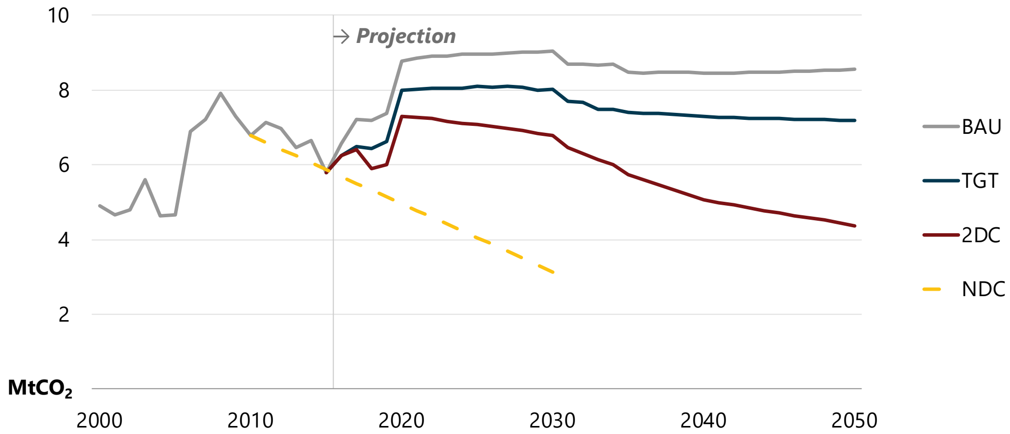
SUSTAINABLE ENERGY PATHWAY

Brunei Darussalam's contribution to global greenhouse gas emissions is small—only 0.016% annually (UNFCCC, 2015). The oil and gas sector are by far the largest emitters. In 2014, the Energy Department of the Prime Minister's Office (since restructured as the Ministry of Energy, Manpower and Industry [MEMI]), published Brunei Darussalam's first EWP, which outlines a framework for improving energy sector sustainability. The government also set the ambitious target of reducing total energy demand by 63% by 2035, compared with a business-as-usual scenario, as announced in its NDC. To this end, the government has banned gas venting and flaring, and announced that it will formulate plans for capital investment in energy efficiency measures. Renewable energy and other green technologies are also listed as measures to lower emissions.

Although renewable energy use in Brunei Darussalam is minimal at present, the EWP goal is to increase the share of renewable sources in the generation mix by 10% (equivalent to 954 gigawatt-hours) by 2035. The economy also aims to reduce energy intensity 45% by 2035 (from 2005), in line with its commitment to supporting the APEC aspirational goal (MEMI, 2014).

In the Outlook projections, energy-related CO_2 emissions peak in 2030 under the BAU reaching 9.1 million tonnes of carbon dioxide ($MtCO_2$) or 38% higher than 2016 levels, after which they drop to 8.6 $MtCO_2$ in 2050 (Figure 2.14). Emissions decline 16% by 2050 under the TGT and 49% under the 2DC compared with the BAU. While the NDC is not achieved under any of the scenarios, emissions only rise to 7.3 $MtCO_2$ in the 2DC, and the downward trend after 2030 is visibly steeper than in the BAU or the TGT, ending at 4.4 $MtCO_2$ in 2050 (30% lower than 2016 levels). This is due to reductions of 92% for electricity production, 64% in domestic transport, and 53% in buildings compared with the BAU. These projections highlight the importance of implementing energy efficiency measures, which significantly reduce emissions in the transport and buildings sectors.

Figure 2.14 • Brunei Darussalam: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDCs = Nationally Determined Contributions (to the COP21 Paris Agreement). The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

While Brunei Darussalam has benefited from abundant fossil fuel resources in the past, there are prospects of domestic reserves being depleted in less than 30 years. Policy action to stop current subsidies that encourage the over-consumption of cheap fossil fuels, and to start investments in renewable development and energy efficiency measures, are required to delay depletion of these domestic resources. Insufficient action would likely have repercussions not only for energy use but also for the entire economy, given its high level of dependence on fossil fuel exports for revenue.

Reliance on the ever-changing international oil and gas market has been recognised as a vulnerability in Brunei Darussalam for some time. In 2004, the Sultan formed a council tasked with shaping a future vision for the economy, and presenting technical, financial and strategic requirements needed for its realisation. This resulted in the publication of the 'Wawasan Brunei 2035' in 2007, which outlined aims to become a dynamic and sustainable economy by promoting industries other than oil and gas, among other strategies (Gov BN, 2007).

Concrete measures taken to address these challenges should begin with policy action to stop current subsidies on fossil fuels. Such subsidies have worked for many decades as a mechanism to share the wealth of domestic natural resources among the population. By merging this spirit with the recognition that such resources are limited, the economy can shift investments to more sustainable energy solutions. For example, funding previously spent on subsidising electricity and gasoline could be distributed to promoting renewable development and energy efficiency measures. Brunei Darussalam has considerable potential for solar energy, but its development remains largely invisible. Factors related to this situation include grid connectivity and cost. With almost 100% accessibility to the grid, solar energy is viable only if costs are equal to or lower than the price of electricity from the grid. To support solar development under such circumstances, the government should consider formulating incentives such as feed-in-tariffs and subsidies for rooftop panel installation.

Brunei Darussalam can also benefit greatly from promoting energy efficiency measures; the amount of electricity consumed in relation to the size of the population is among the highest in the APEC region. While the low costs of subsidised gasoline and electricity have posed disincentives so far, improving energy efficiency is a proven and sustainable method of cutting costs for consumers. The only substantial barrier is the initial investment for measures such as vehicles with higher fuel efficiency, better household appliances or more tightly insulated buildings. This barrier could readily be overcome by redirecting energy subsidies towards energy efficiency schemes.

3. CANADA

KEY FINDINGS

- **Canada's abundant energy resources include the largest oil reserves in APEC and the third-largest uranium reserves in the world.** Canada was the world's sixth-largest energy producer and the fifth-largest natural gas producer in 2016.

- **Net energy exports increase in all scenarios as energy production grows more than domestic needs.** Crude oil production increases by 33% in the BAU and 25% in the TGT but declines 2.2% in the 2DC. LNG exports drive gas production 15% higher in the BAU, but reduced global demand in the alternative scenarios lead to production declines.

- **An economy-wide carbon price (or equivalent) comes into effect in 2019, starting at CAD 20 per tCO_2 and rising by CAD 10 per tCO_2 per year to CAD 50 per tCO_2 in 2022.** Despite policies to phase out coal-fired electricity generation, fossil fuels remain dominant at 78% of TPES in 2050 in the BAU Scenario.

- **Canada's electricity mix gets greener in all scenarios.** Renewables increase from 65% of the 2016 electricity mix to 75% of the 2050 mix in the BAU, 85% in the TGT and 84% in the 2DC.

- **FED increases modestly in the BAU, but decreases in both the TGT and 2DC.** Improved efficiency, particularly in buildings and vehicles, reduces FED to 14% below BAU levels in the TGT and 31% in the 2DC.

- **Current policies are not sufficient to meet Canada's NDC,** as energy-related CO_2 emissions continue to rise in the BAU. While emissions decrease in the alternative scenarios, additional ambition beyond even the 2DC is needed to achieve Canada's NDC.

ECONOMY AND ENERGY OVERVIEW

Canada has the second-largest land area (10 million km^2) of Asia-Pacific Economic Cooperation (APEC) economies and had a population of 36 million in 2016. From 2000-16, GDP increased at a compound annual growth rate (CAGR) of 1.9%, while GDP per capita grew by a CAGR of 0.89% to USD 46 102 (Table 3.1). In comparison, the average APEC GDP per capita was USD 22 536 in 2016 (Table 3.1).

The production of goods and resources drives Canada's economy, with 27% of GDP derived from the natural resources, mining, construction and manufacturing sectors in 2017 (StatCan, 2018a). Energy-intensive manufacturing[14] accounted for 3.3% of real GDP in 2017, and the energy sector (both direct and indirect activities) contributed 9.2%, a slight increase from 8.9% in 2016 (StatCan, 2018a). Of Canada's CAD 113 billion (USD 87 billion[15]) in exports in 2017, 91% went to the United States (NRCan, 2018a). In the same year, Canada imported CAD 41 billion (USD 32 billion) in energy products from 114 economies, including CAD 27 billion (USD 21 billion) from its largest trading partner, the United States (NRCan, 2018a).

Table 3.1 · Canada: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	1 229	1 477	1 673	1 830	2 247	2 726	3 281
Population (million)	31	34	36	38	41	43	45
GDP per capita (2016 USD PPP)	39 983	43 219	46 102	48 669	55 313	63 399	72 993
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	261	272	282	294	305	314	323
TPES per capita (toe)	8.5	8.0	7.8	7.8	7.5	7.3	7.2
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	212	184	169	161	136	115	99
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	192	190	191	196	204	208	213
FED per capita (toe)	6.2	5.6	5.3	5.2	5.0	4.8	4.7
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	156	129	114	107	91	76	65
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	526	521	523	561	560	568	594
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the Business-as-Usual Scenario (BAU); identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using PPP to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

Canada is the sixth-largest energy producer in the world, and the fourth-largest in APEC behind China, the United States and Russia (NRCan, 2018a). The vast majority of ground resources and mineral rights are controlled provincially, while the rest are either under federal jurisdiction or controlled by private companies and individuals (GOC, 1867 and GOA, 2018a). The energy sector is a significant driver of GDP for several provinces because of the geographic concentration of fossil fuel deposits. In 2017, the energy sector contributed 21% of GDP in

[14] As defined by the International Energy Agency (IEA) (iron and steel, chemical and petrochemicals, non-metallic minerals, pulp and paper, and aluminium) and including North American Industry Classification System codes 321, 322, 325, 326, 327 and 331.
[15] All exchange rate calculations in this chapter are based on 2018 daily average CAD per USD exchange rate as of 29 November 2018 (FRED, 2018).

Alberta (down from 30% in 2014, prior to the oil price crash), 19% in Newfoundland and Labrador (down from 26%), and 16% in Saskatchewan (down from 24%) (StatCan, 2018b).

ENERGY RESOURCES

In 2017, Canada had the second-largest proved crude oil reserves in the world, the sixteenth-largest proved natural gas reserves, and the third-largest uranium reserves and was the world's second-largest hydroelectricity generator (NRCan, 2018a). Its fossil fuel resources are located primarily in the Western Canadian Sedimentary Basin (WCSB) in the western provinces of British Columbia, Alberta and Saskatchewan. Less significant offshore resources are found in eastern Canada (Nova Scotia, and Newfoundland and Labrador) as well as in Manitoba, Ontario and the Northwest Territories. Alberta has 165 billion barrels (bbl) (22 550 Mtoe) of oil sands reserves[16] and 1.7 billion bbl (230 Mtoe) of conventional crude oil, accounting for 98% of Canada's crude oil reserves (NEB, 2018a).

High-grade uranium deposits located in Saskatchewan's Athabasca Basin provided 22% of global production in 2017, second only to Kazakhstan (NRCan, 2018a). Coal is found in the western provinces, and although production was relatively flat over the past decade, a 12% decline occurred between 2013 and 2016 (NEB, 2017).

Table 3.2· Canada: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	6 582	111	0.64	16	7
Oil (billion bbl) [a]	169	96	10	3	1
Natural gas (tcm) [a]	1.9	11	1.0	16	7
Uranium (tU) [b]	409 700	31	11	3	2

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. tU = tonnes of uranium. a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kilogram of uranium (kgU).
Sources: For coal, oil and natural gas, BP (2018). For uranium, NEA (2018).

Canada has substantial renewable energy resources, ranking seventh globally in 2016 for renewable energy production (NRCan, 2018a). Significant hydroelectricity capacity, mainly in British Columbia, Manitoba, Quebec, and Newfoundland and Labrador, totalled almost 81 gigawatts (GW) in 2016. There are 111 biomass facilities with a capacity greater than one megawatt (MW), with an aggregate capacity of 2.7 GW, as well as 364 bioheat facilities for large industrial purposes. In 2017, wind power capacity reached 13 GW, the ninth-largest globally, concentrated in Ontario (38%), Quebec (31%), Alberta (12%) and Nova Scotia (4.1%) (NRCan, 2018a), (NEB, 2018a). Almost all of Canada's 2.8 GW solar power capacity (99%) is in Ontario.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Energy policy in Canada is shaped at both the provincial and federal levels. Provincial governments generally control mineral rights, intraprovincial pipelines, and electricity systems; the federal government regulates the environment, federal lands and waters, interprovincial pipelines, and interprovincial and international trade. Federally, energy policy follows three primary principles: 'market orientation, respect for jurisdictional authority

[16] Bitumen (or oil sands crude oil) is a thick, sticky form of crude oil so heavy and viscous it will not flow unless heated or diluted with lighter hydrocarbons, primarily condensate. (Alberta Energy, 2018).

and the role of the provinces, and targeted intervention in the market process to achieve specific policy objectives through regulation or other means' (NRCan, 2014).

Canada began accelerating the phase-out of coal-fired electricity through federal action in 2012 that banned construction of traditional coal plants and set retirement dates for existing units (GOC, 2012). These regulations also set a performance standard for new power plants (equivalent to a natural gas combined-cycle emissions intensity of 420 tonnes of carbon dioxide [CO_2] per gigawatt-hour) and mandated that older (commissioned prior to 1975), less-efficient plants cease operations after 50 years of service or in 2019, whichever comes first. Plants commissioned after 1975 are to be shut down after 50 years or in 2029. The electricity component of Canada's output-based pricing system for electricity generation is currently under construction, but a recent proposal indicates that performance benchmarks will be differentiated by fuel type, with solid and liquid fuels receiving higher carbon compliance subsidies than gas-fired generation (ECCC, 2019). This is notably different to Alberta's system, where benchmarks are the same for all generators regardless of fuel type (GOA, 2017a). As constructed, the federal pricing system would be a significantly weaker deterrent to coal generation in the short term than Alberta's system. Ontario was the first province to legislate the elimination of coal-fired electricity generation through a retirement schedule running from 2003 to (GOO, 2017). In 2015, Alberta announced the phase-out of coal ahead of the federal schedule, setting an early retirement date of 2030 for six of the 18 remaining operating plants (GOA, 2015). New Brunswick plans to eliminate coal from its energy mix by 2030 (GNB, 2017); some of these plants could retire as early as 2020 and plans to retrofit existing units to burn natural gas have also been announced. However, Nova Scotia has an equivalency agreement to keep coal-fired generation past the federal deadline (EC, 2017) and Saskatchewan is permitted to burn coal at its Boundary Dam facility, which is equipped with carbon capture and storage (CCS) (GOC, 2018a).

New provincial and federal carbon pricing mechanisms have been introduced or revised since the *Outlook 6th Edition*. Alberta revised its carbon tax on large industrial emitters, previously under the Specified Gas Emitters Regulation, to a broad-based carbon levy of CAD 20 per tonne of CO_2 (tCO_2) (USD 15 per tCO_2) beginning in 2017, rising to CAD 30 per tCO_2 (USD 23 per tCO_2) in 2018 (GOA, 2017b). British Columbia upgraded its carbon price from CAD 30 per tCO_2 (in effect since 2012) to CAD 35 per tCO_2 (USD 27 per tCO_2) in April 2018, and prices are expected to increase annually to CAD 50 per tCO_2 (USD 39 per tCO_2) in 2021. The federal government announced a new carbon pricing benchmark in 2016 under the Pan-Canadian Framework on Clean Growth and Climate Change that implements a broad-based carbon pricing schedule for all jurisdictions that do not have their own framework in place by the end of 2018 (GOC, 2016a). The carbon pricing system can be explicitly price-based, hybrid or cap-and-trade, but it must meet or exceed the floor prices of CAD 10 per tCO_2 (USD 7.7 per tCO_2) in 2018 and CAD 50 per tCO_2 (USD 39 per tCO_2) in 2022. The backstop includes a system plan to mitigate the competitiveness impacts for trade-exposed, carbon-intensive industrial emitters while still providing them with the incentive to reduce emissions (GOC, 2018b).

For systems that are not explicitly price-based, the federal government has negotiated equivalency agreements to ensure outcomes equivalent to those likely to occur under compliance with the benchmark (GOC, 2018c). However, several provinces are resisting carbon pricing: Saskatchewan is challenging whether the federal government's carbon pricing imposition onto the provinces is constitutional with support from Ontario and New Brunswick (GOS, 2018). Ontario plans to withdraw from the cap-and-trade market operating in Quebec and California, while Manitoba has cancelled its plan to impose a carbon tax of CAD 25 per tCO_2 (USD 19 per tCO_2) in 2018. Other provinces are evaluating whether to enact or implement policies to comply with federal benchmarks, and their decision will be influenced by Saskatchewan's constitutional challenge.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Canada under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 3.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 3.3 · Canada: Key assumptions and policy drivers under the BAU

Buildings	EPS and labelling programs maintained at current levels.
Industry	Cost-effective technology improvements implemented.
Transport	Conservative deployment of hybrid and electric vehicles. Mandated biofuel blend rates for renewable fuel content in gasoline and diesel in some jurisdictions. Existing 2017-26 standards in place for light-duty vehicles; stringent GHG emissions standards for heavy-duty vehicles.
Energy supply mix	Continued oil exports over the Outlook period; less coal and nuclear in the primary supply mix. Increased natural gas production, supplemented by tight natural gas and oil reserve development.
Power mix	Decreased coal-fired generation; deployment of CCS technology; refurbishment and retirement of nuclear facilities. Significant growth of gas and renewables consistent with provincial utility plans and the low resource cost.
Renewables	Provincially set renewables capacity or generation targets.
Energy security	No explicit energy security policies and targets.
Climate change	Economy works towards the goal of reducing GHG emissions by 30% below 2005 level by 2030 (not achieved in the BAU).

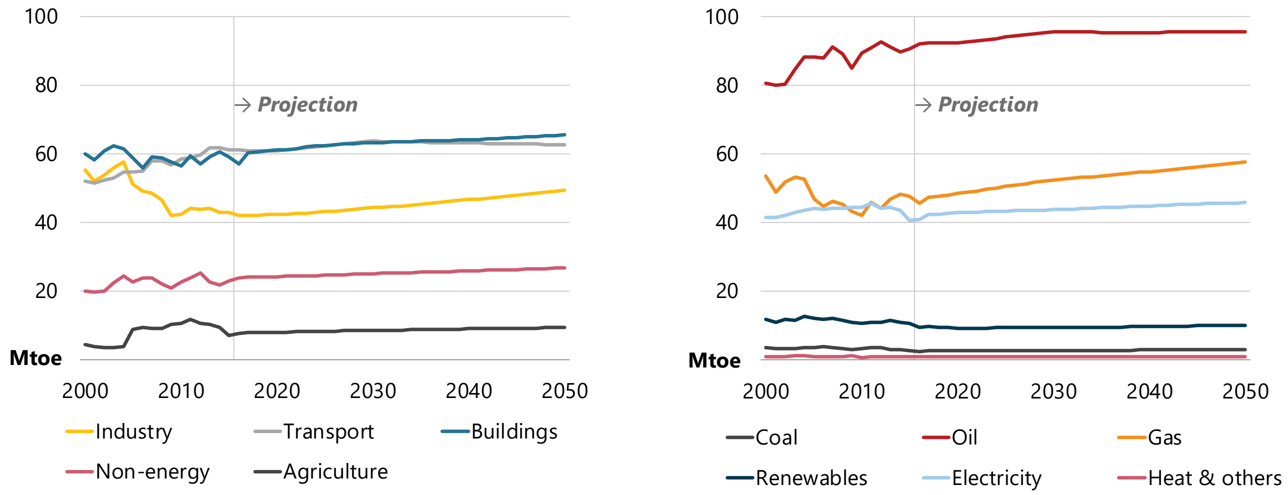
Notes: CCS = carbon capture and storage. GHG = greenhouse gas. MEPS = minimum energy performance standards. Outlook period = 2016-50. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Canada's FED has been flat since 2000 as increases in transport activity were offset by industrial declines related to the impacts of the global financial crisis. Oil and gas production activity has underpinned increased freight transport activity in recent years: the energy-producing provinces of Alberta, Saskatchewan and Newfoundland and Labrador accounted for 62% of transport demand increases from 2000 to 2014 and drove declines since the oil price crash in 2014 (StatCan, 2018c). Over the Outlook, vehicle standards limit increases in transport demand, industry rebounds above its pre-Recession levels, and buildings drive growth (Figure 3.1).

Energy demand in Canada under the BAU Scenario grows modestly over the Outlook period (2016-50), from 191 Mtoe to 213 Mtoe, at a CAGR of 0.32%. FED per capita is projected to decrease at an average rate of 0.31% per year, while FED per GDP falls 1.7% per year as FED grows more slowly than the population or the economy. Domestic transport represented 32% of FED in 2016, while buildings accounted for 30%, followed by industry (22%), non-energy use (12%) and agriculture and non-specified (4.0%). Sector shares of FED remain relatively constant to 2050, while fuel shares see an increase in natural gas at the expense of oil. Buildings and industry drive 73% of the sectoral FED increases over the Outlook, and natural gas drives 55% of the fuel FED increases (Figure 3.1).

Figure 3.1 · Canada: Final energy demand by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

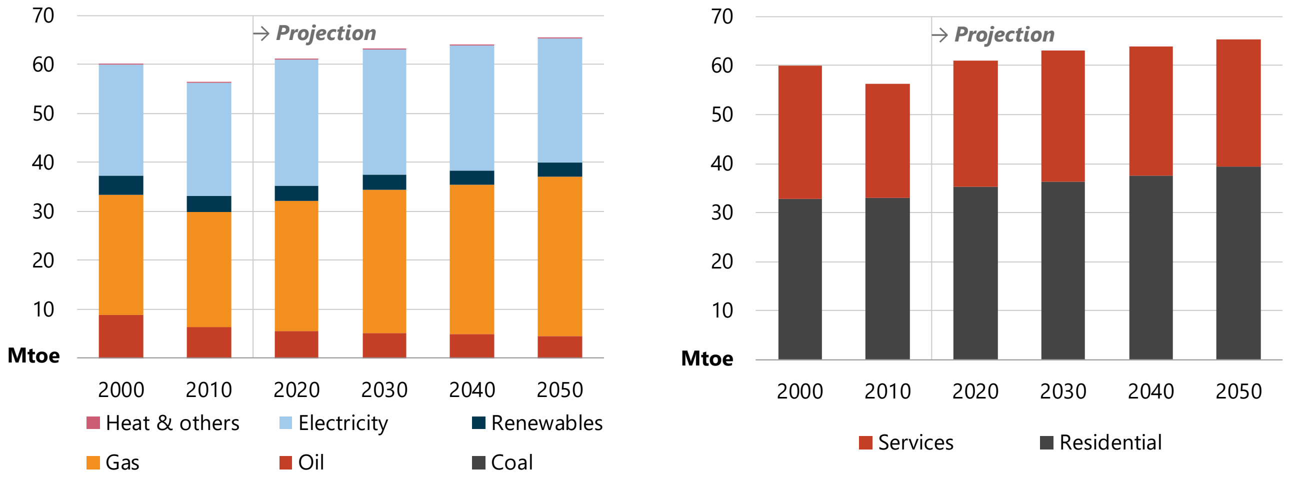
BUILDINGS: ENERGY DEMAND DRIVEN BY CHEAP GAS FOR SPACE HEATING

Building energy demand has been largely unchanged from 2000 to 2016, due to the effects of several competing dynamics. Both the number of households (23%) and the size of houses (5.9%) have increased over this period, while the number of people per household has declined by 3.8% (OEE, 2018). Meanwhile, the presence of energy-intensive end-uses is also on the rise: cooling systems per household rose, from 0.35 in 2000 to 0.54 in 2016, and the number of appliances per household has increased 22% over the same period (OEE, 2018). Despite these upwards pressures, residential energy intensity, measured as FED per household, has declined, from 2.8 toe per household (toe per hh) in 2000 to 2.2 toe per hh in 2016, as building codes and appliance standards have increased. This efficiency improvement marginally outweighed the effects of house size and numbers, and higher appliance penetration, resulting in energy demand falling from 33 Mtoe in 2000 to 32 Mtoe in 2016.

The National Energy Code of Canada for Buildings 2015, which revised 2011 standards, contains more than 90 measures to improve energy efficiency in the sector and awaits adoption by each province. With some regions already moving beyond the code, Canada has developed numerous programs to promote deployment of more efficient technologies, including standards, labelling and benchmarking (such as the ENERGY STAR labelling system), retrofitting guidelines, and a new National High-Performance Building Challenge to encourage building designs that achieve significant progress towards net-zero performance (NRCan, 2017).

In the BAU, these efficiency increases are not enough to stymie demand growth, which rises 15%, from 57 Mtoe to 65 Mtoe (Figure 3.2), over the Outlook period (with natural gas representing over 90% of the increase). Natural gas and electricity continue to dominate buildings energy demand through the Outlook, accounting for 85% of FED in 2016 and 88% in 2050. Renewables demand falls slightly, mainly owing to increased building efficiency and declining biomass consumption for space heating. The residential subsector drives growth, with demand rising from 32 Mtoe to 39 Mtoe. Throughout the Outlook, residential space heating remains the largest end-use, but space cooling is the fastest growing (3.0% CAGR). Energy intensity continues to improve, from 2.2 toe per hh in 2016 to 2.1 toe per hh in 2050.

Figure 3.2 · Canada: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

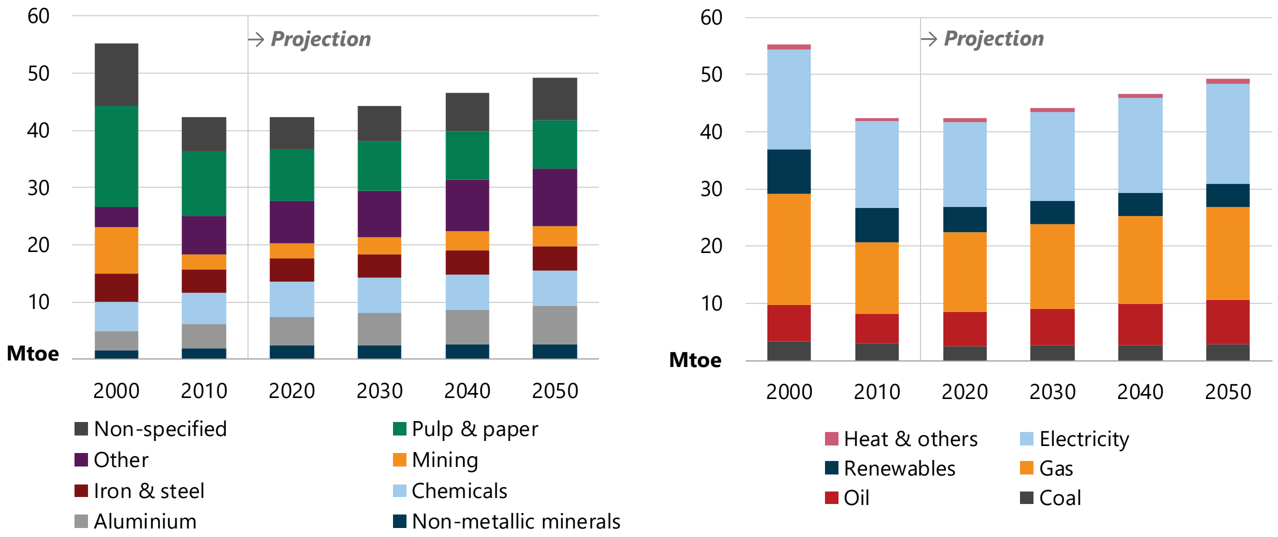
Energy demand in the services subsector, which includes activities related to trade, finance, real estate, public administration, education and commerce, rises marginally, from 25 Mtoe to 26 Mtoe over the Outlook. Energy intensity for service buildings declines from 0.031 toe per million square metres (toe per Mm^2) in 2016 to 0.023 toe per Mm^2 in 2050, as floor area increases 42% and energy demand rises only 5.2%. Space heating demand declines slightly (from 14 Mtoe to 13 Mtoe) and loses share, from 55% in 2016 to 51% in 2050. Natural gas and electricity continue to dominate the energy mix, although oil plays a more significant role in services than in residential, primarily because of diesel-fuelled generators.

INDUSTRY: GROWTH LED BY THE ALUMINIUM SUBSECTOR

Canada's industrial energy demand is historically driven by several energy-intensive, export-oriented sectors, such as pulp and paper, mining, aluminium, iron and steel, and manufacturing, whose output is tied to the economic well-being that of its major trading partners, particularly the United States. Because of this, Canada's industrial demand peaked at 58 Mtoe in 2004, then fell by an average of 6.1% per year to 42 Mtoe in 2009, following the global financial crisis. In 2005, mining energy demand dropped, from 10 Mtoe to 2.7 Mtoe year-on-year, due to an IEA statistical reclassification. Pulp and paper began a long decline, from 18 Mtoe in 2004 to 9.9 Mtoe in 2016, as a result of declining demand and several closures resulting from the 2009 recession. Total industrial capacity utilisation has increased since 2009, but is still below its 2007 pre-recession rate of about 85% (StatCan, 2018d).

Industry energy demand grows over the Outlook period under the BAU, from 42 Mtoe to 49 Mtoe (Figure 3.3). The aluminium subsector leads growth (43% overall increase), with primary aluminium production climbing from 3.2 million tonnes (Mt) to 4.6 Mt. Demand increases in all subsectors except pulp and paper (–15%) and chemicals and petrochemicals (–0.14%). Electricity continues to meet the largest share of total energy demand and increases slightly, from 35% in 2016 to 36% in 2050. Natural gas is close behind, maintaining a flat share of 33% over the Outlook period.

Figure 3.3 · Canada: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Natural Resources Canada's Office of Energy Efficiency provides mandatory and voluntary standards for industry and other demand sectors. The federal government collaborates closely with provincial governments and the private sector, in addition to aligning actions with the United States and other international partners. Greater energy efficiency and a shift towards less energy-intensive activities have contributed to improved energy intensity in industry.

DOMESTIC TRANSPORT: FUEL ECONOMY GAINS STYMIE GROWTH IN THE BAU

Canada's vast land area, low population, large distances between urban centres and lack of significant public transportation underpin above-average transport energy demand per capita: 1.7 toe per person in 2016, compared with the APEC average of 0.49 toe per person. However, in contrast to the overall APEC trend of increasing transport energy intensity, Canada's shrinks to 1.4 toe per person by 2050 in the BAU. Overall, domestic transport energy demand flattens over the projection period (2.3% overall growth over 2016 levels), as vehicle efficiency dampens the increased demand for passenger and freight travel, breaking the historical trend of steady growth (1.0% CAGR in 2000-16).

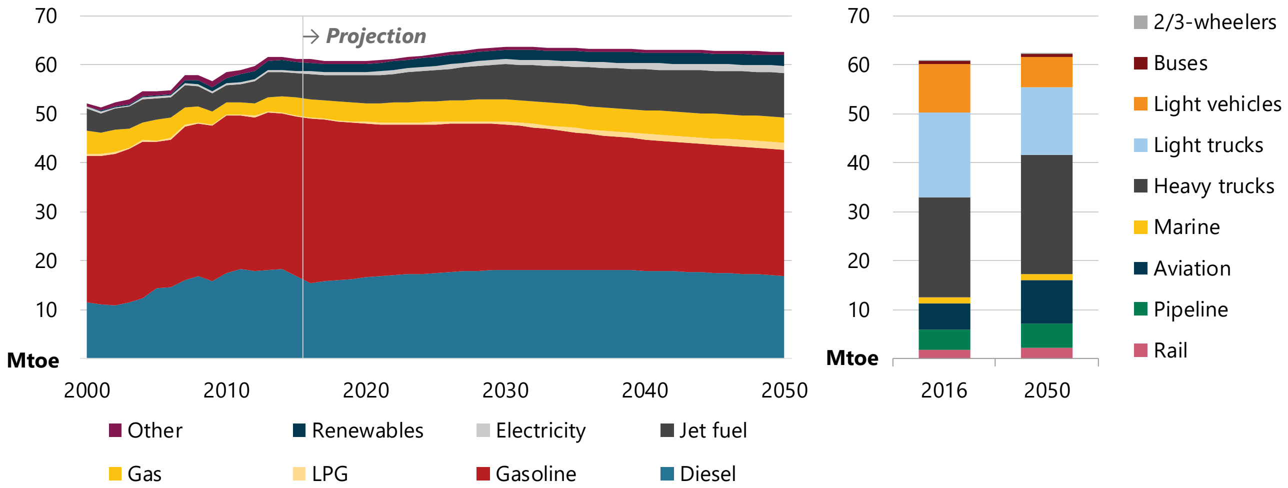
Vehicle sales have continued to grow since 2010, with more Canadians purchasing larger vehicles and trucks, including minivans and sport-utility vehicles: 69% of new passenger vehicles sold in Canada in 2017 were trucks (StatCan, 2018e). Fuel economy standards have increasingly tightened, improving energy efficiency in passenger and freight vehicles.[17] This continues in the BAU Scenario, reducing gasoline demand and limiting diesel growth, which both contribute to a relatively flat demand profile (Figure 3.4).

Although their share shrinks, gasoline and diesel remain dominant in the transport fuel mix, with gasoline accounting for 41% of final energy demand in 2050 and diesel accounting for 27%. The natural gas share increases over the Outlook period, from 5.9% to 8.2%, due to the relatively low price of natural gas compared with petroleum fuels, as does jet fuel (from 8.6% to 15%) due to strong growth in air travel. The combined share of renewables and electricity increases from 3.8% in 2016 to 5.8% in 2050. This is partly due to changes in vehicle stocks: the conventional vehicle (gasoline, diesel, liquefied petroleum gas and compressed natural gas) share of

[17] While Canada historically harmonised fuel economy standards with the United States, a downward revision in light-duty standards by the latter has prompted Canada to reconsider its own standards trajectory (EPA, 2018), (ECCC, 2018). Following the lead of the United States would put upward pressure on transport energy use in the BAU.

the total vehicle stock declines over the Outlook period, from almost 100% in 2016 to 80% in 2050, as consumers switch to more efficient advanced vehicles (flexible, hybrid, plug-in hybrid and battery electric). The share of advanced vehicles grows from 0.067% to 20% over the Outlook period.

Figure 3.4 · Canada: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Canada is a significant energy producer with geographically concentrated energy resources. A high portion of fossil fuel production is exported; however, regulators ensure sufficient fossil fuel supply is available for the domestic market before any export licensing and infrastructure is approved for construction (NEB, 2016). Electricity markets are also under provincial jurisdiction, with excess generation typically exported to neighbouring provinces or the United States.

REFINERIES: INTERCONNECTION CONTINUES TO GROW

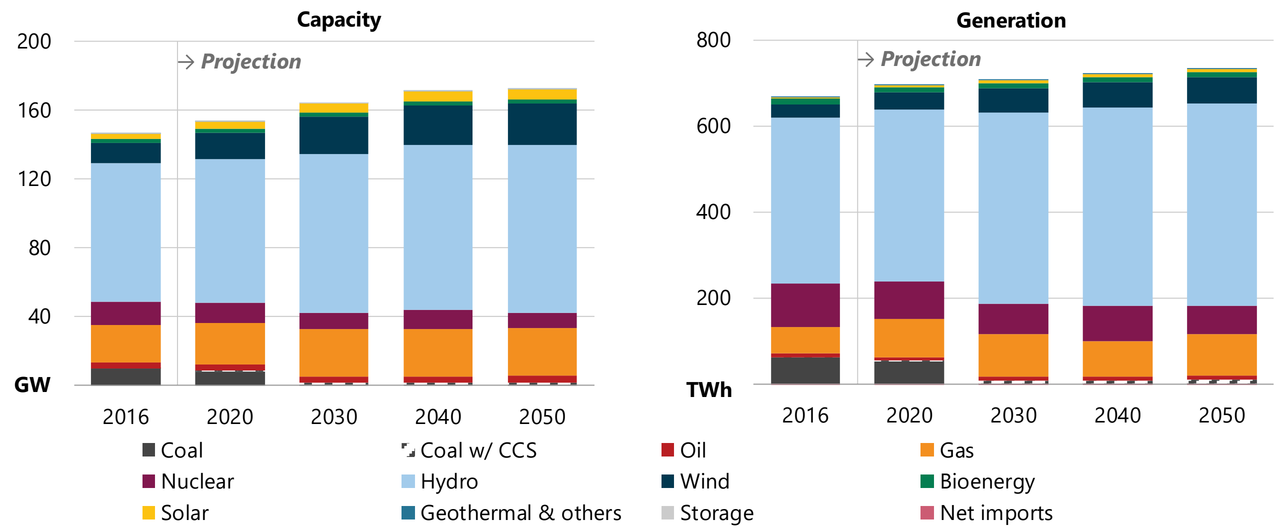
Canada has 17 oil refineries with a crude oil processing capacity of 1.9 million barrels (Mbbl) per day (95 Mtoe per annum) (CAPP, 2017). Eight of them (36% of total refining capacity) are in western Canada, and the oldest refinery was built in 1934. The North West Redwater Partnership's Sturgeon Refinery, the newest in Canada, began processing crude oil in late 2017.

Crude sources vary by geographic region. Western refineries process domestically produced oil; eastern refineries rely on pipeline imports from the United States or crude imported from all over the world by marine tankers. Despite large bitumen and heavy oil production, Canada's refineries are generally configured to process light and medium crude. Therefore, a large portion of heavy oil production is exported to US refineries. In the BAU, Canada's refinery capacity increases slightly, from 102 Mtoe in 2016 to 112 Mtoe in 2022, then remains flat through 2050. Canada is self-sufficient in oil products but balances short-term shortfalls or surpluses via trade with the United States.

POWER SECTOR: NATURAL GAS AND RENEWABLES TO MEET DEMAND GROWTH

Canada's electricity sector is under provincial jurisdiction and is controlled by separate interconnected markets. Alberta and Ontario operate hybrid market structures; other provinces operate as regulated provincial monopolies. In 2016, Canada had 146 GW of power capacity (Figure 3.5). Renewables accounted for the largest share (67%) owing to significant hydro power resources, followed by natural gas (15%), nuclear (9.3%), coal (6.6%) and oil (2.6%). Capacity expands to 172 GW by 2050 in the BAU, with renewables increasing to 130 GW (75%) and natural gas to 28 GW (16%).

Figure 3.5 · Canada: Power capacity and electricity generation by fuel, 2016-50



Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

Electricity generation grows over the Outlook, from 667 terawatt-hours (TWh) in 2016 to 733 TWh in 2050 (9.9% overall). In 2016, renewables accounted for 65% of total generation, comprising hydro (58%), wind (4.6%), bioenergy (1.9%) and solar (0.45%). Nuclear (15%), coal (9.3%) and natural gas (9.2%) were the other main sources of electricity generation in 2016. In the BAU, renewables generation increases, from 434 TWh to 550 TWh, led by growth in solar (2.4% CAGR), wind (2.0% CAGR) and hydro (0.57% CAGR). Most coal-fired generation is phased out over the projection period, declining from 62 TWh in 2016 to 10 TWh in 2050. Almost all (99%) of the remaining coal is equipped with CCS, and thus omitted from the federal phase-out, and the rest reflects the equivalency agreement granting Nova Scotia the right to burn conventional coal past 2030.[18] Nuclear declines from 101 TWh in 2016 to 66 TWh in 2050 but is quite volatile over the Outlook due to scheduled refurbishments and the coal phase-out. Nuclear declines are generally offset by increases in natural gas (1.4% CAGR) and renewables (0.70% CAGR).

PRIMARY ENERGY SUPPLY: FOSSIL FUELS REMAIN DOMINANT

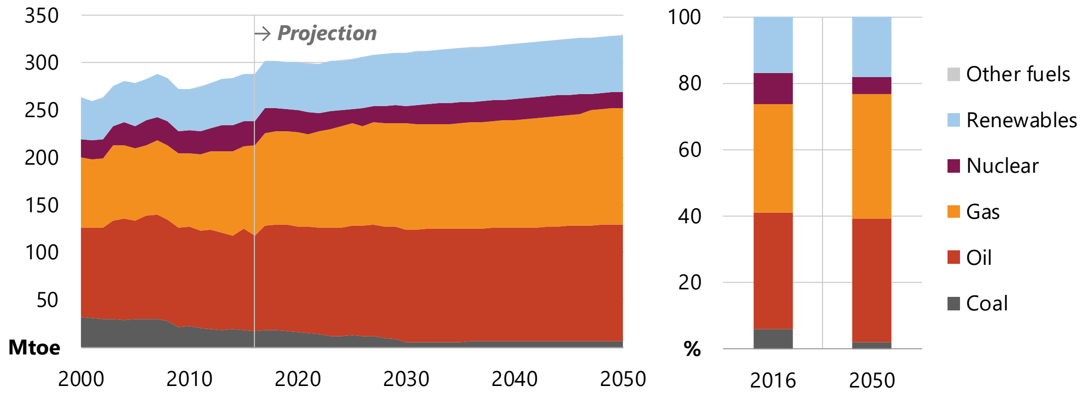
Like power generation, TPES increases steadily, from 282 Mtoe in 2016 to 323 Mtoe in 2050. Canada's TPES was largely fossil fuel-based in 2016: 36% oil, 34% natural gas and 6.0% coal (Figure 3.6). In the BAU, nuclear declines (from 26 Mtoe to 17 Mtoe) and renewable energy increases (from 49 Mtoe to 59 Mtoe). Hydro continues to account for a large share of renewables supply—maintaining its 2016 share of 68% of total renewables in 2050—and TPES from wind more than doubles, from 2.6 Mtoe in 2016 to 5.3 Mtoe in 2050.

Canada's coal supply dropped from 32 Mtoe in 2000 to 17 Mtoe in 2016, mostly due to its declining use in power generation (Figure 3.6). This trend continues through the Outlook due to the federal phase-outs of coal generation from the electricity sector. Some coal supply remains (6.7 Mtoe in 2050), however, as metallurgical

[18] See Energy Policy Context and Recent Development section above for more details.

coal continues to be used for coking and steelmaking. The increasing shares of natural gas (to 38% in 2050), renewables (to 18%) and oil (to 38%), offsets declining shares for coal (to 2.1%) and nuclear (to 5.3%).

Figure 3.6 · Canada: Total primary energy supply by fuel, 2000-50

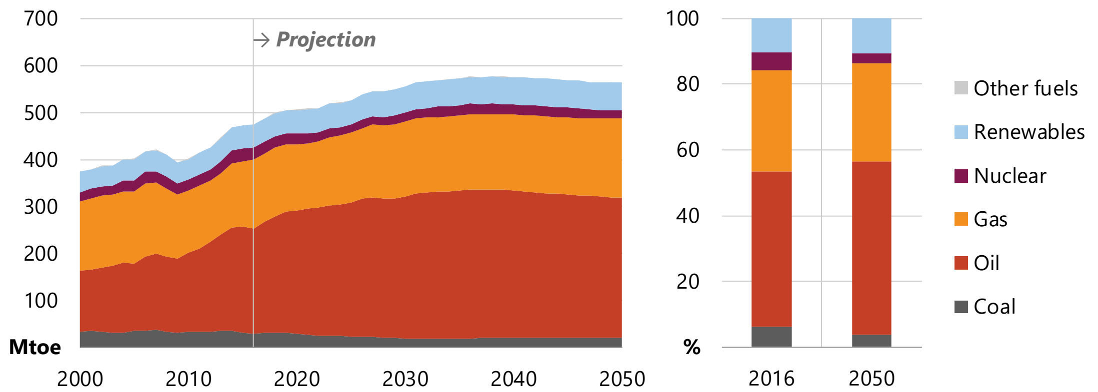


Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: OIL PRODUCTION OUTPACES DOMESTIC DEMAND

Oil production in 2016 was concentrated in Alberta (80%), Saskatchewan (11%), Newfoundland and Labrador (5.2%), and British Columbia (1.7%) (NEB, 2018a). Although the majority of oil production is from oil sands, Canada also produces light and heavy oil, including conventional, tight and shale oil. Increased oil sand activity drives oil production increases over the Outlook period, from 224 Mtoe to 298 Mtoe, but peaks at 317 Mtoe in 2036 (Figure 3.7). Crude oil production continues to outpace domestic demand, driving net exports from 52% of production in 2016 to about two-thirds of production, where the share remains from 2026 to 2050. However, this production trajectory is contingent on Canada's ability to build infrastructure to increase oil exports, and will certainly be decreased if that capacity is not made available. In 2018, members of industry and government have embraced production curtailments to mitigate the low pricing challenges presented by constraints on transporting oil out of the western producing region, which are expected to remain until the constraints are alleviated (GOA, 2018b).

Figure 3.7 · Canada: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Canada is the world's fifth-largest producer of natural gas behind the United States, Russia, Iran and Qatar (IEA, 2018a). Natural gas production occurs primarily in the WCSB: 66% in Alberta and 28% in British Columbia (NEB, 2018a). Canada has historically exported natural gas in excess of domestic needs via a highly integrated North

American pipeline network. Since 2010, Canadian natural gas production has been partially displaced from traditional eastern Canadian and American markets by rising Appalachian natural gas production. This has driven net exports from a high of 85 Mtoe in 2001 to 52 Mtoe in 2016. Production is projected to increase in the BAU, from 146 Mtoe in 2016 to 169 Mtoe in 2050. Pipeline exports continue to decline but are mostly offset by increased liquefied natural gas (LNG) exports, which buoys net gas exports to 51 Mtoe in 2050. With Canada being increasingly phased out of its traditional markets in the United States, this production trajectory is contingent on its ability to reach overseas markets with LNG exports.

Canada is the thirteenth-largest producer of coal in the world and the third-largest exporter of metallurgical coal after Australia and the United States (NRCan, 2018b). In 2016, coal production hit a 30-year low and is projected to continue falling, following declining domestic thermal demand and lower global demand for metallurgical coal (NEB, 2017).

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Canada's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050.

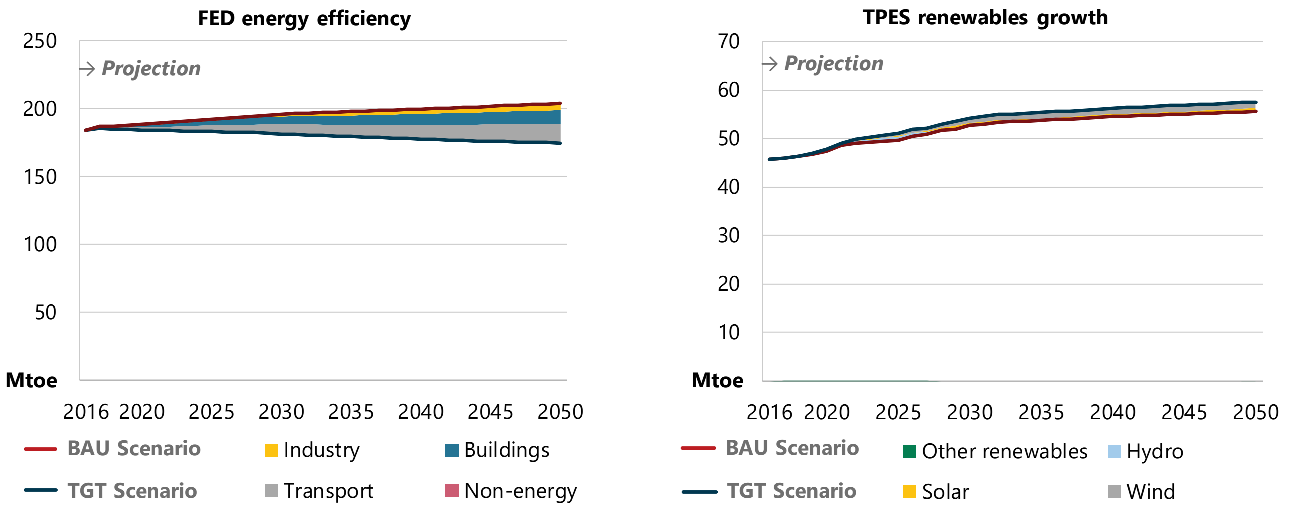
Relative to the BAU, FED is 14% lower while CO_2 emissions are 23% lower in the TGT by 2050. Under the 2DC, Canada's FED is 31% lower and CO_2 emissions are 43% lower. The supply of renewables in TPES is 3.5% higher in the TGT but 3.4% lower in the 2DC, as lower electricity demand requires fewer renewables.

APEC TGT SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. The APEC energy intensity reduction and renewable doubling goals do not articulate specific economy-level targets, but rather emphasise greater efforts to achieve the targets across the entire APEC region. Canada's energy efficiency policies, commitment to reduce GHG emissions and other targeted regulations have historically reduced energy intensity and are expected to further reduce it in the BAU. While the TGT Scenario requires it to make these efforts more ambitious to further decouple energy demand from GDP growth, the assumptions are realistic and achievable in Canada without radical lifestyle or economic changes.

Efficiency improvements in the TGT are mostly achieved in the buildings and transport sectors, and result in lowering FED by 29 Mtoe (14%) below BAU levels in 2050 (Figure 3.8). Domestic transport FED is reduced 13 Mtoe below BAU levels, driven by improved vehicle standards and a shifting of the vehicle stock towards alternative vehicles, which make up 32% of the 2050 vehicle stock in the TGT, compared with 20% in the BAU. Buildings FED is reduced 10 Mtoe below the BAU in 2050, as structures transition to more efficient envelopes and appliances. Increased industry efficiency is achieved through higher scrap recycling rates, a lower clinker-to-cement ratio, higher renewables deployment, shorter plant lifespans, overall improvements in efficiency and a transition to best available technologies; this reduces FED by 5.1 Mtoe in 2050.

Figure 3.8 · Canada: Energy efficiency and renewables development, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Canada's electricity generation is already predominantly CO_2-free, with 65% of generation (434 TWh) from renewable technologies and 15% (101 TWh) from nuclear sources in 2016. In the TGT, the renewables share increases to 85% (561 TWh) in 2050, surpassing the BAU in both share (75%) and absolute terms (550 TWh). Solar generation is the fastest-growing source of renewable electricity over the projection period, increasing at a CAGR of 3.2%, compared with 2.4% CAGR in the BAU. Wind follows at a 2.7% CAGR, compared with 2.0% CAGR in the BAU.

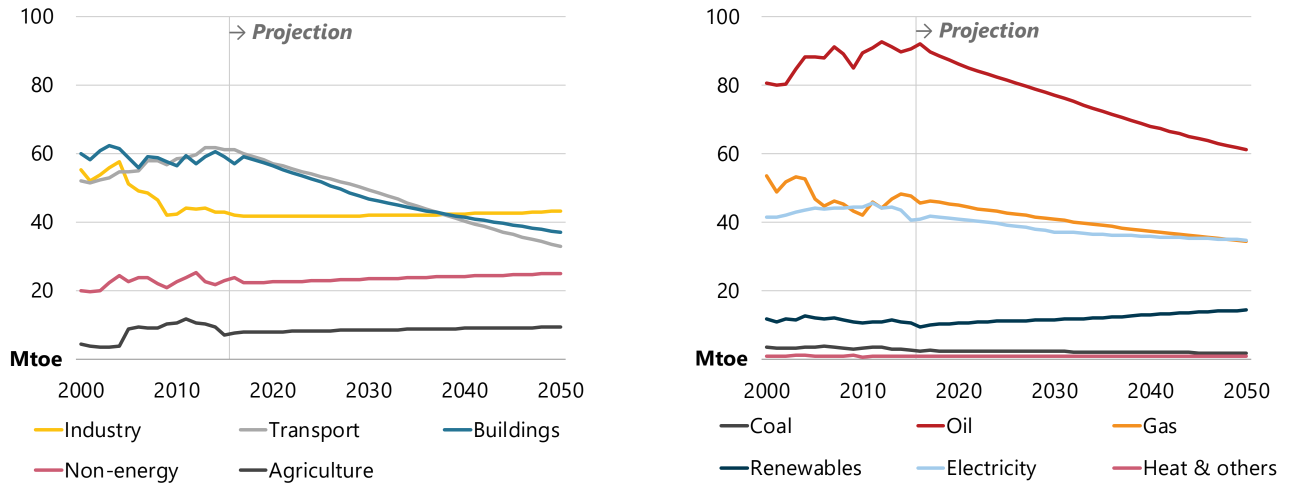
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario explores what additional effort is needed to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the IEA (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective. While the 2DC falls short of meeting Canada's Nationally Determined Contribution (NDC) in the Paris Climate Agreement, it shows significant decarbonisation in most energy sectors in Canada.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Reducing CO_2 emissions in Canada in the 2DC is mainly achieved through increased energy efficiency in the transport and buildings sectors. While fossil fuel use is reduced in the industry and non-energy sectors relative to the BAU, decarbonisation of these sectors is challenging as fossil fuels form a vital component of many industrial processes, especially in the cement, mining, iron and steel, chemical and petrochemicals, other, and non-specified subsectors (Figure 3.9).

Figure 3.9 · Canada: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

In the 2DC, FED decreases, from 191 Mtoe in 2016 to 147 Mtoe in 2050, which is 31% lower than in the BAU. The largest decrease comes from transport (down 30 Mtoe or 47%), followed by buildings (down 28 Mtoe or 43%), industry (down 6.1 Mtoe or 12%) and non-energy (down 1.7 Mtoe or 6.2%). These trends result in industry accounting for the highest share of sectoral FED in 2039, as the share of transport falls below that of buildings arthird place. Significant changes in the composition and efficiency of the vehicle fleet and a decrease in tonne and passenger kilometres are instrumental to the transport demand reduction. The conventional vehicle stock declines to 38%, compared to 80% in the BAU, with more than 20 million technologically advanced vehicles making up 62% of the vehicle stock by 2050, up from 20% in the BAU.

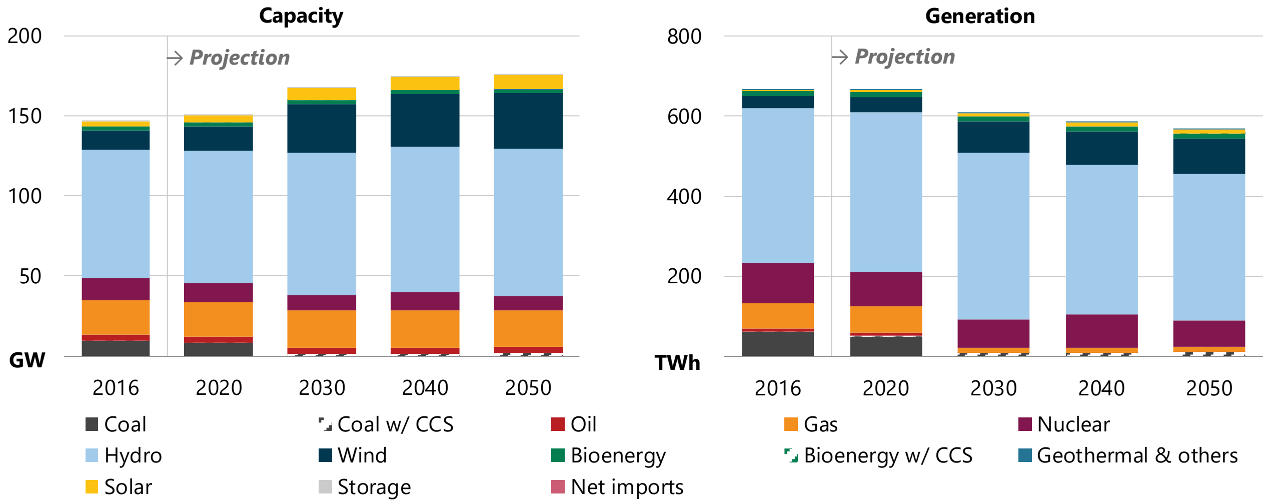
Renewables and electricity replace some natural gas and coal but fossil fuels still meet the majority of energy demand, contributing 66% in 2050 compared with 73% under the BAU. Oil continues to be the dominant fuel in 2050, supplying 42% (61 Mtoe) of FED (Figure 3.9), largely in transport and non-energy. Electricity's share increases to 24% in 2050, surpassing natural gas in 2048 as the latter's share falls to 23%. Renewables grow to meet 9.8% of FED, mainly due to gentle demand growth from buildings and falling overall FED.

TRANSFORMATION AND SUPPLY IN THE 2DC

With lower electricity demand in both Canada and the United States due to efficiency gains, total Canadian electricity generation in the 2DC in 2050 is 567 TWh, compared with 733 TWh in the BAU (Figure 3.10). As Canada's electricity generation and capacity are mostly low emitting already, the scope for increasing the share of renewables is limited. By 2050, they account for 78% of total capacity (138 GW), compared with 75% (130 GW) in the BAU.

Coal-fired electricity capacity without CCS is retired at an earlier and more rapid pace than in the BAU. Oil-fired generation is completely phased out by 2030, whereas 8.2 TWh remains throughout the projection period in the BAU. Natural gas capacity increases from 21 GW to 28 GW in the BAU but rises to only 23 GW in the 2DC because of lower electricity demand (Figure 3.10).

Figure 3.10 · Canada: Power capacity and electricity generation in the 2DC by fuel, 2016-50

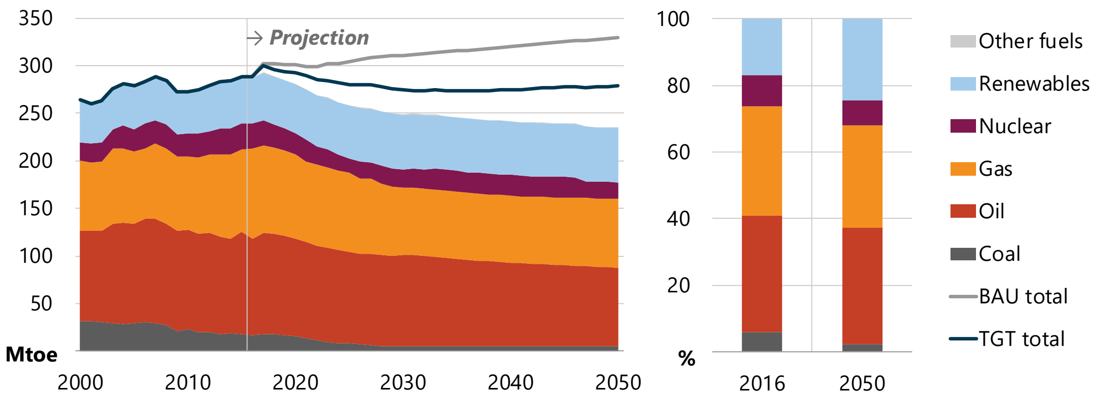


Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

Lower integration costs drive substantial variable renewable energy (VRE) capacity growth in the 2DC. Wind power capacity nearly triples, from 12 GW in 2016 to 35 GW in 2050, compared with doubling in the BAU to 24 GW. Solar power capacity also triples, from 2.7 GW to 9.0 GW, compared to doubling to 6.0 GW in the BAU. With cheaper VRE and lesser electricity demand, hydroelectric capacity growth is slower, 14% over the 2DC compared with 21% over the BAU. By 2050, renewables generation is 477 TWh (84%); nuclear contributes a further 66 TWh (12%) of low-emissions generation. Natural gas generates 13 TWh of electricity (2.3%), coal with CCS generates 10 TWh (1.8%), and other sources generate 0.23 TWh (0.04%). Hydro contributes the majority of renewables generation in 2050 (365 TWh), followed by wind (89 TWh), bioenergy (13 TWh) and solar (10 TWh).

Energy industry own-use consumption, as it relates to both energy demand and resulting CO_2 emissions, is an important consideration as Canada enacts policies to transition to the 2DC. In this Outlook's modelling, sectoral targets are set for the demand sectors, leaving the carbon budget for energy industry own-use consumption modelled as a function of energy production. Box 3.1 outlines the implications for Canada of producing excess fossil fuels for export while domestic demand decreases.

Figure 3.11 · Canada: Total primary energy supply in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Projections for both TPES and energy production are significantly lower in the 2DC compared with the BAU (Figure 3.11). Net trade also shrinks owing to large declines in crude oil and natural gas exports. While production grows in the BAU, from 475 Mtoe to 564 Mtoe in 2050, it decreases to 423 Mtoe in the 2DC. TPES mirrors production, growing from 282 Mtoe in 2016 to 323 Mtoe in 2050 in the BAU, but declining to 230 Mtoe in 2050 in the 2DC. Although fossil fuels supply the majority of TPES and production in the 2DC, the overall share declines from the 2016 level, accounting for 82% of production and 70% of TPES in 2050, compared with 86% of production and 78% of TPES under the BAU.

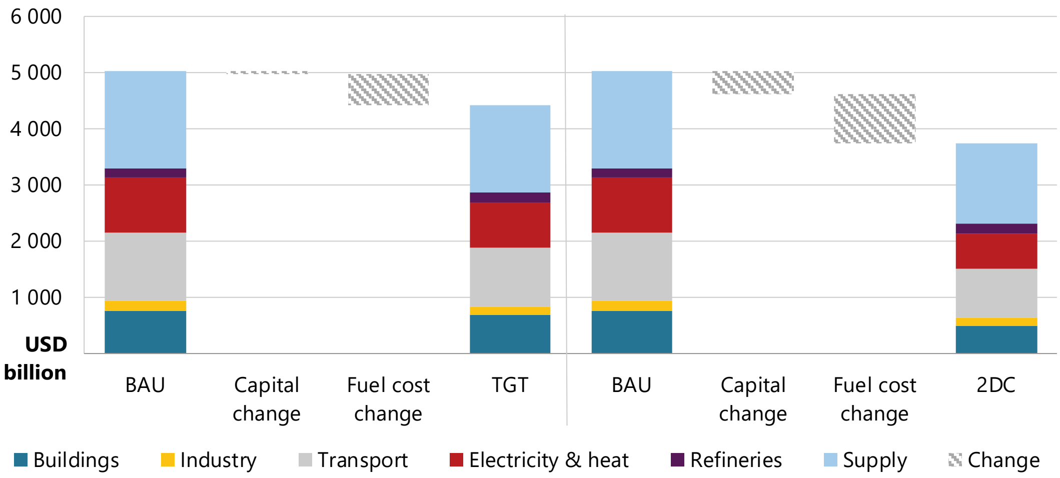
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional incremental energy investments are included in the projections.[19]

In the BAU, total investment over the Outlook period reaches USD 5 026 billion: 52% is capital investment in infrastructure and 48% is fuel costs. Because Canada is a globally significant energy-producer, most energy investment in infrastructure is required in the supply sector to meet growing domestic and foreign energy demand. Supply-side investments in the BAU amount to USD 1 223 billion or 47% of total capital investment (Figure 3.13). Supply-side investments are slightly lower over the projection period in the TGT (USD 1 150 billion) but buildings investment increases by 53%, from USD 300 billion to USD 460 billion. Energy demand reductions in the TGT result in accumulated fuel cost savings of USD 546 billion.

Figure 3.13 · Canada: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

Because supply-side capital investments dominate Canadian energy investment in all scenarios, the reductions in global fossil fuel use and domestic electricity demand in the 2DC decreases total investment to USD 3 746 billion, 25% below the BAU. In the 2DC, upstream capital investment in fossil fuels is reduced by 18% and electricity capital investment falls 34%, relative to the BAU. Cumulative transport investment increases to USD 173 billion, 12% above the BAU, due to the higher costs of advanced vehicles and the costs related to

[19] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

installing their refuelling infrastructure. Fuel cost savings in the 2DC, which amount to USD 867 billion over the projection period, come primarily from transport (42%) and buildings (36%).

ENERGY TRADE AND SECURITY

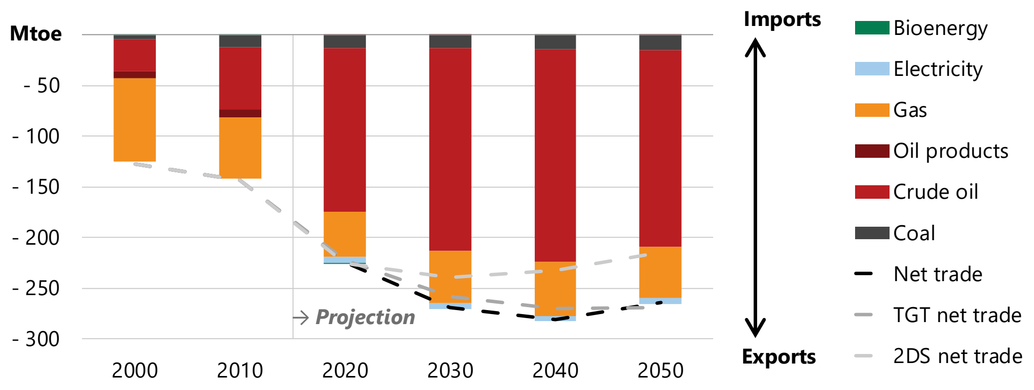
As a major energy exporter, Canada's economy is highly integrated with that of its main trading partner, the United States. North America's natural gas and oil transport infrastructure is highly interconnected by pipelines and has become increasingly dynamic as production sources have shifted with the shale oil and natural gas revolutions. Canada is the largest supplier of crude oil to the United States (3.1 Mbbl per day [154 Mtoe] in 2016) (CAPP, 2017). Its heavy crude is increasingly shipped to the US Gulf Coast, the world's largest heavy oil refining market, gaining market share on Venezuela and Mexico, whose production of heavy oil is declining, while competition in lighter oil markets, such as synthetic crude oil (SCO), has intensified (CAPP, 2018).

Canada continues to struggle to diversify its crude oil export markets, with new pipeline projects and expansions attracting significant opposition from environmental organisations and resistance from federal, provincial and municipal governments, the United States government, and First Nations. This has resulted in the purchase of a private pipeline by the federal government, which preserved the expansion option while allowing private investors to exit their position in the project. In light of the infrastructure gap, incremental crude oil is shipped by rail, while midstream companies, as well as the federal and Albertan governments, endeavour to increase pipeline capacity; the latter has even intervened in the upstream market, mandating an 8.7% cut to Albertan crude oil production starting in 2019, to mitigate the unprofitable price discounts that constrained capacity is incurring to producers (GOA, 2018b). This situation is expected to resolve itself by 2020 as scheduled pipeline capacity starts to come online, but there are downside risks to Canada's oil trade flows if this situation persists.

The Outlook assumes that these constraints are not binding over the projection period, as pipeline export capacity is increased to facilitate trade flows out of Canada and allow production growth to reach global markets. Crude oil exports drive between 67% and 80% of net trade flows in the Outlook period of all scenarios (Figure 3.14).

Although natural gas infrastructure is much more responsive to market dynamics, recent developments have not been a welcome development for WCSB producers. Shale gas production close to demand centres in what were traditional WCSB export markets in eastern Canada and the United States has pushed back WCSB supply and forced it to sell at competitive discounts. However, Canadian supply growth is still occurring, but in new areas of the WCSB, and this is creating bottlenecks throughout the region as infrastructure development has been unable to keep pace. These two developments have kept Alberta's natural gas spot price at a heavy discount to Henry Hub prices. Again, pipeline capacity constraints and lack of alternative markets, such as those available for LNG, have hindered Canadian exports. All scenarios in this Outlook hinge on Canada's ability to address these infrastructure issues, which looks possible now that Canada has received two commitments to build LNG export facilities on the Pacific coast of British Columbia (CERI, 2018). Low North American natural gas prices continue in the short term, with LNG capacity beginning to alleviate oversupply from 2023, buoying net exports (Figure 3.14).

Figure 3.14 · Canada: Net energy trade, BAU with net-TGT and net-2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

As the geographical distribution of major energy-producing basins has shifted dramatically in North America in the past decade, energy markets have had to adapt. Crude oil, natural gas, petroleum products and electricity transport infrastructure are primarily connected north-south with the United States rather than east-west within Canada. Historically, it has been more profitable for energy producers and electricity utilities to sell to US markets. However, with dramatic increases in US energy production, Canadian energy flows have slackened and both the United States and Canada have begun to rely on new export infrastructure and global markets to ease domestic oversupply.

Several provinces trade electricity with one another or with the United States. Quebec, which exports the largest amount of electricity, sent 11 TWh to the New York Independent System Operator and 15 TWh to the Independent System Operator-New England in 2016 (NEB, 2018b). Ontario, British Columbia, Newfoundland and Labrador, and New Brunswick also exported electricity to the northern United States in 2016. Electricity exports remain constant at the 2016 level over the projection period in all scenarios.

Table 3.4 · Canada: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	100	98	100	99	94	99	95
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Crude oil self-sufficiency (%)	100	100	100	100	100	100	100
Primary energy supply diversity (HHI)	0.26	0.3	0.28	0.26	0.3	0.27	0.25
Coal reserve gap (%)	0.67	8.6	8.6	7.7	17	17	12
Gas reserve gap (%)	6.4	101	90	81	249	204	181
Crude oil reserve gap (%)	1	17	17	17	43	42	38

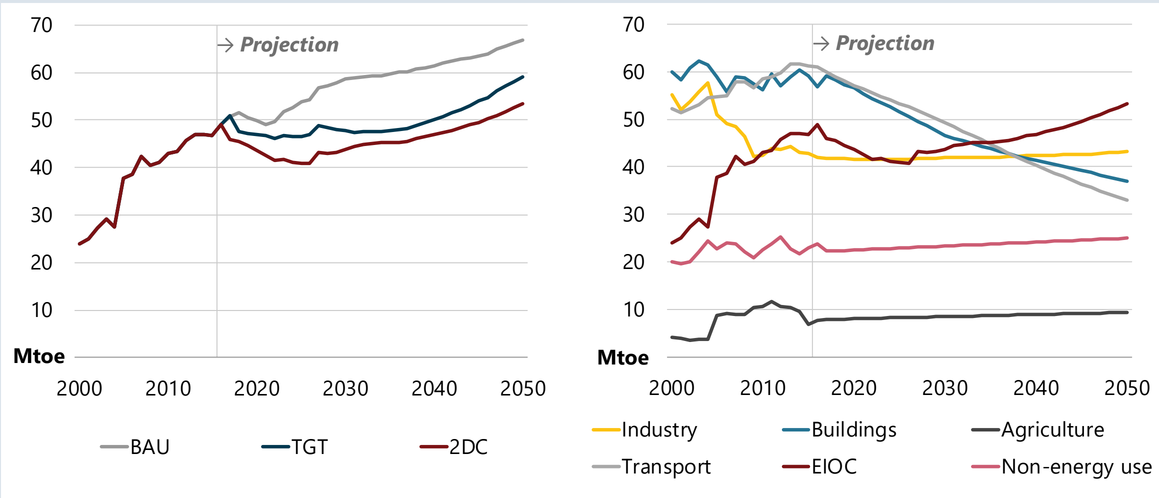
Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

Box 3.1 · Canada: CO_2 emissions from energy industry own-use in the BAU, TGT and 2DC

Energy industry own-use consumption (EIOC) can be generally categorised into five subsectors: oil and natural gas extraction, mining, refineries, power plants (electricity and heat), and other industry. In 2016, oil and natural gas extraction was the largest energy industry own-use subsector in Canada (83% of the total), followed by refineries (14%), power plants (3.3%) and mining (0.37%).

EIOC has doubled, from 24 Mtoe in 2000 to 49 Mtoe in 2016 (Figure 3.12). In the BAU, the energy industry consumes 67 Mtoe for own use in 2050, with oil and natural gas extraction accounting for 57 Mtoe. This is larger than the entire industry sector. In the 2DC, it becomes the largest source of energy demand as other sectors accelerate their decarbonisation and become increasingly energy efficient and reliant on renewables.

Figure 3.12 · Canada: EIOC by scenario and sectoral demand in the 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

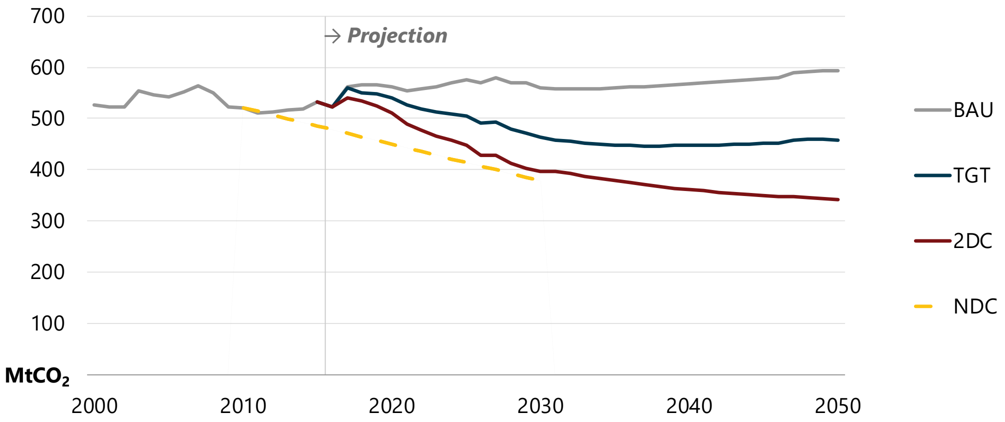
The composition and trends of EIOC highlight a key challenge: a large portion of economic activity is expected to be driven by a fossil fuel-intensive oil and natural gas sector, whose emissions currently make up 26% of total emissions (UNFCCC, 2018). In designing policies to put the economy on a 2DC pathway, Canada will need to consider trade-offs in allocating its limited carbon budget. Industry and government have recently made efforts to decouple energy use and emissions from activity, process changes by oil sands producers have reduced its emissions intensity to 12% below the 2005 level (UNFCCC, 2018), carbon prices now cover the majority of Canada's oil and natural gas emissions, and Alberta committed to cap oil sands emissions (GOA, 2016). However, these steps may prove insufficient to achieve Canada's NDC[1] and longer-term emissions reduction goals. The regional sector pathways presented in this Outlook may not be the most cost-effective ways to reduce energy demand and emissions, but if oil and natural gas extraction prove as resilient to carbon policy as it has been to commodity prices, reductions in other sectors will be necessary to make up the difference.

SUSTAINABLE ENERGY PATHWAY

At COP21, Canada announced its intention to ratify the Paris Agreement and include in its NDC an economy-wide target to reduce GHG emissions to 30% below the 2005 level by 2030 (GOC, 2015). Canada's parliament formally ratified the Agreement in October 2016 (GOC, 2018d). As Canada's NDC covers all GHG emissions (not just energy-related CO_2 emissions), the historical emissions and future pathways presented in this Outlook may differ from government calculations.

Canada's energy-related CO_2 emissions have declined 3.6%, from 542 $MtCO_2$ in 2005 to 523 $MtCO_2$ in 2016. In the BAU, these emissions increase 14% between 2016 and 2050, as electricity sector decarbonisation is outweighed in gains in all other sectors, except domestic transport, which is flat. The TGT realises a 12% reduction in energy-related CO_2 emissions by 2050 while the 2DC projects a 35% reduction by 2050. In 2030, 2DC emissions are only 27% below 2005 levels, falling short of achieving the 30% identified in Canada's NDC (Figure 3.15).

Figure 3.15 · Canada: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

Buildings emissions peak in 2026 in the TGT, while domestic transport emissions decline immediately and industry emissions increase through the Outlook period. Transformation again accounts for the greatest reduction, as emissions continue their steep decline through 2030, aside from a brief period of higher emissions in 2017-19 to meet higher electricity demand.

In the 2DC, decarbonisation accelerates, driven by rapid near-term declines in buildings, transport and the electricity sector, and a flattening of the emissions trends of agriculture and industry. Compared with the TGT, 2DC electricity emissions fall more rapidly, dropping to 92% below 2016 levels by 2050. The 2DC pathway relies on several assumptions: rising efficiency and electrification of demand sectors and strong decarbonisation of the electricity sector by 2030. The projected global shift implies that less fossil fuel development will be needed to meet lower domestic and export demands, so energy production declines. Although Canada has made significant progress in CO_2-related policy, more ambitious measures will be required to put the economy on a sustainable energy pathway in the near term and even stronger action will be required to make net CO_2 neutrality by mid-century a possibility.

OPPORTUNITIES FOR POLICY ACTION

In accordance with the COP21 Paris Agreement, Canada voluntarily submitted a Mid-Century Strategy to the UNFCCC secretariat in 2016. The submission identifies: a) the risks of inaction or delayed action on climate change; b) the possibility that misallocated investments would increase the probability and cost of stranded assets, as well as reduce access to emerging global markets for clean energy goods and services; and c) other impacts from more frequent severe weather events and rising sea levels (GOC, 2016b).

Canada's Generation Energy was launched with the goal of helping identify actions to reduce emissions and support a competitive energy industry. The report, *Canada's Energy Transition: Getting to our Energy Future Together*, builds on an ambitious public consultation on energy and climate and identifies four low-carbon pathways for Canada: wasting less energy, using clean power, supporting renewable fuels, and producing cleaner oil and gas (NRCan, 2018c).

The Mid-Century Strategy and the Generation Energy report both help elected officials and policymakers to understand what position Canada needs to be in by 2050 to maintain consistency with the United Nations (UN) long-term target of net zero CO_2 emissions, which will keep average global temperature rises between 1.5°C and 2°C. The requirement that net emissions drop 80% from the 2005 level by 2050 requires an augmentation of ambitious policies and actions. The UN has emphasised that greater policy ambition will be necessary by 2020 when NDCs are updated, and that meeting the 2°C rise goal will be extremely unlikely if the emissions gap is not closed by 2030 (UNEP, 2017). Canada's Mid-Century Strategy identifies several key near-term policy actions to mitigate emissions (GOC, 2016b):

- Supply greater electrification through non-emitting generation, more inter-jurisdictional electricity transmission and demand-side management.
- Transition to low-carbon fuels, second-generation biofuels or hydrogen in subsectors such as heavy industry, marine transport, freight transport and aviation.
- Behavioural change, including the way Canadians work, live and consume energy.

Canada has made climate change mitigation commitments as part of collective action towards a global low-GHG emissions economy and has outlined a potential pathway towards this goal. Nevertheless, further action, collaboration, and more stringent policies are needed for Canada to reach its self-determined domestic and regional targets.

However, Canada needs to be mindful of political acceptability when developing carbon policy. This means creatively constructing policy frameworks that achieve meaningful emissions reductions without provoking current and future policymakers to undo climate policy in successive political cycles, which could push Canada's carbon pathway upwards, preventing it from achieving its NDC (Jaccard et al., 2016). Canadians have shown a sensitivity to end-user prices in recent years, particularly the impact that regulatory and government policy can have on these prices. Policymakers have responded to this sensitivity with price controls—in the form of electricity price caps and point-of-sale reductions in fossil fuel prices—and rejection or resistance of broad-based carbon pricing. If end-user price increases are politically unacceptable, Canadian policymakers will need to come up with other, less economically efficient policy options to reduce emissions or risk not meeting the NDC.

Canada must ensure that it engages in meaningful two-way dialogue with First Nations prior to the approval of energy infrastructure projects, or risk being unable to connect Canadian supply with the growing energy needs of APEC and the world. Inadequate indigenous consultation was a core reason behind the Federal Court of Appeal's recent decision to quash the approval of a federally owned Trans Mountain Pipeline expansion (FCA, 2018). Informed consent of affected indigenous peoples prior to the approval of infrastructure projects is the core principle behind article 32(2) of the United Nations Declaration on the Rights of Indigenous Peoples (UN, 2008), which Canada endorsed fully in 2016 (INAC, 2017).

4. CHILE

KEY FINDINGS

- **TPES increases 34% under the BAU, from 38 Mtoe in 2016 to 50 Mtoe in 2050.** Fossil fuels imports account for 69% of the growth, while domestic renewable supply contributes the other 31%, with wind growing by 1.6 Mtoe, hydro 1.0 Mtoe and solar 0.87 Mtoe over the Outlook.

- **FED rises 44% under the BAU, from 26 Mtoe in 2016 to 38 Mtoe in 2050.** FED is 14% lower in the TGT and 28% lower in the 2DC. Energy efficiency programs, including energy efficiency labelling for light vehicles, will continue to be a priority in all sectors.

- **Electricity generation from renewable sources expands from 34 TWh in 2016 to 74 TWh in 2050 in the BAU—a 118% increase. By 2050,** renewables produce 67% of electricity in the TGT and 94% in the 2DC. Deploying renewables will continue to be a priority to decrease reliance on fossil fuel imports and contribute towards achieving Chile's NDC.

- **Chile falls short of achieving its NDC to reduce its emissions intensity in 2030 to 30% below 2007 levels in the BAU but achieves it in both the TGT and 2DC.** Total energy-related CO_2 emissions rise 25% under the BAU, from 86 $MtCO_2$ in 2016 to 106 $MtCO_2$ in 2030, and 112 $MtCO_2$ in 2050.

- **Energy efficiency, conservation and renewable energy deployment are all essential to achieving emission reductions in the alternative scenarios.** The 2DC demonstrates the greatest energy sector CO_2 emissions reductions, at 40% less than under the BAU in 2050; TGT emissions are 21% lower than in the BAU.

ECONOMY AND ENERGY OVERVIEW

Chile is bordered by Peru to the north, Bolivia to the north-east and Argentina to the east. One of three Latin American members of the Asia-Pacific Economic Cooperation (APEC), Chile has a land area of 756 102 square kilometres. Its Pacific coastline is 6 435 kilometres (km) long and its land area has an average width of 175 km. The north is almost entirely desert, and mining drives energy demand in the region, most of which is met with imported fossil fuels despite high solar and wind energy potential. In central and southern Chile, which are colder and wetter, abundant hydro and biomass resources are the main energy sources.

Administratively, Chile has 16 regions headed by president-appointed regional governors. In 2017, the population reached just over 18 million, with 40% residing in the Santiago Metropolitan Region (INE, 2017). Gross domestic product (GDP) was USD 432 billion in 2016 (Table 4.1), a 1.3% increase from 2015. Chile's overall net installed electricity capacity was 23 gigawatts (GW) in December 2018, with thermal power plants representing 50% of total capacity (coal (17%), oil (1%), natural gas (20%) and diesel (12%)) and hydropower (28%), solar photovoltaic (PV) (10%), onshore wind (7%), others[20] (5%) and geothermal (0.17%) accounting for the remainder (CNE, 2018a).

Final energy intensity per-capita use was 1.5 tonnes of oil equivalent (toe) per capita in 2016, a 5.0% increase from 2015. Total primary energy supply (TPES) per capita increased 5.5% from 2015 to 2016, and the amount of TPES consumed per unit of GDP was 87 toe per 2016 USD million at purchasing power parity, a 5.1% increase from 2015.

Table 4.1 · Chile: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	233	353	432	514	757	993	1 238
Population (million)	15	17	18	18	20	20	21
GDP per capita (2016 USD PPP)	15 274	20 745	24 129	27 804	38 566	48 715	59 765
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	25	30	38	40	46	49	50
TPES per capita (toe)	1.7	1.8	2.1	2.2	2.3	2.4	2.4
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	109.17	85.59	87.22	78.43	60.58	48.96	40.66
APEC TPES per GDP (toe per 2016 USD million PPP)	167.53	146.67	123.30	110.52	84.98	67.18	56.08
Final energy demand (Mtoe)	20	24	26	29	33	36	38
FED per capita (toe)	1.3	1.4	1.5	1.5	1.7	1.8	1.8
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	87.43	67.69	61.30	55.64	44.17	36.32	30.84
APEC FED per GDP (toe per 2016 USD million PPP)	111.99	95.37	82.87	74.06	56.86	44.91	37.62
Energy-related CO_2 emissions ($MtCO_2$)	51	69	85	92	106	111	112
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	98	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

[20] Includes biomass, biogas and petroleum coke.

ENERGY RESOURCES

Despite Chile's geographical diversity and abundant renewable resources (solar, wind, hydro and geothermal), it has very limited fossil fuel resources and is a net importer of oil, gas and coal. In 2016, Chile imported almost all of the oil it used (16 Mtoe) from Brazil (69.9%) and Ecuador (29.3%) and domestic production was only 0.26 Mtoe. Natural gas was supplied mostly from Trinidad and Tobago (72%) and the United States (17%) and the rest from other economies. Coal was mostly imported from Colombia (59.5%), the United States (28.1%) and Australia (9.1%) (CNE, 2018b) Some domestic natural gas is produced in the Magallanes Region, the southernmost region of Chile, and is also used to meet local electricity and heating demand (Valenzuela, 2018).

Chile has vast untapped potential for solar power (PV and concentrated solar power [CSP]) as well as for onshore wind, geothermal and hydro energy. Solar PV potential is estimated at 829 GW, CSP at 510 GW, onshore wind power at 37 GW, geothermal energy at 2 GW and hydropower at 6 GW (Ministerio de Energía, 2018a). These estimates are based on geo-referencing data and assessments of technical, territorial and environmental constraints.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Chile's Ministry of Energy released the National Energy Policy 2050 in December 2015 to guide long-term energy policy development. The four pillars of Chile's energy policy that will help make its energy sector 'reliable, inclusive, competitive and sustainable' by 2050 are: a) ensuring quality and security of supply; b) viewing energy as a driving force for development; c) developing environmentally friendly energy; and d) promoting energy efficiency and energy education (Ministerio de Energía, 2015).

In December 2017, Chile announced an electro-mobility strategy that outlines actions to be taken in the short- and medium-term to meet the government's goal of having 40% of private vehicles and 100% of the public transport fleet powered by electricity in 2040. The new strategy's objectives are to establish regulations and requirements to standardise components and promote the efficient development and increased penetration of electric vehicles (EVs), to support research and development, and to enhance human capital and knowledge transfer (Ministerio de Energía, 2017a).

In May 2018, the Ministry of Energy presented an Energy Roadmap to serve as a guideline for government action in promoting socially responsible energy policies for the next four years (2018-2022). It contains short-term commitments based on the following pillars (Ministerio de Energía, 2018b):

- Energy modernisation.
- Energy with a social seal.
- Energy development.
- Energy low in emissions.
- Efficient transport.
- Energy efficiency.
- Energy education and training.

During the joint presentation of the Energy Roadmap, the president requested that the Ministry of Energy place special emphasis on 10 'mega-commitments' (Gobierno de Chile, 2018) and President Piñera included the 11th commitment related to energy integration with neighbouring economies:

- Create the economy's first map of energy vulnerability, identifying families without electricity and other energy services, with a view to narrowing the existing gaps.
- Modernise the energy institutional framework to increase governmental efficiency and provide the public with a better service, specifically the Superintendency for Electricity and Fuels (Superintendencia de Electricidad y Combustibles, SEC) and the Chilean Nuclear Energy Commission (Comisión Chilena de Energía Nuclear, CCHEN).
- Reduce the processing time associated with obtaining environmental permits for projects that join the +Energy Plan by 25% with respect to the time taken over the last four years.
- Achieve a fourfold increase in the current capacity of renewable small-scale distributed generation (less than 300 kW) by 2022.
- Achieve a tenfold increase in the number of electric vehicles circulating in Chile.
- Modernise the regulation of electricity distribution through a participatory process, so it allows new circumstances of the energy sector to be identified and facilitates more efficient and competitive implementation.
- Regulate solid biofuels, such as firewood and its derivatives, empowering the Ministry of Energy to establish technical specifications and the regulations for the commercialisation of firewood in urban areas.
- Establish a regulatory framework for energy efficiency that provides the necessary incentives to promote the efficient use of energy in the sectors with the highest consumption (industry and mining, transport and construction) and create a true energy culture in Chile.
- Launch the process of decarbonisation of the energy mix by preparing a schedule for the withdrawal or reconversion of coal-fired power plants, and introducing specific measures for electro-mobility.
- Train 6 000 operators, technicians and professionals, developing skills and competencies for energy management and sustainable energy use in the electricity, fuels and renewable energy sectors, certifying at least 3 000 people.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Chile under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 4.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 4.2 · Chile: Key assumptions and policy drivers under the BAU

Buildings	Efforts to reduce energy demand are not sufficient to achieve the goal of a 30% reduction by 2022, but drive some improvements.
Transport	Tenfold increase in the number of EVs by 2022. Increased deployment of highly efficient buses (such as electric, hydrogen and gas-powered) over 2018-22.
Energy supply mix	Oil remains dominant in FED.
Power mix	Coal capacity decreases as two units are decommissioned at the Tocopilla complex in 2019. No nuclear energy developed under the National Energy Policy 2050 or Energy Roadmap 2018-2022.
Renewables	Committed renewable energy projects and historical capacity trends considered. 20% of electricity generated from non-conventional[21] renewable sources by 2025. As per National Energy Policy, 60% of electricity generated from renewable sources by 2035 and 70% by 2050. Capacity for distributed small-scale renewable energy (less than 300 kW) quadrupled by 2022.
Energy security	Expanded oil and gas exploration. Greater deployment of renewable energy.
Climate change	Efforts made towards meeting the UNFCCC NDC target of GHG emissions intensity 30% below 2007 level by 2030.

Notes: FED = final energy demand. UNFCCC = United Nations Framework Convention on Climate Change. NDC = Nationally Determined Contributions. GHG = greenhouse gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

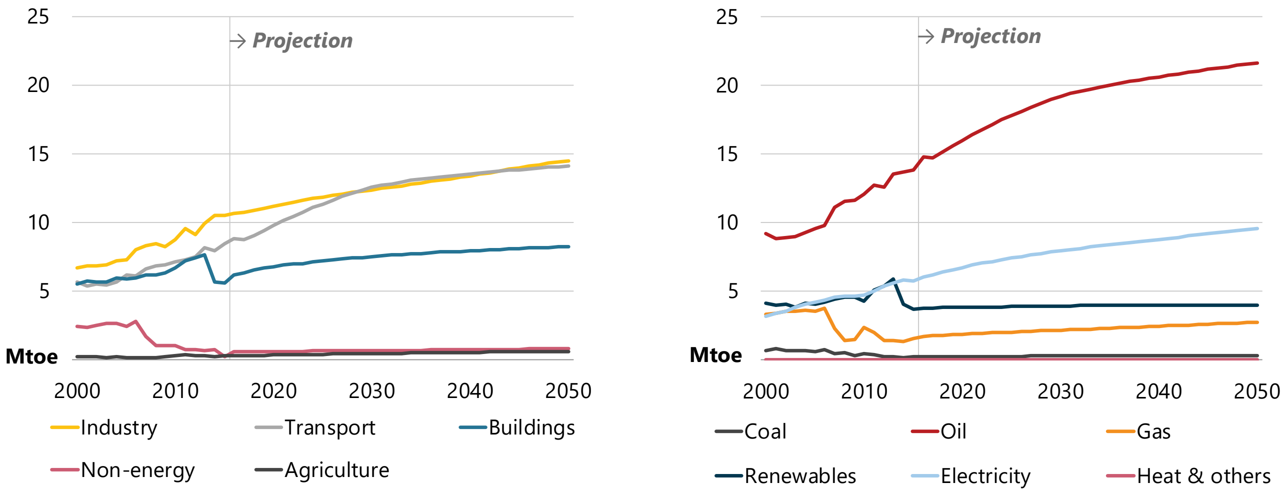
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Chile's fuel mix has historically been dominated by oil, most of which is consumed in the industry and transport sectors. Industry oil use has risen in the past decade in response to the severe energy crisis that occurred when natural gas imports from Argentina dropped suddenly in 2004 (Chavez-Rodriguez, et al., 2017). Transport is the largest oil consumer (99%), however, and has the second-highest overall energy consumption (8.8 Mtoe) after industry (11 Mtoe). As economic growth has improved living standards, the number of private vehicles has increased.

Final energy demand (FED) grows robustly over the Outlook period (2016-50) under the BAU Scenario, rising 44% from 26 million tonnes of oil equivalent (Mtoe) in 2016 to 38 Mtoe in 2050 (Figure 4.1). In 2016, the industry sector consumed 40% (11 Mtoe) of FED, domestic transport 33% (8.8 Mtoe) and buildings 23% (6.2 Mtoe). Throughout the Outlook period, industry demand rises by 37%, domestic transport 59% and buildings 33%. In 2016, oil accounted for 56% (15 Mtoe) of FED, electricity for 23% (6.0 Mtoe), renewables for 14% (3.7 Mtoe), gas for 6.4% (1.7 Mtoe), and coal for 0.84% (0.22 Mtoe). Throughout the Outlook period, gas demand expands by 61%, oil 46%, electricity 58%, renewables 6.1% and coal 35%. Chile's final energy intensity per capita is 1.5 toe in 2016 and 1.8 toe in 2050, a 25% rise.

[21] Includes biomass, hydro power less than 20 megawatts (i.e. run-of-river), geothermal, wind and solar.

Figure 4.1 · Chile: Final energy demand by sector and fuel, 2000-50

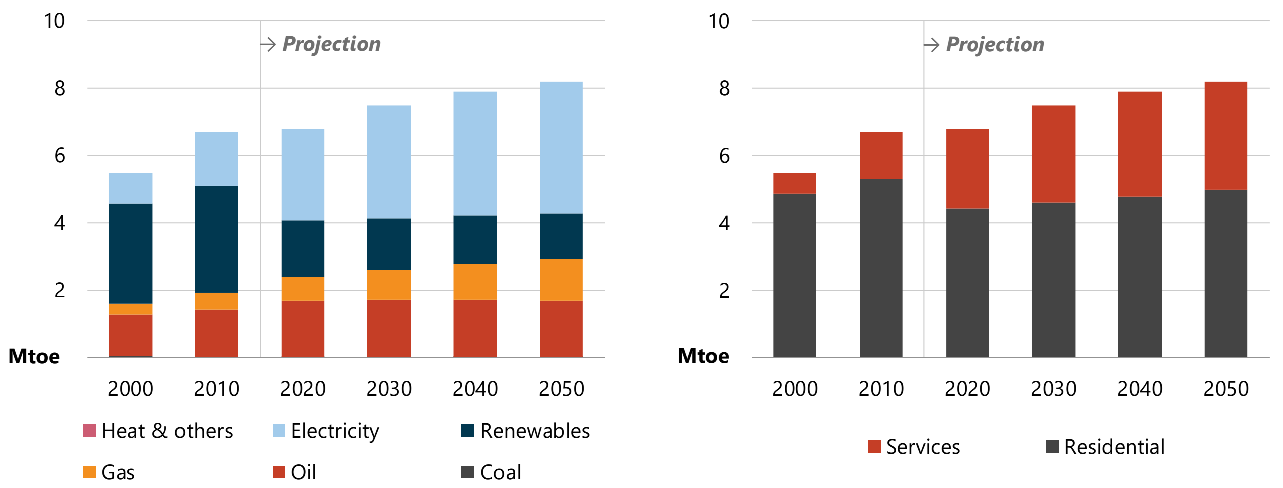


Sources: APERC analysis and IEA (2018a).

BUILDINGS: DEMAND GROWTH DRIVEN BY SERVICE BUILDINGS

To curb growing energy demand, Chile established an energy labelling programme in 2005 that has since become one of the most comprehensive in the world (IEA, 2018b). Energy demand in both the residential and service buildings subsectors continues to rise in the BAU, at a compound annual growth rate (CAGR) of 0.83%, but is moderated by ongoing efficiency improvements. In terms of fuel use, electricity demand increases by 79% and gas 108%, while renewables demand falls 24% (Figure 4.2). The fall of renewables used in buildings is because of traditional biomass, which is widespread but results in air quality and health problems.

Figure 4.2 · Chile: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

While population only grows at 0.43% CAGR, moderately stronger growth in household numbers (0.77% CAGR) and household size (1.2% CAGR) combine to double residential floor area over the Outlook period to 776 million m^2. Residential demand increases at a CAGR of 0.38% to 5.0 Mtoe, as strong growth in residential floor area (2.0 CAGR) is limited by energy efficiency initiatives. Although renewables constituted the largest fuel source for residential buildings in 2016 at 1.7 Mtoe (40% share), their use declines to 1.3 Mtoe (26%) in 2050 as less traditional biomass is employed for space heating. Electricity becomes the largest fuel source by 2050 at 1.8 Mtoe (36%), driven by expanded use in space cooling, space and water heating, and 'other' end-uses. Natural gas grows to 0.85 Mtoe (17%), driven by its increasing role in space and water heating.

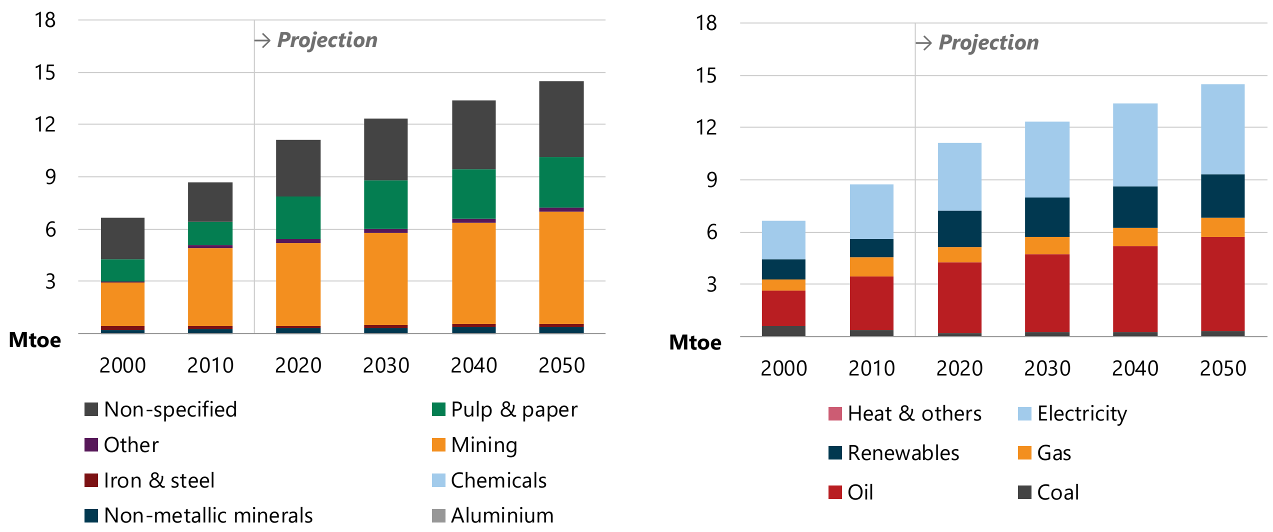
Electricity use in service buildings has risen strongly since 2000 with increases in floor area and GDP. Higher temperatures have also spurred greater air conditioner use during the summer, with temperatures 3°C above the long-run average in 2017 (Ministerio de Energía, 2018c). Service buildings energy consumption almost doubles over the Outlook period (1.8 Mtoe to 3.2 Mtoe) as GDP rises at a CAGR of 3.7% and floor area expands from 171 million m^2 in 2016 to 386 million m^2 in 2050. The amount of electricity used to meet this demand increases 106% by 2050 (at a 2.2% CAGR), while oil demand remains almost flat (7.6% overall growth) and gas use rises 195% (3.2% CAGR). The service buildings subsector follows different trends from residential buildings, mainly because of stronger growth in the 'other' end-use category, which includes appliances and electronics such as computers, which become more widespread over the projection period.

A modification to the residential generation law was enacted in October 2018 to promote residential/distributed generation by extending the maximum limit for private installations from 100 kW to 300 kW. This law promotes distributed generation for service and small industrial users and also for residential customers, who often decide to invest in clean generation sources for their homes or businesses (Ministerio de Energía, 2018d), and acts to moderate demand growth for fossil fuels in the buildings over the Outlook period.

INDUSTRY: MINING, NON-SPECIFIED, AND PULP AND PAPER REMAIN KEY

Industry has the largest final energy demand sector: starting from 11 Mtoe in 2016, it rises to 14 Mtoe by 2050 at a CAGR of 0.92% (Figure 4.3). The largest shares of industrial energy are used in mining (43% in 2016 and 44% in 2050), followed by the 'non-specified'[22] subsector (29% in 2016 and 30% in 2050) and pulp and paper (22% in 2016 and 20% in 2050). While demand for all fuel types increases in absolute terms, the industry fuel mix remains relatively unchanged over the Outlook period with a slight decrease in renewables (from 18% share in 2016 to 17% in 2050) due to marginal increases in electricity and oil.

Figure 4.3 · Chile: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Chile's mining sector has been expanding steadily in recent years to supply growing demand from international markets; for example, exports to China rose 27% (to 4.7 million tonnes) in 2016 (Business Insider, 2018). Chile's copper production is a key driver of medium-term growth in mining sector energy demand and is projected to

[22] According to International Energy Agency definitions, this should include only the rubber and plastic products, and furniture and other (including jewellery, musical instruments, sporting goods and games) manufacturing industries. These industries do not account for almost one-fifth of Chile's industrial energy demand; rather, this category is acting as a catch-all for energy use that cannot be disaggregated by subsector.

grow 13% from 2017 to 2027 (Cochilco, 2018). Chile is also a significant exporter of pulp products, currently accounting for 10% of a growing global market (LIGNUM, 2015). Growth in demand for paper and paperboard products from the domestic service and export markets are the main drivers of higher energy demand. The pulp and paper industry energy demand expands at a CAGR of 0.68% over the Outlook period and remains the third-largest sub-sector after mining and non-specified.

Box 4.1 · Chile: Program to replace 200 000 streetlights

Chile's 2014 Energy Agenda, a policy document that established short-term energy commitments for the government period 2014-2017, established goals for using energy efficiently and reducing demand by 20% by 2025. Support for municipal energy management of public lighting was particularly strong, and a program was established to replace 200 000 streetlights over a four-year period, starting in August 2014 with the launch of a contest to select applicable municipalities. The program emphasised replacing light bulbs that used more inefficient technologies, modernising the public lighting of communities that had not yet invested in energy efficiency and generating economic savings through public lighting projects. This program has helped municipalities significantly reduce electricity consumption and has established a bidding model that the Ministry of Energy can use for other projects.

The five guidelines for new lightning established under the program are:

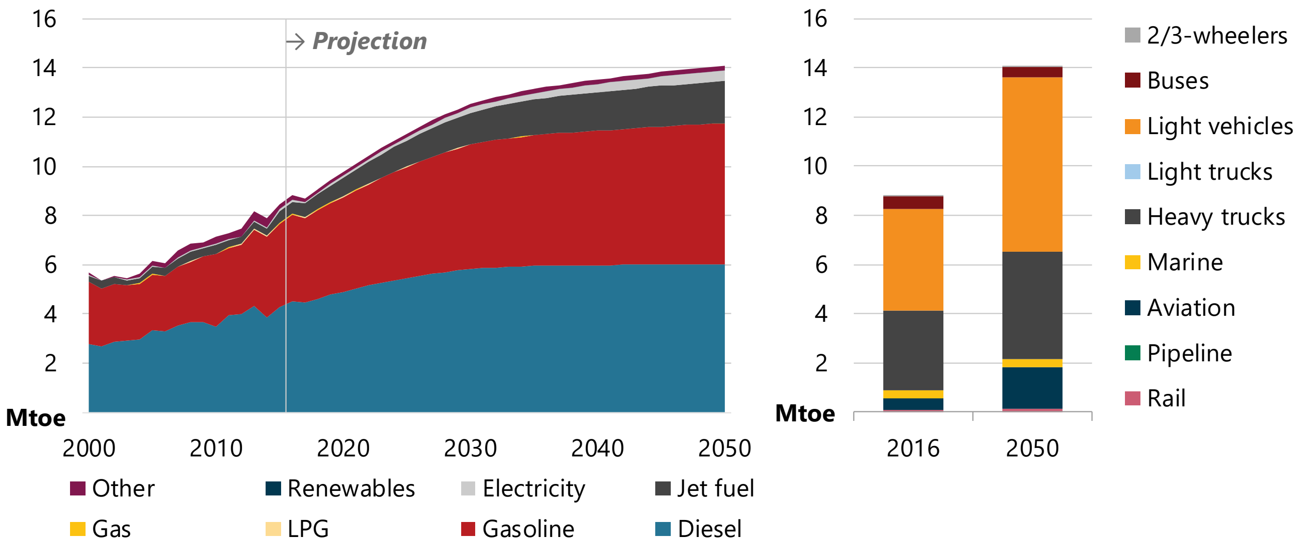
- Uniform lighting: should make it easier for people to see and prevent dark spaces between lamps.
- Light efficiency: efficiency greater than 85% is required so that 25% less energy is consumed per year.
- Lighting levels: lighting should be adequate to allow greater use of public spaces, reduce feelings of insecurity and deter crime.
- More efficient technologies: new technologies that have a longer useful lifetime, maintain higher performance and reduce maintenance costs should be used.
- Direction of illumination: lamps should be oriented to achieve better light use and be directed towards the surfaces in need of illumination.

The program benefited 1.9 million people from 2015 to 2017 (Ministerio de Energia, 2017b). A total of 97 163 light bulbs were replaced at a cost of USD 45 million (in 2016 USD).

TRANSPORT: LIGHT-DUTY VEHICLES DOMINATE LONG NORTH-SOUTH JOURNEYS

Road transport is the main mode of domestic transport in Chile for both passengers and freight (Figure 4.4). Light-duty vehicles (LDVs) dominate FED due to the lengthy north-south distances travelled within Chile's long, narrow land area. Road transport represented 83% (7.9 Mtoe) of total transport sector energy demand in 2016—43% from LDVs and 34% from heavy-duty trucks.

Figure 4.4 · Chile: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

A record for private vehicle sales was achieved in 2018, with 417 038 new cars sold, a 16% increase on 2017 (24Horas, 2019). Private car ownership is projected to continue to outpace economic growth (although moderate compared to 2016-17), resulting in LDV stock expanding by 82% over the Outlook period, and the heavy-duty truck stock expanding 107%. Buses and two- and three-wheeler stocks remain almost flat over the period. Overall, road transport energy demand increases by 50% over the Outlook (at a 1.2% CAGR), as vehicle efficiency dampens the increased demand for passenger and freight travel.

Since February 2013, new LDVs weighing less than 2.7 tonnes have been required to have energy efficiency labelling. The labels display the energy efficiency of the new car and information about its energy consumption and emissions. In June 2017, the labelling scheme was expanded to medium-duty and commercial vehicles (light-duty trucks) as well as electric and hybrid models (MMA, 2018). These policies help to moderate demand growth in road transport over the Outlook period and contribute to average fuel efficiency improving for both domestic passengers (from 1.6 megajoules per passenger-kilometre [MJ per pkm] to 1.0 MJ per pkm) and domestic freight (from 3.2 MJ per tonne-kilometre [MJ per tkm] to 2.4 MJ per tkm).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

With modest domestic fossil fuel reserves, Chile's transformation sector is smaller than FED. Electricity generation is dominated by coal (38%) and renewables (43%) while refineries has a capacity of 11 Mtoe and total production of 10 Mtoe (mainly dominated by gasoline 3.2 Mtoe). Energy production (12.5 Mtoe) is dominated by renewables (10 Mtoe), and Chile imports significant amounts of coal (6.6 Mtoe), gas (3.7 Mtoe), and crude oil (8.4 Mtoe) and oil products (8.5 Mtoe) to meet domestic demand. Oil accounts for 42% of TPES in 2016, with renewables accounting for 27%.

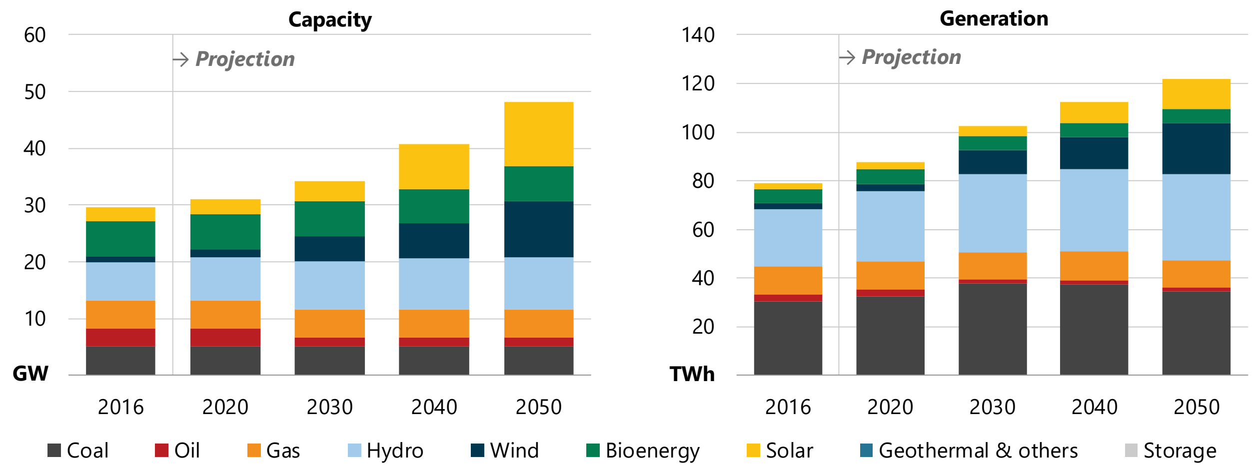
RENEWABLES GROW STRONGLY IN THE POWER SECTOR

Hydro power has long been a key component of Chile's electricity generation mix and natural gas started to play a leading role in the late 1990s. Chile imported 100% of its natural gas from Argentina from 2000 to 2008 but when Argentina began curtailing exports to Chile in 2003, the use of hydro power, coal and diesel generation rose significantly. Chile's energy transformation has most recently shifted to the adoption of renewable energy.

In 2010, only 4% of electricity capacity used unconventional[23] renewable energy (URE) sources: totalling 532 megawatts (MW) in onshore wind farms, small amounts of solar PV, small hydro, biomass and biogas plants. By 2018, URE sources made up 21% of the total electricity generation mix, with 4 988 MW of installed capacity (47% solar PV, 32% onshore wind farms, 10% small hydro, and the rest in biomass, geothermal and biogas plants) (CNE, 2018a). New policies, such as a 20% target for renewables by 2025, combined with declining capital costs and outstanding renewable resources have helped transform the market.

In 2016, Chile's total generation was 79 terawatt-hours (TWh), an increase of 51% from 2005. Thermal power plants provided 57% of generation (coal 38%, oil 3.7% and gas 15%), followed by hydro power (30%), bioenergy (7.5%), wind (2.8%) and solar (3.1%). In 2005, solar PV and wind technologies made no contribution to total generation, but in 2016 they accounted for 6% combined (Figure 4.5).

Figure 4.5 · Chile: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

Renewables are the leading power generation source (61%) by 2050, with hydro contributing 29%, wind 17% and solar 10%. The share of thermal power plants, such as those fuelled by coal, falls to 28% (from 38% in 2016). Total projected generation in 2050 is 122 TWh, an overall growth of 54% from 2016 (1.3% CAGR).

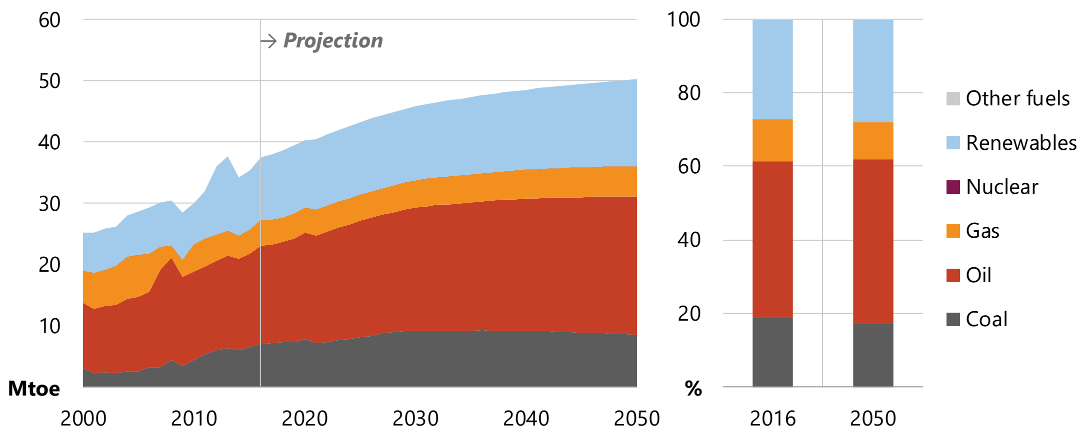
Modification of Chile's tendering mechanism in the 2014 New Electricity Act on Energy Auctions allows renewable energy developers to compete in power tenders, making it possible to include seasonal and hourly blocks of energy supply in addition to the traditional 24-hour blocks. This has allowed variable generation from renewables to be more competitive with baseload generation, and has provided renewables developers the opportunity to acquire power purchase agreements and develop new generation investment.

[23] Includes biomass, hydro power less than 20 megawatts (i.e. run-of-river), geothermal, wind and solar.

TOTAL PRIMARY ENERGY SUPPLY GROWS IN THE SHORT TERM

Under the BAU Scenario, TPES increases 34% (13 Mtoe) from 2016 to 2050, predominately owing to greater use of oil and renewables. Overall, the share of oil in TPES rises from 42% in 2016 to 45% in 2050, an increase of 41% (6.6 Mtoe) (Figure 4.6). The portion of renewables (hydro and non-hydro) expands from 10 Mtoe in 2016 to 14 Mtoe in 2050, for a share of 28% by 2050. The share of coal in TPES falls to 17% in the BAU, and the gas share also decreases very slightly, from 11% to 10%. Policy measures adopted over the past six years continue to boost renewable integration and reduce technology costs, resulting in their share of TPES growing and contributing to coal's declining share. Continued growth in the mining sector throughout the Outlook period sees the amount of oil used for transportation and mechanical work steadily increase, which raises its share of TPES from 42% in 2016 to 45% in 2050.

Figure 4.6 · Chile: Total primary energy supply by fuel, 2000-50



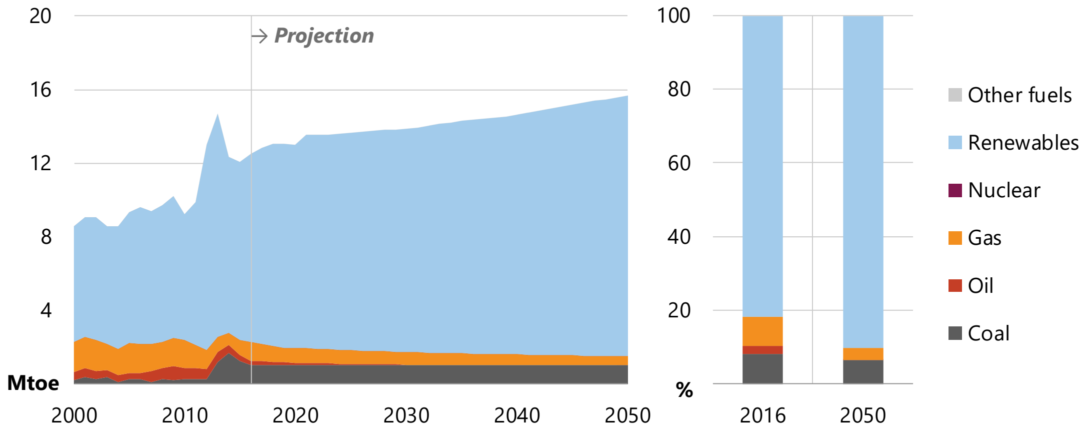
Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: RENEWABLES DOMINATE PRODUCTION

Chile's renewable energy resources are outstanding. The Atacama Desert in the north boasts direct normal irradiance of more than 9 kilowatt-hours per square metre per day, the highest in the world (IEA, 2018b). In its extreme south, Chile has some of the best onshore wind resources in the world (IEA, 2018c). Renewables (mainly biomass, solar, wind and hydro) have long dominated energy production in the economy, as fossil fuel reserves are limited, accounting for 82% in 2016 (10 Mtoe). They have also been the fastest-growing source of energy production, increasing by 43% in 2005-16 in order to compensate for lower natural gas imports from Argentina (Figure 4.7).

Although Chile has historically imported most of its liquefied natural gas (LNG) from Trinidad and Tobago (73% in 2016), the expansion of the Panama Canal in 2016 reduced the transit time from the Atlantic Ocean and import sources have subsequently become more diversified. In 2016, in addition to Trinidad and Tobago, Chile imported LNG from the United States (17%), Qatar (1.9%) and Equatorial Guinea (1.9%) (CNE, 2018b). Overall natural gas imports are projected to expand from 3.7 Mtoe in 2016 to 4.5 Mtoe in 2050. Imported crude oil forms the main source of supply for Chile's two refineries, with imports rising under the BAU, from 8.4 Mtoe to 10 Mtoe, in line with growing domestic demand.

Figure 4.7 · Chile: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

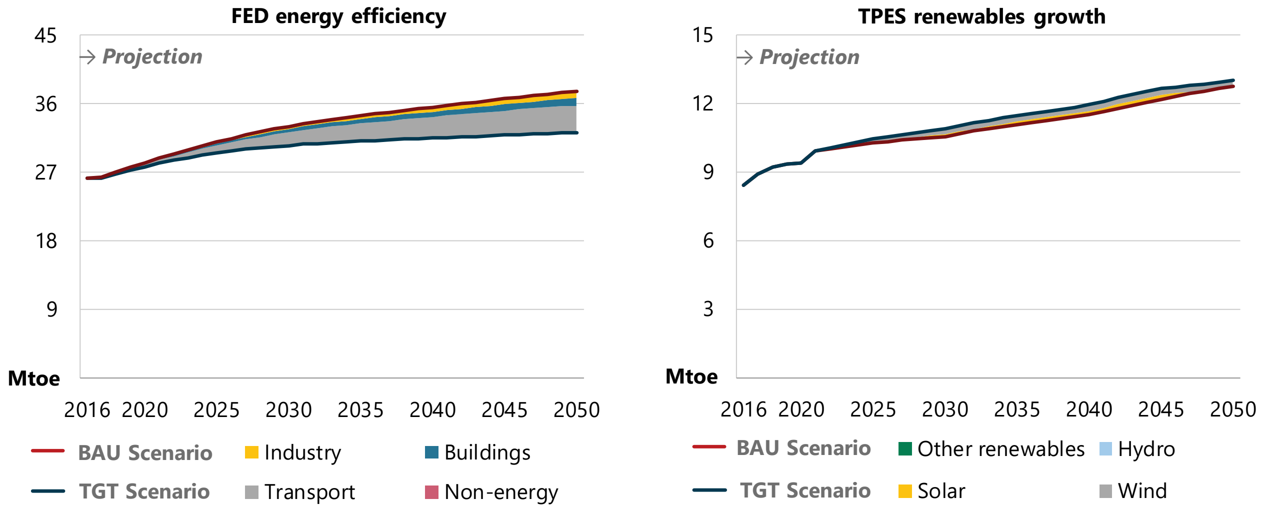
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Chile's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The APEC Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and carbon dioxide (CO_2) emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 14% lower and CO_2 emissions are 21% lower under the TGT by 2050. Under the 2DC, Chile's FED is 28% lower and CO_2 emissions are 56% lower. The share of renewables in TPES is 33% in the TGT and 55% higher in the 2DC, compared to 28% in the BAU

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. These goals are consistent with Chile's National Energy Policy 2050 (Ministerio de Energía, 2015). FED increases 24% in the TGT Scenario, from 26 Mtoe in 2016 to 33 Mtoe in 2050, making it 14% lower than in the BAU (38 Mtoe) (Figure 4.8). Much of the demand decrease relative to the BAU happens in the transport sector, with smaller drops in buildings and industry.

Figure 4.8 · Chile: Energy efficiency and renewables development, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Domestic transport energy demand rises 19% from 2016 to 2050 (to 11 Mtoe, or 25% less than under the BAU). This more moderate increase under the TGT is a result of increased ambition in policy measures discussed in the BAU section as well as greater labelling. Additionally, there is wider deployment of more efficient vehicles—average fuel efficiency of LDVs increases by 51% and heavy-duty trucks by 43% over the Outlook in the TGT (compared with 40% for LDVs and 35% for heavy-duty trucks in the BAU).

Higher efficiency resulting from stricter building and appliance regulations is the key reason for the 1.0 Mtoe reduction in buildings energy demand in 2050 relative to the BAU. The fall in industry sector FED is driven by the National Energy Efficiency Action Plan 2020, which spurs the uptake of more efficient technologies and processes.

Although the TGT aims for greater renewables deployment because of Chile's high deployment of renewable electricity generation in the BAU, production from renewables in 2050 is only 0.18 Mtoe greater in the TGT. Falling electricity demand, however, causes renewables to make up a larger share of the fuel mix in 2050 (77%, compared with 76% in the BAU).

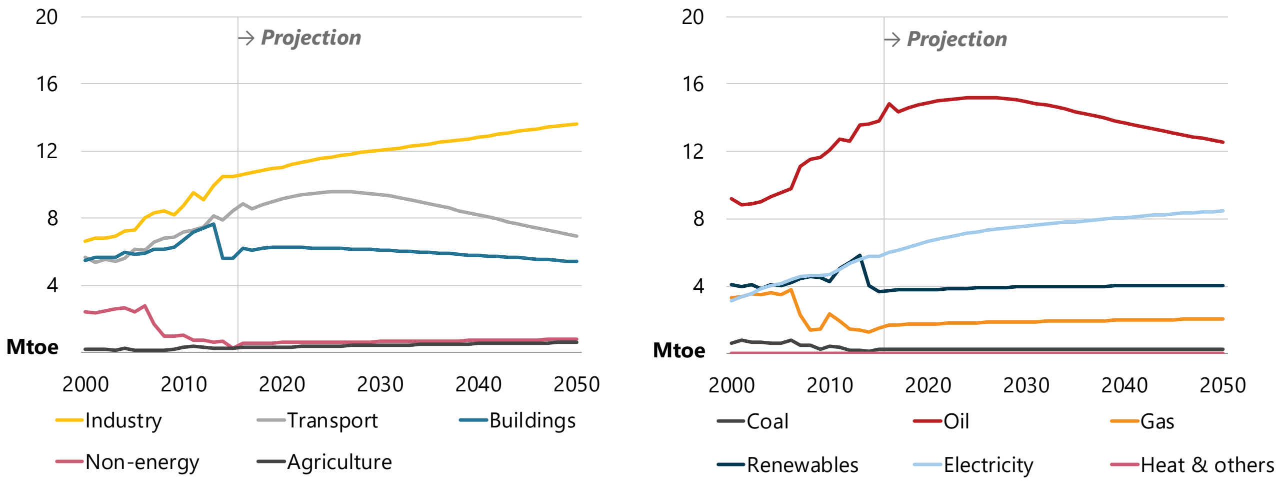
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, the energy sectors in Chile will have to undergo varying levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

FED stays almost unchanged under the 2DC, rising marginally from 26 Mtoe in 2016 to 27 Mtoe in 2050 (Figure 4.9). FED in 2050 is 28% lower in the 2DC than in the BAU, with most of the reduction occurring in the transport sector (7.1 Mtoe lower in the 2DC than in the BAU). This is reflected in oil FED, which in the 2DC is 9.1 Mtoe lower in 2050 than in the BAU.

Figure 4.9 · Chile: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

The transport sector is key in Chile's efforts to attain a low-carbon energy system. Wider use of low-emissions technologies and better energy efficiency see transport demand fall from 8.8 Mtoe in 2016 to 6.9 Mtoe in 2050 (-21%). Oil demand for domestic transport decreases 31% and gas demand virtually disappears as they are replaced by electricity, which increases elevenfold. Chile's electro-mobility strategy, announced in December 2017, outlines the short- and medium-term actions that should be taken to ensure that 40% of private vehicles and 100% of public transport run on electricity by 2040 (Ministerio de Energía, 2017a). In the 2DC, the number of private vehicles running on electricity (light-duty electric battery vehicles) is equivalent to 14% of the light-duty stock by 2050, and hybrid and plug-in hybrid vehicles account for a further 51%).

The buildings sector delivers the second-highest energy demand reductions through the use of higher-efficiency appliances and more efficient water heating and space cooling. Significant improvements in building envelopes as well as behavioural changes in the services subsector (e.g. more teleworking) are also essential to building reductions in the 2DC. While the use of most fuels in the buildings sector decreases over the Outlook period, electricity demand grows 19%.

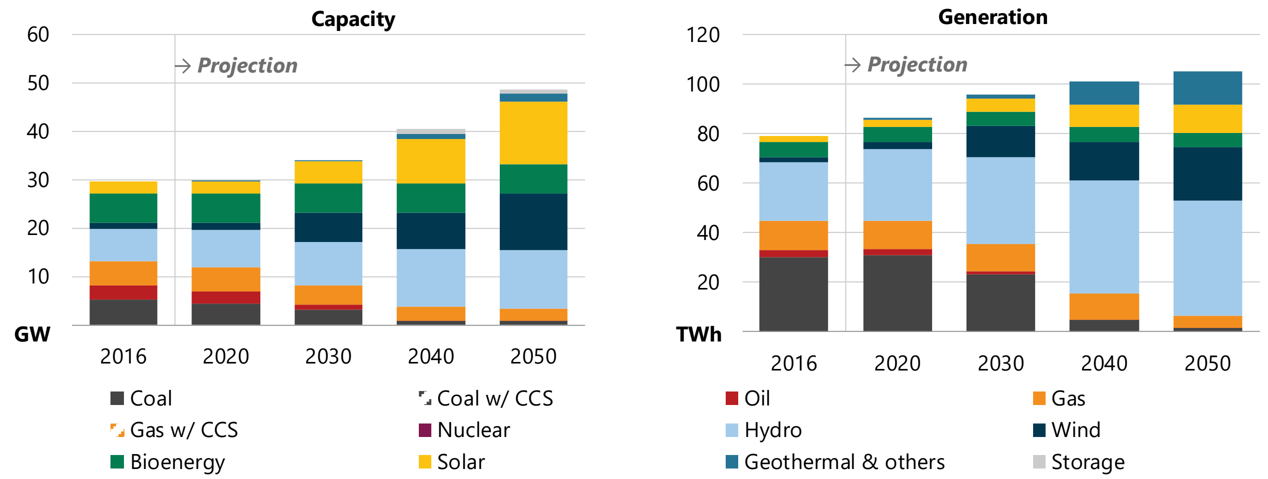
Industry FED is not strongly impacted by the 2DC, growing 28% over the Outlook period to 14 Mtoe, which is 6.0% below BAU levels. Non-metallic minerals industry demand remains at similar levels from 2016 to 2050, despite an increase on cement production, as clinker production becomes more energy efficient. On the other hand, mining industry energy demand rises 31% from 2016 to 2050 (0.44 Mtoe, or 6.8% less than under the BAU).

TRANSFORMATION AND SUPPLY IN THE 2DC

Chile's share of renewables expands even further in the 2DC in response to more ambitious goals and policies. Electricity demand is 13% lower in the 2DC, resulting in generation of 105 TWh in 2050 compared with 122 TWh in the BAU. Renewables generation is 99 TWh (a 94% share) by 2050 in the 2DC, while natural gas's is 5.0 TWh (4.7%). Coal-fired plants contribute minimally to the generation mix by 2050, as their capacity and generation is significantly decreased due to the high carbon compliance costs inherent to their carbon-intensity; generation falls from 30 TWh in 2016 to 1.3 TWh by 2050 (-96%). Hydro supplies the largest share of renewable generation in 2050 (44%), followed by wind at 20% (21 TWh), geothermal at 13% (14 TWh), solar at 10% (1.2% from rooftop PV generation, 6.5% from utility and 3.4% from CSP, for a total of 11 TWh) and bioenergy at 5.7% (6.0 TWh).

By 2050, 91% of installed capacity (44 GW) uses renewable resources, compared with 55% (16 GW) under the BAU (Figure 4.10). While coal-, gas- and oil-fired electricity capacity persists throughout the projection period under the BAU, gas capacity decrease 52%, and oil-fired drops 99% over the Outlook period in the 2DC. Wind capacity is projected to grow from 1.2 GW in 2016 to 12 GW in 2050, and solar capacity similarly climbs from 2.4 GW in 2016 to 13 GW in 2050 under the 2DC—2 GW higher than in the BAU.

Figure 4.10 · Chile: Power capacity and electricity generation in the 2DC by fuel, 2016-50

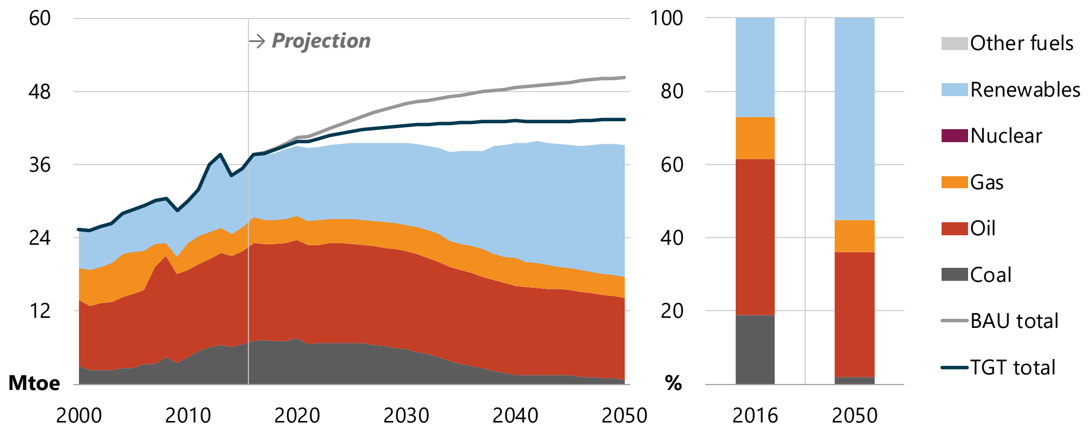


Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

With a 93% share of electricity generated from renewables by 2050, the 2DC far exceeds the National Energy Policy 2050 goal of 70% (Ministerio de Energía, 2015). The APEC targets of reducing energy intensity and increasing the share of renewables in the energy system seem realistic given the goals and policies already in place in Chile.

Similar to the electricity sector, TPES is transformed in the 2DC with the near-disappearance of coal (Figure 4.11). The share of oil in the fuel mix remains steady, but renewables become the dominant fuel by 2050, accounting for 55% of TPES. This overhaul is mainly underpinned by the transport and electricity sectors, which use significantly less fossil fuels in the 2DC compared with the BAU.

Figure 4.11 · Chile: Total primary energy supply in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Primary energy production is significantly higher under the 2DC, reaching 23 Mtoe in 2050 (compared with 16 Mtoe in the BAU). This increase is almost entirely attributed to renewables and results in imports falling by 34% (from 27 Mtoe in 2016 to 18 Mtoe in 2050) over the 2DC, compared with an increase of 35% (to 37 Mtoe) over the BAU. Under the BAU, TGT and 2DC, refinery capacity is unchanged over the Outlook period as domestic demand for oil products exceeds production.

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

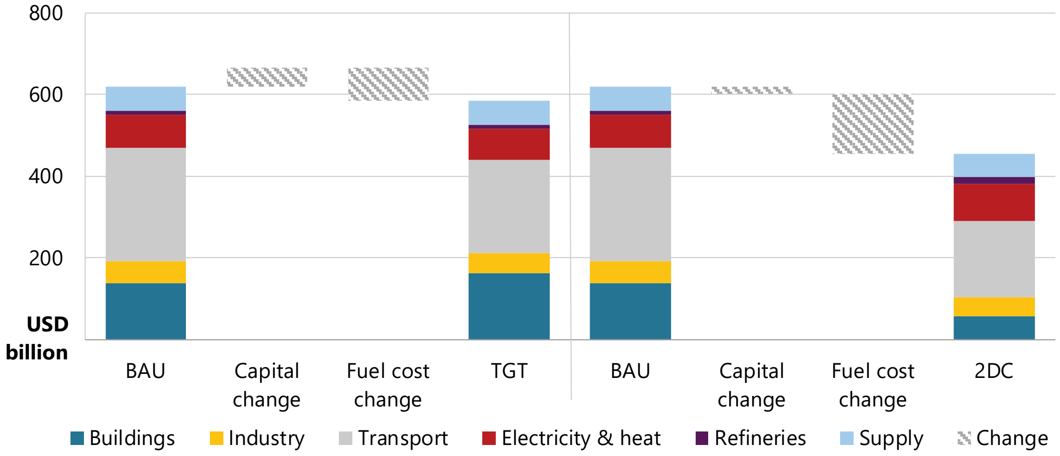
The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[24]

The energy sector has been the main axis of investment in Chile for the past two years (2016 and 2017). At the end of 2015, 411 new projects valued at USD 82 billion had been registered, accounting for 47% of total investment for the year (8.4% above 2014). The majority of this investment (88%) was in the generation system and located in three regions: Antofagasta (27%), Atacama (25%) and Biobio (7.7%) (Deloitte, 2018). The government’s new open energy auction process, which attracts new participants and electricity generation technologies, has contributed to this investment growth by promoting competitiveness and improving price mechanisms (CNE, 2018a).

With limited domestic fossil fuel resources, a population growing at an CAGR of 0.43% over 2016-50, and a rapidly developing economy, total energy investments for Chile from 2016 to 2050 range from USD 619 billion (in 2016 USD) under the BAU Scenario to USD 585 billion under the TGT and USD 454 billion in the 2DC (Figure 4.12). Chilean energy investments are dominated by transport in all three scenarios, due to significant fuel costs as well as the investment required to overhaul the fleet with advanced vehicles.

[24] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 4.12 · Chile: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

Total investments in the TGT are 5.6% lower than in the BAU, as increased capital expenditure for buildings is offset by larger fuel savings—which are 20% below BAU levels. Increased building capital investment is 2.6 times larger in the TGT due mainly to installing more efficient water heating and space cooling equipment, and higher-efficiency appliances. Transport fuel costs in the TGT are 20% lower than in the BAU owing to a wider use of low-emissions technologies and better energy efficiency. Capital investments in the electricity sector are 6.8% higher and fuel costs are 2.1% higher than in the BAU as oil-fired power capacity decreases by 51%.

Compared with the BAU, total investments under the 2DC are reduced by 27% as significant fuel-cost savings outweigh a slight increase in capital expenditures. Building expenditures in the 2DC are also lower (-73%), again because fuel-cost savings eclipse the increased capital expenditures needed to reduce the energy intensity of space heating and cooling. Additional capital investments in electricity generation are earmarked for phasing out coal-fired power plants and replacing them with solar and wind generation, which significantly reduces sectoral fuel costs.

ENERGY TRADE AND SECURITY

Chile's limited natural endowment of hydrocarbons has made the economy a net importer of primary energy and results in low self-sufficiency indicators for coal, gas and crude oil. Overall primary energy supply self-sufficiency increases in the TGT and 2DC Scenarios, however, due to the increasing penetration of renewables and the declining demand for fossil fuels in both scenarios (Table 4.3). Primary energy supply diversity also improves slightly over the Outlook period as the shares of various renewable energy technologies in TPES expand.

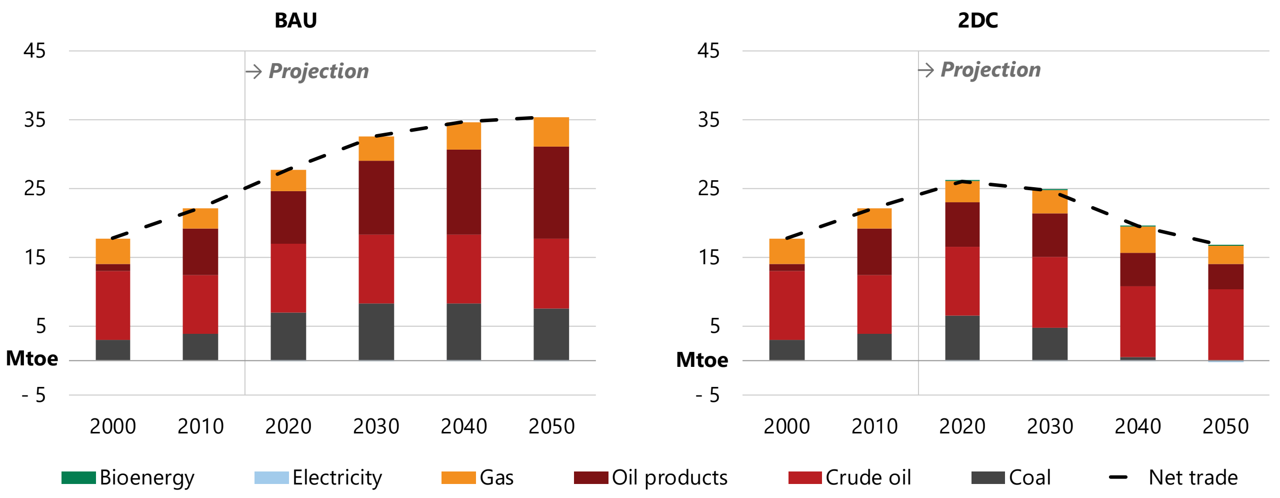
Table 4.3 • Chile: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	33	30	33	39	31	37	58
Coal self-sufficiency (%)	14	11	13	18	12	16	100
Gas self-sufficiency (%)	23	15	16	16	10	11	15
Crude oil self-sufficiency (%)	3	1	1	1	0	0	0
Primary energy supply diversity (HHI)	0.28	0.29	0.28	0.28	0.29	0.28	0.33
Coal reserve gap (%)	0	2	2	2	4	4	4
Gas reserve gap (%)	16	224	224	224	445	445	445
Crude oil reserve gap (%)	1	11	11	11	13	13	13

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

Net imports grow at 0.88% CAGR under the BAU Scenario, from 26 Mtoe in 2016 to 35 Mtoe in 2050 (Figure 4.13). Over the Outlook period, crude oil imports rise from 8.4 Mtoe to 10 Mtoe and oil products from 7.8 Mtoe to 13 Mtoe as a result of energy demand growth in the transport sector. Although coal imports rise from 6.2 Mtoe to 7.5 Mtoe, they account for only 21% of total imports in 2050 (up from 24% in 2016). Under the 2DC, gas and oil products imports decrease (19% and 52%, respectively) owing to declining end-use demand. Coal imports disappear over the Outlook period, as coal-fired plants are replaced by renewables. This raises coal self-sufficiency in the 2DC to 100% by 2050).

Figure 4.13 · Chile: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Chile began trading electricity with Argentina in February 2016 as stipulated in Supreme Decree No. 7 of July 2015, which authorised AES Gener S.A. to export electricity to Argentina via a 345 kilovolt transmission line in northern Chile (Ministerio de Energía, 2018e). The interconnection enabled the export of surplus energy from the power plants of Chile's Greater Northern Interconnected System, and in 2016 approximately 100 825 megawatt-hours of electricity was exported (CDEC, 2016). However, exports to Argentina expired in November 2017 when Chile's two main systems—the Greater Northern Interconnected System and the Central Interconnected System—became interconnected.

In 1995, the Governments of Chile and Argentina signed an agreement for gas integration. In 1996, Chile started importing gas from Argentina through the Bandurria pipeline in the extreme south. Since then, 7 pipelines were built across the Andes Mountains connecting the two economies. However, in 2004 Argentina began curtailing (and eventually stopped) exports, prompting a group of Chilean companies to build two LNG terminals, and since 2010 they have been Chile's main sources of gas supply. In October 2018, Argentina restarted pipeline exports as a significant step towards regional energy integration. An interruptible contract expiring 30 April 2019 was signed by both parties in 2018 (Ministerio de Energía, 2018f).

Expanding emergency stocks and incorporating disaster preparation and resilience measures into the energy system would help improve energy security and maintain supply during emergency situations such as those caused by earthquakes and tsunamis, which occur relative frequency in Chile. This has been acknowledged in the Energy Roadmap, and the government plans to implement resilience measures, starting with its regulatory institutions. The current mandatory minimum oil inventory is the equivalent of 25 days of average sales (or average imports).

SUSTAINABLE ENERGY PATHWAY

At the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, hereafter referred to as the 'COP21 Paris Agreement', Chile submitted a Nationally Determined Contribution (NDC) reflecting policy action to support the Agreement. The NDC includes a target for carbon intensity, expressed in greenhouse gas (GHG) emissions per unit of GDP, and another for tonnes of carbon dioxide equivalent (tCO_2) from LULUCF activities.[25] While Chile contributes only 0.24% of global emissions (Banco Central, 2018), 77% of its CO_2 emissions came from the energy sector in 2013 (Ministerio de Energía, 2017c). To reduce emissions under the COP21 Paris Agreement, Chile's NDC commits to (Gobierno de Chile, 2015):

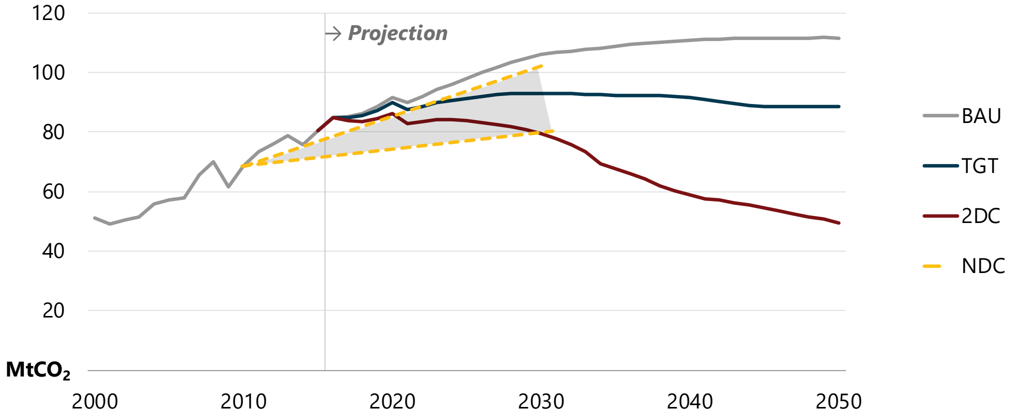
- Unconditionally reduce the intensity of emissions per unit of GDP to 30% below the 2007 level by 2030, not including LULUCF activities.
- Conditional on international funding, reduce CO_2 emissions per unit of GDP to 35% to 45% below the 2007 level by 2030, not including LULUCF activities.
- Make specific LULUCF contributions of:
    - Sustainably developing and recovering 100 000 hectares (ha) of forest land, mainly native, for GHG sequestrations and reductions equivalent to around 600 000 tCO_2 annually by 2030.
    - Reforesting 100 000 ha, mostly with native species, to sequester the equivalent of 900 000 tCO_2 to 1 200 000 tCO_2 annually by 2030. This commitment is conditional on the extension of Decree Law 701 and approval of a new Forestry Promotion Law.

Chile has adopted several policies, including an energy labelling programme (which is rated as one of the most comprehensive in the world by the IEA) and energy efficiency labelling for LDVs, among other programs, which are sufficient to put Chile on track to achieve the unconditional NDC in all scenarios. Total energy-related CO_2 emissions rise 31% under the BAU, from 86 $MtCO_2$ in 2016 to 112 $MtCO_2$ in 2030 (Figure 4.14), but they should

[25] Land use, land-use change and forestry.

be in the order of 106 $MtCO_2$ to achieve the unconditional 30% GHG emissions intensity reduction by 2030. This target is met under the TGT and 2DC (94 $MtCO_2$ in TGT and 80 $MtCO_2$ in 2DC).[26]

Figure 4.14 · Chile: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

Chile's unconditional NDC commitment to reduce its emissions intensity to 30% below the 2007 level by 2030 (NRDC, 2018) is achieved in the TGT and 2DC scenarios, but the conditional commitment to reduce emissions intensity to 45% below the 2007 level by 2030 is achieved only in the 2DC. Despite strong improvements over the projection period, more can be done to improve energy efficiency, especially in industry and transport. More stringent efficiency labelling for light- and heavy-duty cars should reduce CO_2 emissions in the transport sector in the near term, as should the electro-mobility strategy and the Energy Roadmap goals.

As outlined in the Energy Roadmap 2018-2022, deploying battery storage and EVs would also help reduce CO_2 emissions in the electricity and transport sectors, and creating new policies to promote research, development and innovation in this area could boost economic growth. Incentives such as rebates or tax breaks, free public parking, or even a reduction in the vehicle registration permit could help increase EV sales until the relative price of EVs converges to that of conventional vehicles.

Chile should raise incentives for renewable energy production to take advantage of some of the world's best solar and wind resources and reduce its reliance on imported fossil fuel resources. For example, in all three scenarios, less than 2% of electricity generation is from rooftop PV installations, a feed-in-tariff could help achieve this. Also, as significant decarbonisation in the industry sector is required to meet the CO_2 emissions reduction target, more efficient use of energy in that sector's processes should be encouraged: deploying CSP and geothermal as a substitute for baseload coal-fired generation is an ideal option. More aggressive decarbonisation of the power sector through the greater use of renewables and natural gas with CCS technology, in addition to heightened energy efficiency, would make Chile's COP21 Paris Agreement commitments realisable.

[26] New policies, such as the coal-fired power decarbonisation process, which have been implemented by Chile since the completion of Outlook model runs and drafting are not reflected in the BAU and TGT CO_2 pathways.

While Chile began trading electricity with Argentina in February 2016, exports expired after Chile's two main systems became interconnected in November 2017, as stipulated in Supreme Decree No. 7 of July 2015. Serious consideration should be given to reinstating the interconnection with Argentina, and to developing new ones, to give Chile's energy system more flexibility and security. Policies to create additional interconnections with neighbouring economies in the medium-term should be considered. The recently renewed gas pipeline trade between Chile and Argentina is a step in the right direction but further efforts should be made to extend the length of the contract and strengthen its terms, as it is interruptible and expires on 30 April 2019.

Finally, Chile should re-evaluate its emergency liquid fuel stocks to bolster energy security. Chile's minimum inventory currently covers 25 days, because Chile relies so heavily on fuel imports, instituting a policy to expand its reserves could ensure it has adequate supplies during emergency situations, natural disasters or contract disputes.

5. CHINA

KEY FINDINGS

- **Economic growth, increasing urbanisation and improving living standards all underpin higher FED in the BAU (a 17% increase over 2016-50) and TGT (3.9%).** In the 2DC, FED declines by 9.3% over the Outlook period, as greater improvement in energy efficiency outweighs these effects.

- **Under the BAU, energy intensity drops by 65% and energy-related CO_2 emissions intensity drops by 68% from 2005 to 2030 (the period stated in China's NDC), and by 64% and 71% from 2016 to 2050 (the Outlook period), despite growing energy demand.**

- **Similarly to FED, TPES increases in the BAU and TGT but falls from 2 983 Mtoe in 2016 to 2 716 Mtoe in 2050 in the 2DC.** Coal's share declines rapidly, from 65% in 2016 to 20% in 2050, while shares of nuclear (1.9% to 15%), gas (5.7% to 20%) and renewables (8.9% to 30%) all increase more than threefold.

- **Trends in energy production and trade reflect TPES across the three scenarios.** Production and imports are highest in the BAU, reaching 2 655 Mtoe and 943 Mtoe in 2050, and lowest in the 2DC with 2 146 Mtoe and 566 Mtoe.

- **Cumulative CO_2 emissions under the 2DC are around 214 billion tonnes between 2016 and 2050, 100 billion tonnes less than in the BAU.** Most of this reduction is linked to power sector decarbonisation and expansion of nuclear and renewables capacity.

ECONOMY AND ENERGY OVERVIEW

China, with a population of 1.4 billion in 2016 and a land mass of 9.6 million square kilometres, has been the largest economy in the world since 2013 in purchasing power parity terms. Since reforming and opening up in 1978, China has been one of the fastest-growing economies in the Asia-Pacific Economic Cooperation (APEC) region. From 2010 to 2016, gross domestic product (GDP) increased at a compound annual average growth rate (CAGR) of 7.7% to reach USD 21 trillion. China's GDP accounted for about 15% of the world total in 2017 and it contributes about 30% to total world growth (SCPRC, 2018a). GDP per capita in 2016 was USD 15 094, 33% lower than the APEC average of USD 22 536.

China's economic structure has been changing in recent years, culminating in the achievement of two main government goals: 'consumption overtakes investment' in the demand structure and 'the tertiary (service) sector overtakes the secondary (industrial) sector' in the economic structure. In 2017, the bulk of China's GDP was from the tertiary (52%) and secondary (41%) sectors, with the primary sector (agriculture, mining, etc.) having a relatively small share (7.9%) (NBS, 2018). This reflects China's gradual transformation from 'the world's factory' to a service, engineering and high-end manufacturing powerhouse. Emerging strategic industries (e.g. new materials and information technology), services (e.g. business services and industrial design), and modern manufacturing (e.g. high-speed railway equipment and nuclear power equipment) are replacing traditional, high-energy-intensity industries (e.g. coal mining, iron and steel, and non-metallic minerals) to become the economic pillars under China's 'new normal' economic growth status.

Table 5.1 • China: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	4 986	13 596	21 184	26 561	39 456	54 710	68 586
Population (million)	1 283	1 360	1 404	1 425	1 441	1 417	1 364
GDP per capita (2016 USD PPP)	3 885	9 999	15 094	18 645	27 377	38 597	50 267
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	1 135	2 543	2 983	3 102	3 288	3 448	3 586
TPES per capita (toe)	0.88	1.9	2.1	2.2	2.3	2.4	2.6
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	228	187	141	117	83	63	52
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	781	1627	1979	2061	2156	2236	2322
FED per capita (toe)	0.61	1.2	1.4	1.4	1.5	1.6	1.7
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	157	120	93	78	55	41	34
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	3207	8317	9255	9180	8998	8873	8668
APEC energy-related CO_2 emissions ($MtCO_2$)	14421	20033	20694	20891	21152	21586	21917
Electrification rate (%)	95	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

Over the past three decades, China has made significant achievements in modernising and developing its energy system. Between 2012 and 2017, the population in urban areas grew by 80 million, and the urbanisation rate grew from 53% to 59% (SCPRC, 2018b). By the end of 2015, all of China's population had access to electricity, with only small groups of citizens in remote regions using stand-alone photovoltaic (PV) systems instead of being connected to the power grid (SCPRC, 2015). By 2016, piped natural gas was available to over 310 million people in urban areas (NEAC, 2017a).

China has been the world's biggest energy producer since 2005. In 2016, China produced 2 359 million tonnes of oil equivalent (Mtoe) of energy, accounting for 31% of total APEC energy production. Coal represents 73% of China's primary energy production. China is the biggest coal producer in the world; it ranks 8th in oil production and 6th in natural gas production (BP, 2018). In 2009, China became the world's largest energy consumer with final energy demand (FED) reaching 1 979 Mtoe (37% of APEC total demand) in 2016.

China has become a global leader in the development and deployment of modern renewable energy in recent years. In 2017, total installed renewable capacity reached 619 gigawatts (GW), about 100 GW more than total European capacity (IRENA, 2018). By the end of 2017, China had cut carbon dioxide emissions per unit of GDP by 46% from the 2005 level, meeting its 2020 carbon emission target—reducing carbon emissions by 40~45% by 2020 from the 2005 level—three years ahead of schedule with the help of the economy's carbon trading system. China has also raised the volume of forest stock by 2.1 billion cubic meters (bcm) from the 2005 level, meeting the goal of a 1.3 bcm increase by 2020 (UNFCC, 2018).

ENERGY RESOURCES

China is rich in natural energy resources. Coal is China's largest fossil fuel resource, with remaining reserves and resources of 1 598 billion tonnes in 2016 (MNR, 2017). Proved energy reserves at the end of 2017 comprise coal (139 billion tonnes), oil (26 billion barrels) and natural gas (5.5 trillion cubic metres [tcm]). Unconventional fossil fuel resources are also abundant in China, but a large portion of them are undeveloped or technically difficult to exploit. In 2016, China's technologically recoverable reserves of coalbed methane were 334 bcm and shale gas was 122 bcm (MNR, 2017).

Table 5.2 • China: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	138 819	39	13.4	4	4
Oil (billion bbl) [a]	26	18	1.5	14	4
Natural gas (tcm) [a]	5.5	37	2.8	9	3
Uranium (tU) [b]	136 700	80	3.5	9	4

Notes: Mt = million tonnes. bbl = barrels. tU = tonnes of uranium. a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kgU.
Sources: For coal, oil and natural gas, BP (2018). For uranium, NEA (2018).

China's technical potential for renewable energy resources is rich, particularly for hydro, wind and solar power. Total hydro power potential is 660 GW, the largest in the world. Only around 37% of this capacity has been developed (calculated by power generation), however, substantially lower than most developed economies (e.g. 73% in Japan and 67% in the United States) (NEAC, 2016a). For wind power, the technical exploitable capacity potential at 70 metres height is about 5000 GW; while total land solar power reserves are estimated at 1 860 000 GW (CMA, 2015). Wind and solar energy potential is undermined by the fact that a large portion of these resources are located in remote and sparsely-populated areas in the north and northwest, far away from demand centres in the east.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

China's current energy policy focuses on establishing a modern energy system by improving the energy supply mix, energy efficiency, sustainable development and energy security. Three key documents provide the main supporting policies for China's energy development during the 2016 to 2020 period: the 13th Five-Year Plan (2016-20) for Energy Development (hereafter noted as the 13th FYP for energy development); the Innovation Action Plan of Energy Technology Revolution (2016-20); and the Strategic Action Plan for Energy Development.

Since the 12th FYP period (2010-15), the principal challenge in China's energy sector has been gradually shifting focus from energy supply shortages to addressing environmental problems caused by fossil fuel consumption. In December 2016, the National Development and Reform Commission (NDRC) and the National Energy Administration (NEAC) jointly issued the 13th FYP for energy development, which outlines basic principles, major development targets and primary missions (NDRC, 2016a). Compared with the 12th FYP (2011-15), the new plan specifies targets in four areas: domestic energy security, CO_2 emissions reduction in the energy sector, prevention of renewable power overcapacity and resolution of coal-fired power overcapacity.

For the first time, this plan sets strict constraints on the rate of domestic energy self-sufficiency and clear targets for reducing CO_2 emissions per GDP. By 2020, China aims to maintain energy self-sufficiency levels above 80% (down from 84% at the end of 2015) and to reduce CO_2 emissions per unit of GDP by 18% (constrained target) from the 2015 level.

Limiting the overdevelopment of generation capacity, especially for thermal power plants, is another key aim in the 13th FYP for energy development. At present, such overcapacity leads to several issues. Of particular note is the low annual utilisation hours of power plants. In 2015, the rate for all types of power plants with a capacity of 6 megawatts (MW) and above was 45%—the lowest levels since 1978 (NEAC, 2016b). Curtailment of hydro, solar and wind power is also an issue, as the average reserve margin was roughly 28% at the end of 2014, almost twice the global standard level of 15% (BerkeleyLab, 2016).

To prioritise solving wind and solar power curtailments, the 13th FYP for energy development bans approvals for construction of new thermal plants in the first two years of the period. This Plan also prioritises cutting production overcapacity, adjusting the fuel mix, promoting market dynamics and setting a series of energy sector development targets for 2020. With sustained, strong economic growth (projected as 6% to 7%) during the 13th FYP period, by 2020 total primary energy production is estimated to reach 2 800 Mtoe, while consumption is less than 3 500 Mtoe and installed electricity capacity climbs to 2 000 GW (NDRC, 2016a).

Controlling environmental pollution and smog problems, especially during winter in northern areas, is an urgent and major concern in China. The Action Plan on Prevention and Control of Air Pollution dedicates political and financial support to assist central and local governments in replacing coal-fired heating boilers with gas-fired and electrical alternatives. This increases demand for natural gas during winter in northern areas and widens the winter-to-summer demand ratio for natural gas. It also increases China's pipeline natural gas imports from Central Asia and Russia, and its dependence on imports of liquefied natural gas (LNG).

The proportion of solar and wind power in China's energy mix has increased sharply over the past decade, but current policy for renewable energy is evolving from 'vigorously developing' to 'orderly developing'. The NDRC plans to gradually lower renewable subsidies and targets, aiming to reduce wind power feed-in tariffs (FiTs) to the same level as those for conventional thermal plants by 2020 (SCPRC, 2017). Current policy also encourages construction of distributed solar PV and wind power facilities by both enterprises and individuals, and also calls for solving the issue of wind and solar power curtailment by 2020 (NEAC, 2017b).

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for China under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 5.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 5.3 • China: Key assumptions and policy drivers under the BAU

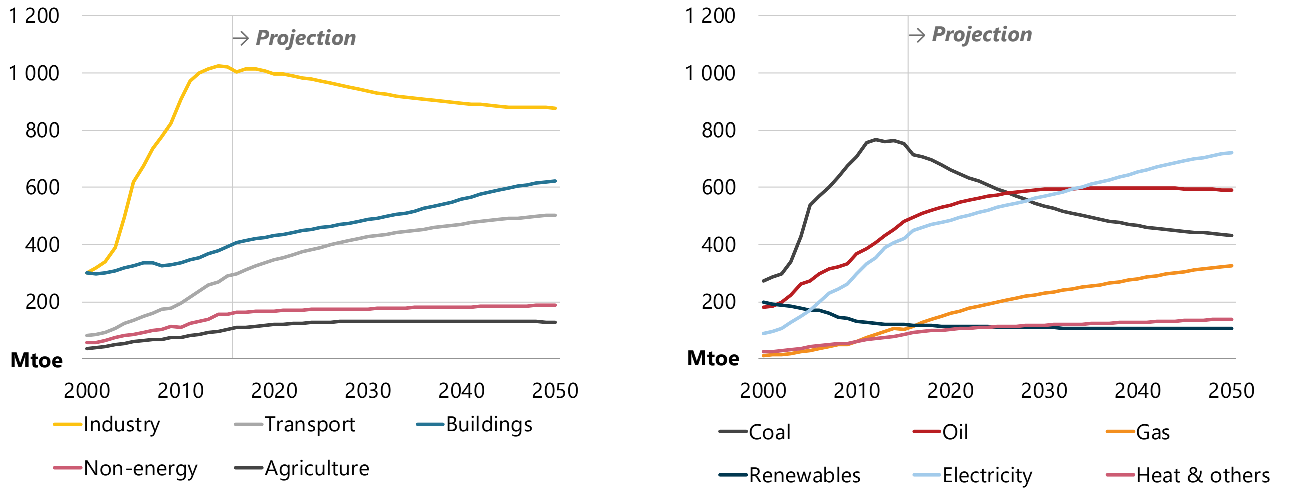
Buildings	Promote the installation of distributed renewable energy systems on large-scale buildings to increase renewable consumption and facilitate selling excess electricity to the grid. Continue to shift rural buildings from coal and traditional biomass to electricity and modern biomass for heating and cooking.
Transport	Continue public transport development, such as the high-speed railway network, city subways and light railway systems. Promote the sale and use of advanced vehicles such as electric vehicles (EV) and plug-in hybrid EVs (PHEV).
Energy supply mix	Increase the overall shares of nuclear and renewable energy. Increase the non-fossil fuel energy consumption share to 15% by 2020. Increase the natural gas consumption share to 10% by 2020.
Power mix	Increase the non-fossil energy share of installed generating capacity to 39% by 2020. Increase the share of coal used for power generation in total coal consumption to more than 55% by 2020. Target nuclear power capacity of 58 GW by 2020.
Renewables	2020 targets for wind (210 GW) and solar (110 GW).
Energy security	Maintain the domestic energy self-sufficiency rate above 80% by 2020. Improve energy efficiency and boost the share of clean and renewable energy.
Climate change	To achieve peak CO_2 emissions around 2030, increase China's share of non-fossil fuels in final energy consumption to around 20% by the same year.

Note: This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Under the BAU, China's FED increases from 1 979 Mtoe in 2016 to 2 322 Mtoe in 2050, with a CAGR of 0.47%. With the changing structure of the economy—via the rapid development of the services sector and high-end manufacturing—energy demand in industry decreases while buildings and transport both grow. Despite this, industry retains the largest share of FED in 2050 (38%), followed by buildings (27%) and transportation (22%), with lower shares in non-energy use (8.1%) and agriculture (5.6%) (Figure 5.1).

Figure 5.1 • China: Final energy demand by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy demand in industry declines by 12% from 1 003 Mtoe to 878 Mtoe throughout the Outlook period, mainly due to changing industrial structure and improving energy efficiency. Growth in buildings continues (1.3% CAGR over the Outlook), mainly due to higher electricity and gas consumption as incomes rise, urbanisation expands and the economy shifts to become more service-oriented. Similarly, transport continues to grow throughout the Outlook (1.6% CAGR) due to the expansion of transport activities and strong growth of vehicle stock. Lower growth is seen in agriculture (0.48% CAGR) and non-energy use (0.43% CAGR).

The shares of electricity (31% in 2050), oil (25% in 2050), and gas (14% in 2050) increase throughout the Outlook period, while that of coal—the largest source (36%) in 2016—falls to the third place (19%) in 2050. Electricity overtakes coal and oil to meet the largest share of FED by 2034. Demand growth mainly comes from residential and commercial buildings, as people become wealthier and China's economy continues to become more service-oriented. Growth in oil demand mainly comes from road freight transport expansion and the continued growth of private vehicle ownership.

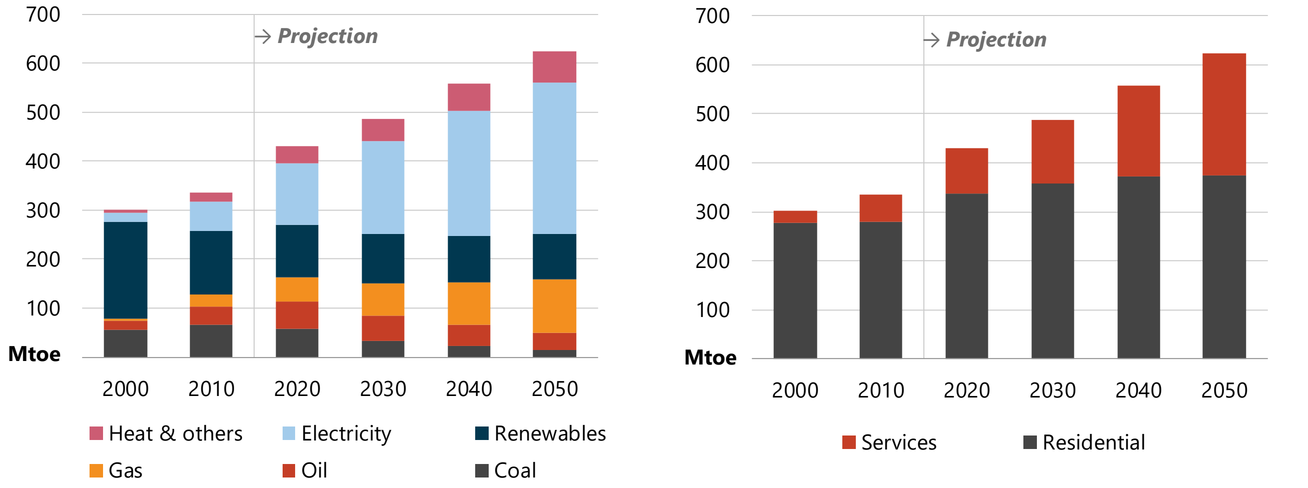
BUILDINGS: ELECTRICITY DEMAND GROWS WHILE COAL DEMAND DECLINES

China's buildings energy demand was dominated by renewable energy, mostly traditional biomass, as recently as 2000. Since then, significant efforts to expand electricity and gas networks have resulted in strong growth in those fuel types to both meet growing demand and displace traditional biomass. Demand keeps growing at 1.3% CAGR throughout the Outlook period, underpinned by strong growth in electricity (increasing from a 25% to 50% share of buildings FED) and gas (from 11% to 17%). The share of coal demand, in contrast, shrinks considerably from 17% in 2016 to 2.4% in 2050 (Figure 5.2).

In the residential subsector, with rising income (GDP per capita increases 3.3 times over 2016-50) and urbanisation, more households purchase electric appliances for cooling, heating and cooking, which results in electricity consumption almost doubling (from 72 Mtoe in 2016 to 139 Mtoe in 2050). Total demand increases by only 15% (from 325 Mtoe in 2016 to 375 Mtoe in 2050), due to energy efficiency improvements and the decline of coal and oil demand as China adopts policies to replace coal with electricity and gas for winter heating to mitigate air pollution.

In the services subsector, FED more than doubles from 2016 to 2050 (3.3% CAGR) as China's service industries become the new engine of economic development. With greater urbanisation and rising living standards, commercial activities spur the need for more infrastructure (including offices, schools, hospitals and government buildings) and leisure/entertainment facilities (malls, theatres, hotels, restaurants, etc.). This growth sees total commercial service floor area nearly quadruple, from 4 838 million m^2 2016 to 18 748 million m^2 in 2050. Increased floor area and activity drives expansion in all end-uses, particularly water heating (3.9% CAGR), other uses (3.8% CAGR), space cooling (3.1% CAGR), lighting (2.2% CAGR) and space heating (1.6% CAGR). Growth in these end-uses in unison with government efforts to reduce local air pollution result in the share of electricity in services growing from 35% in 2016 to 68% in 2050 and gas from 13% to 17%, while coal and oil both shrink.

Figure 5.2 • China: Buildings final energy demand by fuel and subsector, 2000-50



Source: APERC analysis and IEA (2018a).

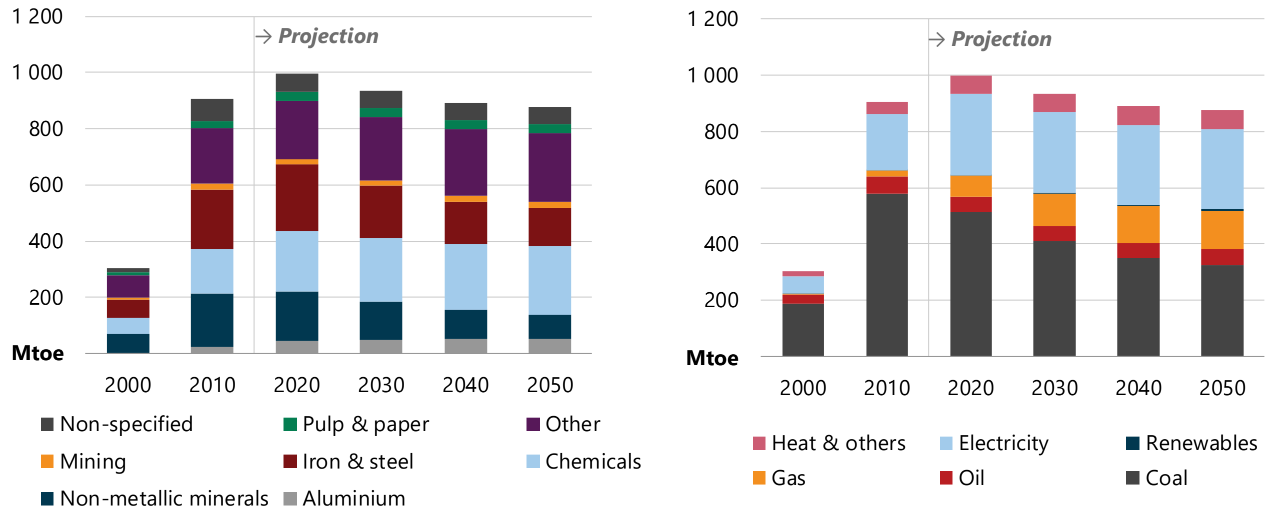
INDUSTRY: DEMAND FALLS WITH SHARE OF ENERGY-INTENSIVE SUBSECTORS

Industry is the largest energy-consuming sector in China, with demand accounting for 51% of total FED in 2016, and 38% in 2050. Industry energy demand peaks in 2018 at 1 015 Mtoe and declines by 12% over the Outlook, from 1 003 Mtoe in 2016 to 878 Mtoe in 2050 (Figure 5.3). This gentle decline is in sharp contrast to the rapid growth experienced over the first two decades of the 21st century (7.8%, CAGR) as China moves from rapid industrialisation towards a more service-oriented economy.

The changes in China's economic structure over the Outlook are most clear in the iron and steel and non-metallic minerals subsectors, with energy demand in the former decreasing by 43% from 239 Mtoe in 2016 to 136 Mtoe in 2050, and the latter decreasing by 56% from 194 Mtoe to 86 Mtoe. In contrast, advanced manufacturing energy demand grows significantly—the 'other' subsector[27] increases by 22% over the Outlook (from 199 Mtoe to 242 Mtoe) and the chemical and petrochemical subsector increases by 20% (from 205 Mtoe to 246 Mtoe). The share of coal falls steadily through the Outlook, from 55% in 2016 to 37% in 2050, reflecting these changes in subsector demand, while the share of electricity increases from 29% to 32%, and gas increases from 4.3% to 16%.

[27] The 'other' subsector includes non-ferrous metals except aluminium, transport equipment, machinery, food and tobacco, wood and wood products, construction, and textiles and leather, of which machinery is the largest end-use at 5.7% of total industry FED in 2016.

Figure 5.3 • China: Industry final energy demand by subsector and fuel, 2000-50



Source: APERC analysis and IEA (2018a).

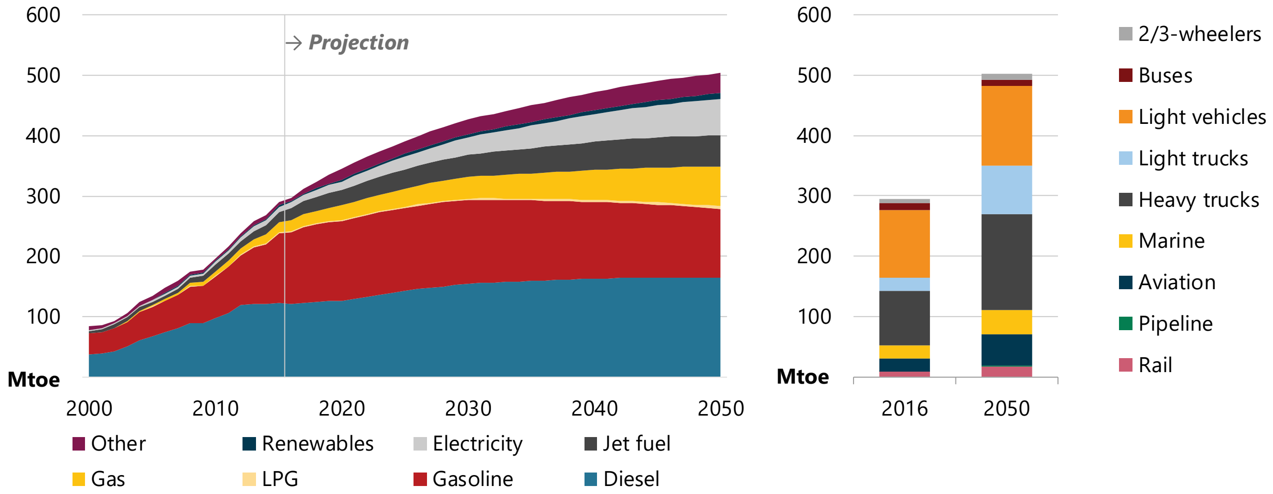
The changing composition of China's industrial sector reflects efforts to optimise industrial structure, shifting from energy-intensive to high value-added manufacturing subsectors and the saturation of the real estate market (which reduces cement and iron and steel demand growth). A series of regulations and policies issued by the government aiming to shut down outdated, inefficient—and even illegal—iron and steel and cement factories, especially those around the major economically developed areas (such as the Jing-Jin-Ji and Yangtze River Delta[28] zones). These policies and regulations also target air pollution and greenhouse gas (GHG) emission problems. The BAU considers these as long-term mandatory actions that will be implemented over the full projection period.

TRANSPORT: FREIGHT TRANSPORT GROWTH DRIVES ENERGY DEMAND

China's domestic transport energy demand has mushroomed in recent years—increasing more than threefold between 2000 and 2016. This growth moderates over the Outlook, with demand growing by 70%, from 297 Mtoe in 2016 to 504 Mtoe in 2050 (Figure 5.4). Growth is more rapid in the near-term (2.6% CAGR over 2016-30), but slows down in the long-term (0.83% CAGR from 2030-50) as China's economic development enters the 'new normal state' with population peaking in 2029 then declining. Road transport dominates domestic transport energy demand, with the share remaining around 80% throughout the Outlook period.

[28] Jing-Jin-Ji metropolitan region is the area around Beijing, Tianjin and Hebei; it is the largest urbanised region in Northern China. The Yangtze River Delta includes Shanghai and areas of Jiangsu and Zhejiang provinces.

Figure 5.4 • China: Domestic transport final energy demand by fuel and mode, 2000-50



Source: APERC analysis and IEA (2018a).

Over the Outlook period, freight is the main driver of transport energy demand growth, more than doubling from 138 Mtoe in 2016 to 297 Mtoe in 2050, and the share growing from 47% to 59%. Passenger transport energy demand, in contrast, grows more moderately, by 31% from 157 Mtoe to 205 Mtoe. Although the government plans to reduce the fuel consumption of newly manufactured vehicles to less than 5.0 litres per 100 kilometres in 2020 (MST, 2017), strong growth of total vehicle stock and transport activities still leads to overall growth in road transport energy demand. Light-duty vehicle (LDV) stock increases from 163 million in 2016 to 367 million in 2050, while heavy-duty truck stock expands similarly—from 6.6 million to 15 million. Domestic freight transport activities expand from 13 trillion tonnes kilometres (tkm) in 2016 to 29 trillion tkm in 2050.

Fossil fuels remain the backbone of transport energy demand in China, especially in the road freight subsector, although the share of diesel drops from 41% in 2016 to 33% in 2050 and gasoline from 40% to 23%. The share of electricity in domestic transport energy demand increases from 3.3% to 12% over the Outlook, underpinned by a rapid expansion in the light electric vehicle (EV) stock from 0.6 million in 2016 to 91 million in 2050 (16% CAGR). China has set an ambitious target to have 5 million EVs by 2020, and has rolled out a series of measures to promote advanced vehicles, including tax exemptions, subsidies and requirements for the government car fleet to constitute more advanced vehicles (NDRC, 2016a) (MST, 2017). These efforts moderate and even offset some energy demand growth over the Outlook, especially for fossil fuels, which remain dominant in freight transport.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Energy demand in China's transformation sectors has grown explosively since 2000, as end-use demand for electricity, coal, gas and oil products has increased in line with the economy. Supplying these fuels has seen a huge expansion in electricity generation and refining capacity as well as the size of the coal mining and oil and gas production industries. Total primary energy supply (TPES), primary energy production and trade are all dominated by fossil fuels, but gas and oil increase their share of the fuel mix over the Outlook period compared with coal.

ENERGY INDUSTRY OWN-USE: OVERCAPACITY IN REFINERIES

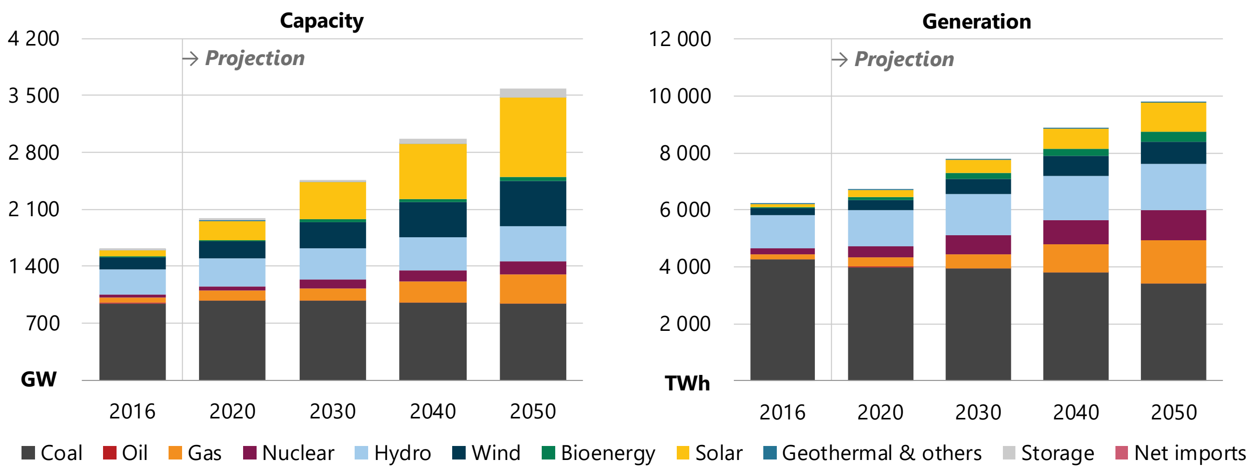
China's refinery capacity was 550 Mtoe per year at the end of 2016, which was second only to the United States in the APEC region, but its utilisation rate was below 70% because of structural overcapacity, which is low by international standards (Sina, 2016). State-owned enterprises dominate the refinery market in China, while local refinery enterprises own only a 35% share of capacity (193 Mtoe). Since 2015, China has been reforming the refining industry, primarily by eliminating import and export restrictions. The government granted crude oil importing licences to local independent refinery enterprises, under the condition that they shut down small and outdated plants. This has resulted in crude oil imports by local refinery enterprises rising rapidly, from 1.1 Million tonnes (Mt) in 2015 to 45 Mt in 2016, which accounted for 12% of China's total imports (CNPC, 2017a).

POWER SECTOR: RENEWABLE AND NUCLEAR CONTRIBUTE TO CAPACITY GROWTH

China's power sector has long been dominated by coal-fired electricity generation, which has accounted for more than 70% of total generation since 2000. This generation has expanded immensely to meet the more than fivefold increase in electricity demand during 2000-16. Hydro power has traditionally been the second largest electricity generation source, accounting for at least 15% of generation over that period.

Electricity demand continues to grow under the BAU, although less rapidly than in the past, resulting in generation reaching 9 766 terawatt-hours (TWh) in 2050 (from 6 200 TWh in 2016) (Figure 5.5). Total capacity expands rapidly as well, reaching 3 588 GW by 2050 (from 1 623 GW in 2016); coal-fired capacity declines to 26%, nearly half of its 2016 share (58%). Spurred by the goals of seeing CO_2 emissions peak before 2030 and mitigating air pollution, China continues to decarbonise its power sector. During the 13th FYP period, the government places special emphasis on optimising the coal-fired subsector through three measures: stop or suspend construction of 150 GW of capacity; shut down over 20 GW of inefficient existing capacity; and retrofit 980 GW of capacity with ultra-low emission and energy-saving technologies (NEAC, 2017c). Additional gas-fired plants are planned to replace outdated coal-fired plants, with a target for total gas-fired capacity exceeding 110 GW by 2020 (NDRC, 2016b).

Figure 5.5 • China: Power capacity and electricity generation by fuel, 2016-50



Source: APERC analysis and IEA (2018a).

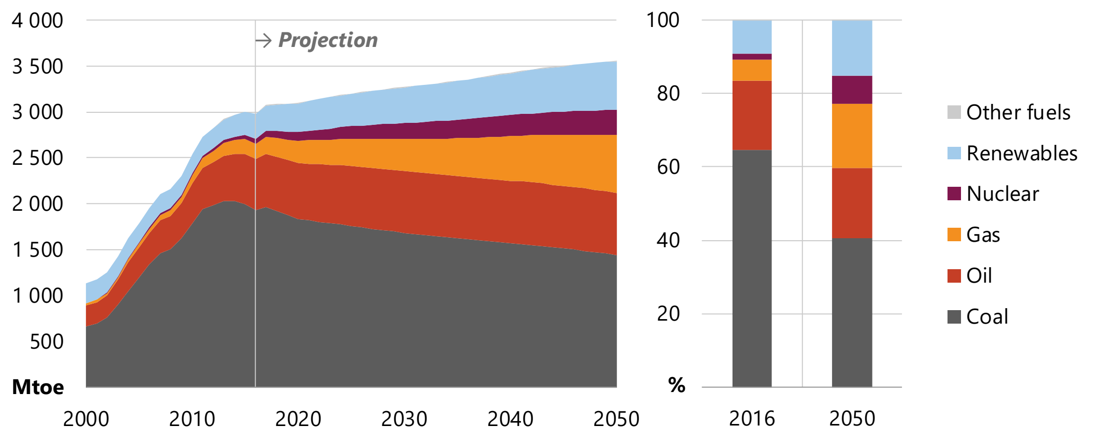
Expanding non-fossil fuel power capacity is another key element of China's energy policy outlined in the 13th FYP for energy development. In 2017, China surpassed its 2020 solar PV target with installed capacity reaching 130 GW. By the end of 2017, installed wind capacity reached 164 GW (NEAC, 2018a). Over this period, China accounted for more than 40% of global renewable capacity growth (IEA, 2018b). Under the BAU, renewables are the fastest-growing fuel type; capacity increases throughout the Outlook period are 7.7% CAGR for solar, 4.8% CAGR for nuclear and 3.9% CAGR for wind.

China announced plans for an economy-wide emission trading scheme (ETS) in December 2017 after several years of regional projects. The first phase of this cap-and-trade system covers about 1 700 power firms with total CO_2 emissions in excess of 3 billion tonnes and is scheduled to begin operation in 2020 when it will become the world's largest carbon market. The government has announced plans to expand the ETS to cover seven other sectors, including petrochemical and chemical, building materials, and iron and steel in the future (CEC, 2017).

TOTAL PRIMARY ENERGY SUPPLY: RENEWABLES, GAS AND NUCLEAR INCREASE SHARPLY

As China's economy increases steadily across the Outlook period, TPES rises from 2 983 Mtoe to 3 586 Mtoe, an overall growth of 20% (Figure 5.6). Fossil fuels still dominate China's primary energy supply from 2016 to 2050, accounting for 89% of TPES in 2016, but declining to 77% in 2050. Coal's share in TPES declines from 65% to 40%, while that of gas increases from 5.7% to 17%, and that of oil remains stable between 18% and 20%.

Figure 5.6 • China: Total primary energy supply by fuel, 2000-50



Source: APERC analysis and IEA (2018a).

Driven by aims to improve China's economic structure and policy commitments to move to cleaner, lower-carbon energy supply, the shares of renewable and nuclear energy in TPES increase steadily. Under the BAU, the Chinese government implements strong policies and subsidies to develop renewable energy and low-carbon technologies. From 2010 to 2016, China's new renewable power generation[29] capacity increased from 233 GW (30 GW wind; 0.4 GW solar) to 541 GW (149 GW wind; 78 GW solar) (IRENA, 2018). Through ongoing efforts to implement policies and regulations to support environmental protection, energy saving and GHG emissions control, China's renewable energy supply grows at a CAGR of 2.1% during the Outlook period—the highest among APEC economies. By 2050, China accounts for 58% of APEC's total renewable power capacity (including hydro, wind, solar, bioenergy and geothermal). Nuclear power also grows to keep pace with rising electricity demand, accounting for 7.6% of TPES by 2050.

[29] Not including large-scale hydro.

Box 5.1 • China: Winter heating gas supply

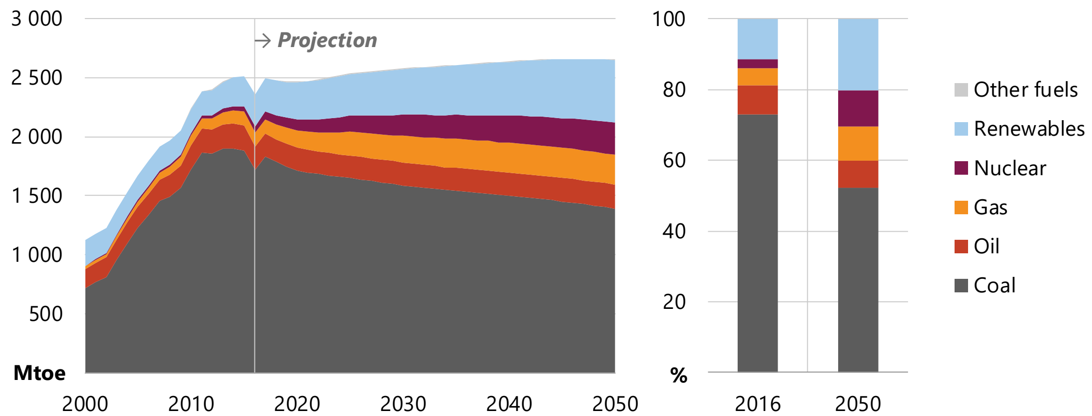
China experienced severe gas shortages during the 2017-18 winter and gas prices were driven to record highs, due to limited domestic output, low storage capacity, distribution network bottlenecks and slow pipeline imports. The government has taken measures to avoid a repeat of these shortages and price spikes during the 2018-19 winter, including by increasing domestic natural gas production, boosting gas pipeline infrastructure and connectivity, improving gas storage capacity, and making pre-arrangements for peak demand. China has also established targets for all gas supply companies to ensure they have sufficient gas storage by 2020. The implementation of a coal-to-gas switching policy has moderated, taking expectations of gas demand into consideration. The NDRC has also pledged to strengthen monitoring to ensure stable gas prices and supply throughout the winter heating season (Guangming Online, 2018).

ENERGY PRODUCTION AND TRADE: COAL SHRINKS AS GAS GROWS

Coal production in China decreases from 1 719 Mtoe in 2016 to 1 390 Mtoe in 2050 under the BAU, accounting for 52% of total primary energy production in 2050 (21% lower than in 2016) (Figure 5.7). China's 'supply-side reform', launched in 2016 with the primary aim of cutting coal production capacity, has already had substantial influence (NEAC, 2018b). China plans to shut down outdated coal production capacity at a rate of 800 Mt per year and increase advanced production capacity by 500 Mt per year during the 13th FYP (NDRC, 2016c).

China has ambitious plans for developing nuclear and renewable energy to meet increasing domestic electricity demand while also mitigating air pollution and GHG emissions in power generation. Both central and local governments administer financial and policy support for the wind power and solar PV industries. Construction of third-generation nuclear reactors is planned in development areas along the east coast (NEAC, 2017b). Within TPES, the share of renewables expands to 15% (532 Mtoe) by 2050 (from 8.9% in 2016) while that of nuclear rises to 7.6% (274 Mtoe; from 1.9% in 2016).

Figure 5.7 • China: Primary energy production by fuel, 2000-50



Source: APERC analysis and IEA (2018a).

China has been a net energy importer since 1997. Because of rich domestic coal reserves, China's energy self-sufficiency rate was around 80% in 2016. Crude oil supply, however, depends heavily on imports, which continue growing through the Outlook period, peaking at 461 Mtoe in 2038. Despite production more than doubling, natural gas imports increase the most, due to rapidly growing demand for less-polluting fossil fuels. Imports of natural gas reach 376 Mtoe in 2050 (from 59 Mtoe in 2016).

Energy imports to China are mainly from five regions: Russia and Central Asia, the Middle East, Africa, the Americas, and Asia-Pacific. The biggest LNG exporters in 2016 were Australia, Qatar and the United Arab Emirates, together accounting for more than 50% of China's total LNG imports. Pipeline natural gas imports come mainly through three channels: the north-west channel (Turkmenistan-Shanghai); the north-east channel (Irkutsk-Beijing) and the south-west channel (Myanmar-Chengdu). In 2016, 59 Mtoe of gas was imported, of which 31 Mtoe was transported via pipeline.

Under the 'Belt and Road Initiative', China has conducted a series of energy cooperation initiatives with other regional economies. In April 2017, the Sino-Myanmar oil and natural gas pipelines, which connect the south-west area of China with Myanmar, began operations. In April 2017, construction was completed on the southern Kazakhstan natural gas pipeline, which will deliver over 5.0 bcm per year (4.5 Mtoe) to China. On 1 January 2018, an extension (Line 2) of the East Siberia-Pacific Ocean oil pipeline started operations, doubling Russia-to-China crude oil export volume to 30 Mtoe annually (NEAC, 2017d).

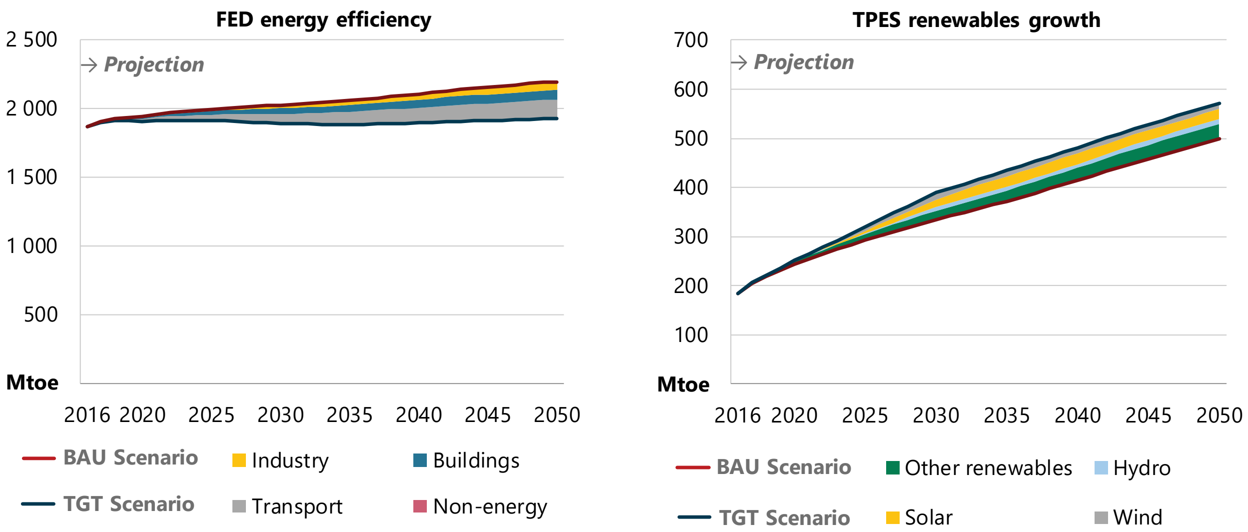
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of China's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. Modelling for the 2DC is underpinned by targets for energy sector emissions reduction that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 11% lower while CO_2 emissions are 20% lower in the TGT by 2050. Under the 2DC, China's FED is 23% lower and CO_2 emissions are 63% lower. The share of renewables in TPES in the TGT is 4.3% higher and 15% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase deployment of renewables. Under this scenario, China's FED in 2050 is 11% lower than in the BAU, a reduction of 267 Mtoe. The largest saving comes from transport (131 Mtoe, 49%), followed by buildings (72 Mtoe, 27%), industry (60 Mtoe, 22%) and the non-energy sector (4.5 Mtoe, 1.7%) (Figure 5.8). FED peaks in 2024 at 2 041 Mtoe, then decreases to 2 015 Mtoe in 2035, before gradually growing again to 2 055 Mtoe in 2050, mainly due to buildings and transportation demand increasing with economic growth, urbanisation and electrification.

Figure 5.8 • China: Energy efficiency and renewables development, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Source: APERC analysis and IEA (2018a).

The TGT outlines how a series of actions and improvements in each sector can be deployed to contribute to total demand reduction. Contribution from transport is mainly through faster deployment of high-efficiency LDVs, heavy-duty vehicles and electric vehicles (EVs), as well as through more efficient urban planning including expanding high-speed railway systems and highway networks. In the buildings (residential and services) sector, reduced demand mainly comes from stricter green building standards and MEPS, and from additional labelling schemes for electric appliances. In industry, energy efficiency improvements, higher rates of electrification and faster elimination of high-energy-intensity subsectors are the major drivers of demand reduction.

In 2014, APEC Leaders agreed on an aspirational goal of 'doubling the share of renewables in the APEC energy mix, including in power generation, from the 2010 level by 2030'. Because of its leading position in deploying modern renewable energy and the scale of its economy, China's contribution is essential to achieving this goal. Under the TGT, China's renewable power generation reaches 3 111 TWh by 2030 and 4 251 TWh by 2050, which is around half of the APEC total in both years. Renewable power generation in China grows 176% overall from 2016 to 2050 (3.0% CAGR), with solar power expanding nearly fifteen-fold and wind power nearly threefold.

Essential policy support and substantial investment underpin China's leading position in renewable energy deployment. Since 2005, China has consistently increased renewable energy research and development and had the world's largest renewable investment (excluding large hydro) in 2015 with USD 103 billion (a 17% increase from 2014), representing well over a third of the global total (BNEF, 2016). The US was a distant second, with USD 44 billion, up 19%. In parallel, China has shown rapid growth in renewable energy-related patent applications and technologies, in areas such as solar and wind power utilisation, ultra-high voltage transmission, and insulation. Despite the significant growth in the renewable energy sector, China must overcome a series of challenges to achieve the TGT goals, including balancing renewable and fossil fuel shares in the power sector, reducing wind and solar power curtailments, and addressing the high FiT.

Box 5.2 • China: Wind power curtailment

Since 2010, limitations of grid transmission connectivity and capacity have led to China's wind power industry being constrained through curtailment. In 2012, 21 TWh of electricity was curtailed, equivalent to 17% of total wind power generation. Improved policy and regulation helped bring the curtailment rate down to 11% in 2013, then to 8.5% in 2014. The curtailment rate has not yet stabilised, however, and high rates (15% to 17%) occurred in recent years (NEAC, 2015; 2016c; 2017e; 2018c).

The Regulation on the Administration of Renewable Energy Power Generation (issued by NDRC in 2006) authorised provincial-level governments to approve wind farm constructions under 50 MW without involving the central government. This regulation led to large increases in capacity, with some enterprises dividing their projects to benefit from the expedited administrative procedures. In many cases, the added wind power capacity outweighed local electricity demand and transmission line capacity. In parallel, the rapidly increasing demand for wind turbines forced local enterprises to expand production and cut costs. These actions reduced the cost per kilowatt for the entire wind turbine manufacturing industry. Ultimately, this regulation prompted much of the wind power curtailment in China, but also significantly contributed to pushing down the costs of wind power generation worldwide (since China is a significant producer and exporter of wind power components).

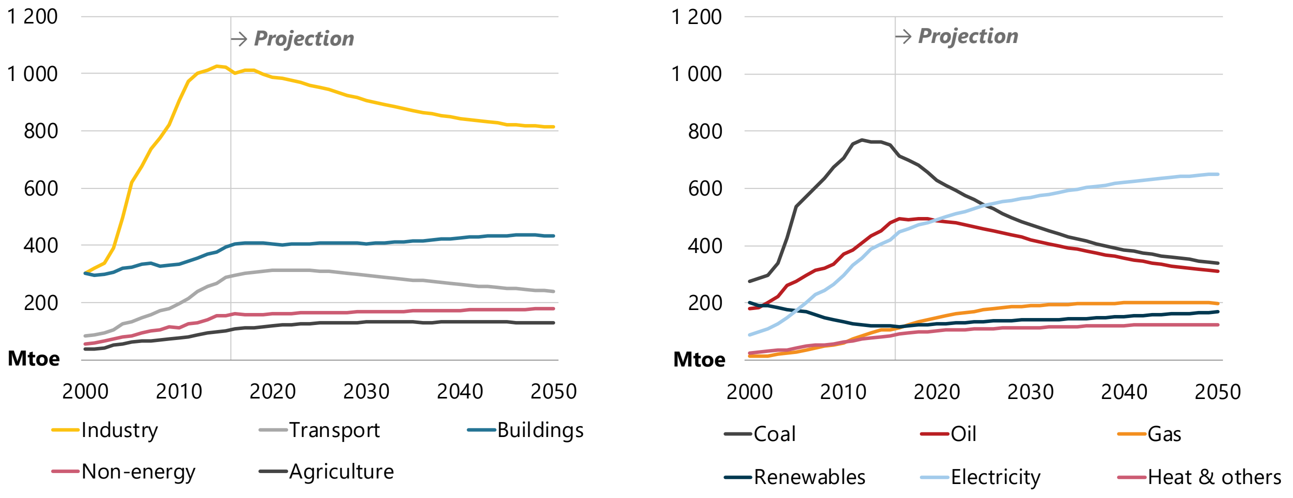
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in China will have to undergo significant decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective. The 2DC provides an effective pathway for China to decarbonise its energy sector, reduce GHG emissions and make a significant contribution to the COP21 Paris Agreement. In effect, this scenario goes beyond the goals of the TGT, requiring greater efficiency improvement, deeper emissions reduction in each sector and substantial behavioural change.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

In the 2DC, FED in China reaches a peak of 1 998 Mtoe in 2018, then gradually decreases to 1 795 Mtoe in 2050, for an overall decline of 9.3% throughout the Outlook period (-0.29% CAGR). The fastest rates of reduction come from industry (-0.62% CAGR) and transport (-0.61% CAGR), which outweigh growth in agriculture and other (0.48% CAGR), non-energy use (0.29% CAGR) and buildings (0.19% CAGR) (Figure 5.9). As electrification accelerates in industry, transport and buildings, electricity demand overtakes coal to dominate FED after 2026 (with a share of 36% in 2050). Over the Outlook period, both coal and oil demand decrease at a CAGR of -2.3% and -1.4%, while gas and renewable demand grow at a CAGR of 1.7% and 1.1%. In 2050, FED in the 2DC is 23% below the BAU and 13% below the TGT.

Figure 5.9 • China: Final energy demand in the 2DC by sector and fuel, 2000-50



Source: APERC analysis and IEA (2018a).

Energy demand in buildings increases slightly (6.6%) to 434 Mtoe over the Outlook period, much less than the TGT (36%) and the BAU (53%). In 2050, energy demand in buildings is 190 Mtoe lower than that of the BAU, and 118 Mtoe lower than that of the TGT. The low growth of buildings energy demand in the 2DC is mainly due to more rapid fuel switching from fossil fuel to electricity (the share of fossil fuel decreases from 41% in 2016 to 14% in 2050 in the 2DC, compared to 25% in the BAU and 21% in the TGT), and the energy efficiency improvement in building envelopes and electric appliances.

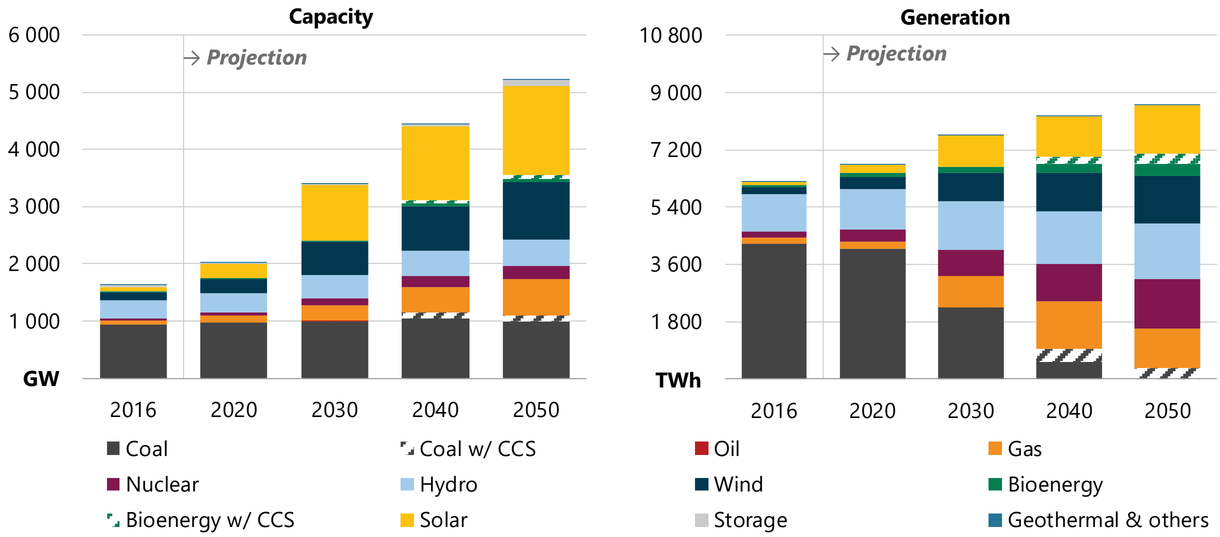
In contrast to the growth in the BAU and TGT, demand for domestic transport declines by 19% in the 2DC (from 297 Mtoe in 2016 to 241 Mtoe in 2050). This improvement occurs mainly due to passenger transport activity shifting from gasoline-powered private cars to a mix of electric cars and public transport, and freight transport activity shifting from road to rail. Over the Outlook period, the share of electricity demand in transport increases from 3.3% to 40% in the 2DC, compared to 12% in the BAU, and the share of oil demand decreases from 90% to 48% in the 2DC, compared to 72% in the BAU.

FED in industry decreases by 19% from 1 003 Mtoe in 2016 to 813 Mtoe in 2050 in the 2DC, slightly more than in the BAU (878 Mtoe in 2050) and TGT (818 Mtoe). Electricity demand in industry overtakes coal by 2045 with the share of 33%, followed by coal (30%), gas (16%). The reduction in industry energy demand is mainly due to China cutting overcapacity in the iron and steel and non-metallic minerals subsectors and further deployment of best available technologies across heavy industry (such as greater use of more efficient electric arc furnaces in iron and steel). To mitigate CO_2 emissions, CCS technology is implemented in some high-energy-intensity industries, especially iron and steel, that use coal.

TRANSFORMATION AND SUPPLY IN THE 2DC

Decarbonising the power sector is key to China achieving the CO_2 emissions reduction goal set out in the 2DC. Two main actions are essential to this: implementing CCS and decreasing the share of fossil fuel in the generation mix. The capacity of coal-fired plants equipped with CCS reaches 97 GW (70% of APEC total) in 2050 and 72 GW (66% of APEC total) for bioenergy-based plants with CCS (Figure 5.10). While CCS is effective for moderating CO_2 emissions in China's power sector, APERC assumes the technology is used only after 2030 due to the large capital costs, competition from renewable energy and issues around technological maturity.

Figure 5.10 • China: Power capacity and electricity generation in the 2DC by fuel, 2016-50

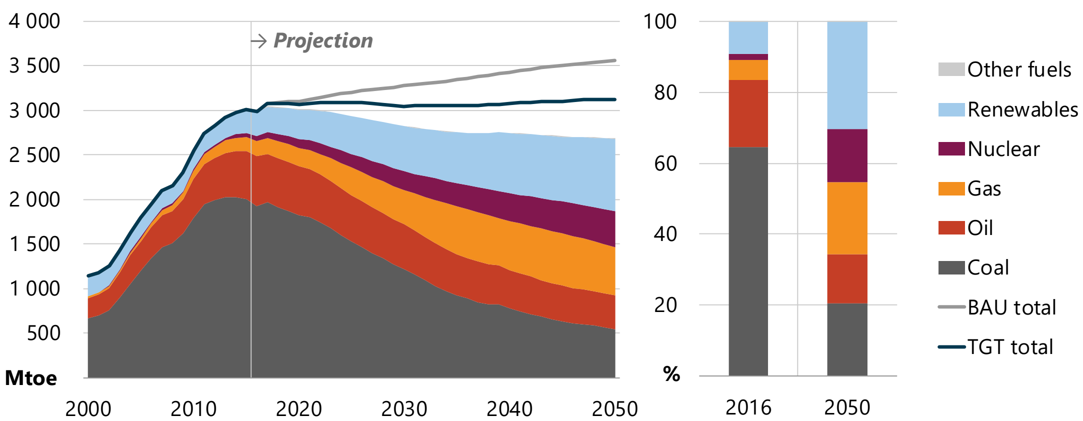


Note: CCS= carbon capture and storage.
Source: APERC analysis and IEA (2018a).

China's power generation mix changes greatly in the 2DC, resulting in CO_2 emissions for the sector approaching 349 Mt by 2050, which is only 8.7% of that in the BAU (4 028 Mt). Accelerating deployment of renewables and nuclear, coupled with the early retirement of inefficient coal-fired plants, prompts fossil fuel-based generation to decline to 1 594 TWh by 2050 (18% of total) compared with 4 923 TWh under the BAU (50% of total). By 2050, nuclear power generation (with low CO_2 emissions) contributes 1 544 TWh (18%) to the power mix, while renewables contribute 5 474 TWh (63%)—including 1 737 TWh from conventional hydro (20%), 1 526 TWh from solar (18%) and 1 520 TWh from wind (18%).

In contrast to the BAU and TGT, TPES in the 2DC peaks in 2018 and declines through the remainder of the Outlook period. The fuel mix in TPES mostly reflects the changes in the power sector with the share of coal declining from 65% in 2016 to 20% in 2050, while that of renewables increases from 8.9% to 30%, nuclear increases from 1.9% to 15%, and gas increases from 5.7% to 20%, throughout the Outlook period (Figure 5.11). Oil declines moderately, from 19% in 2016 to 14% in 2050, due mainly to reduced demand from the transport sector.

Figure 5.11 • China: Total primary energy supply in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

The 13th FYP for Oil Development identifies security of crude oil supply as a major challenge over the 2016-20 period. In 2016, China's imports of crude oil reached 381 Mtoe, a 14% year-on-year increase which pushed China's rate of dependence on foreign crude oil to 65% (CNPC, 2017b). Under the 2DC, China's oil demand falls from 495 Mtoe in 2016 to 310 Mtoe in 2050. When compared with the peak of 599 Mtoe in 2041 under the BAU and 512 Mtoe in 2022 under the TGT, the 2DC provides a possible pathway for China to achieve a higher level of energy security, earlier.

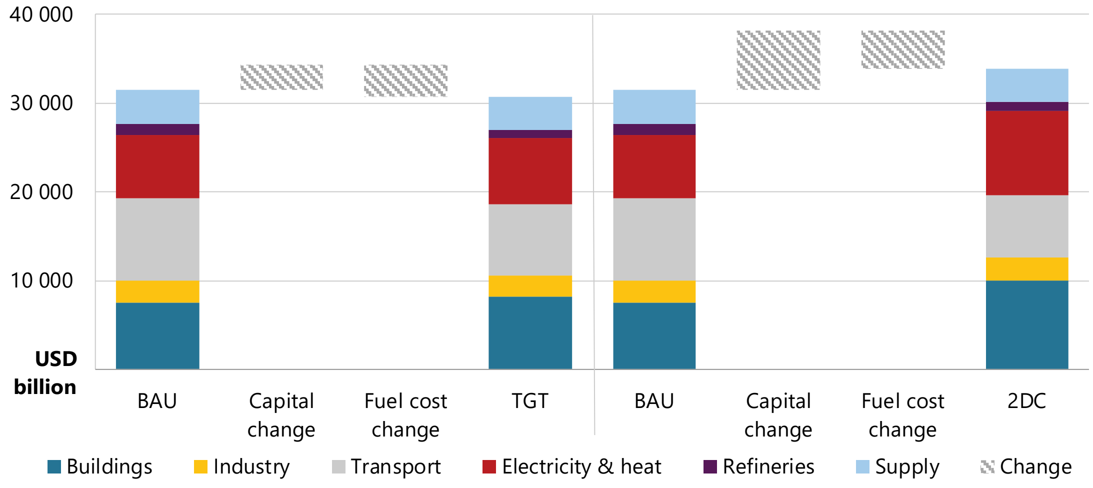
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[30]

Under the BAU Scenario, China's total energy-related investment through the Outlook period reaches almost USD 32 trillion in capital and fuel costs, accounting for 30% of total investment in the APEC region. Investment for transport garners the largest share (30%), followed by buildings (24%), electricity and heat (23%), and supply[31] (12%) (Figure 5.12). Strong demand for private vehicles and policy support for development of battery EVs leads to significant investment costs for the road subsector in transport. Increasing demand for electrical appliances leads to significant investment costs in buildings sector. Deploying modern renewable capacity carries the highest costs in electricity and heat.

Figure 5.12 • China: Energy sector capital and fuel costs, 2016-50



Source: APERC analysis and IEA (2018a).

[30] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.
[31] Supply investment refers to investment in upstream coal (open-pit and underground), upstream oil and gas production (onshore and offshore), LNG terminals, energy transport (oil and gas pipelines, oil and coal trains, and coal ports), and uranium production.

Cumulative investments under the TGT reach USD 31 trillion, some USD 0.87 trillion less than under the BAU, as more efficient vehicles deliver nearly USD 2.0 trillion in fuel savings. The share of buildings increases to 27%, as implementation of stricter energy efficiency requirements leads to incremental cost increases of USD 2.2 trillion. In China's case, where existing floor areas are huge, renovating and updating existing buildings is the major cost.

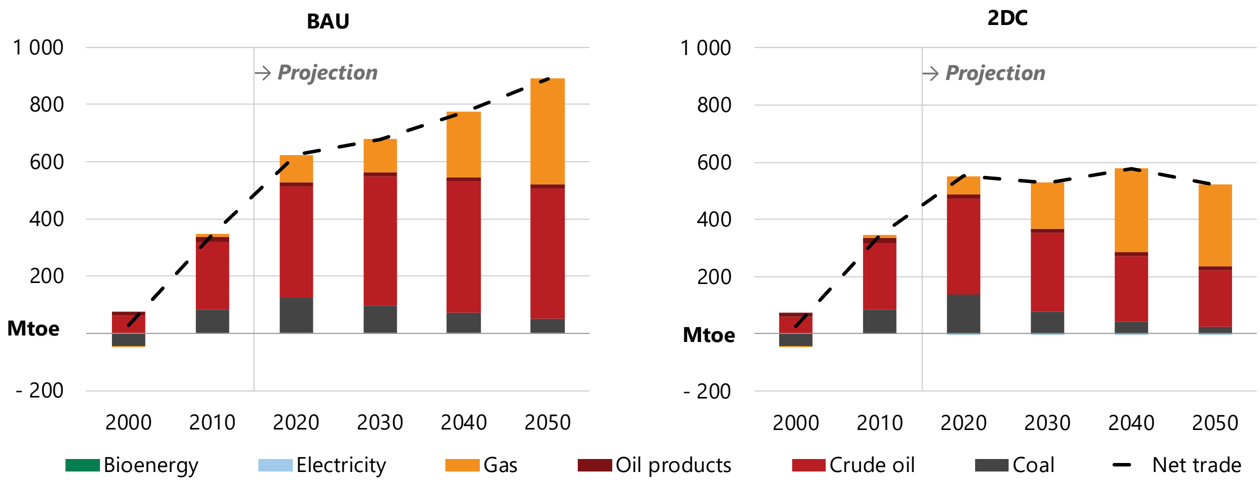
At USD 34 trillion, investment in the 2DC is USD 2.3 trillion more than the BAU: fuel savings worth USD 4.3 trillion don't totally offset USD 6.6 trillion of extra capital investment. The main changes come from buildings (projected to further increase to account for 30% of total investment) and electricity and heat (28%). Higher efficiency standards, greater smart-meter installation and thermal performance, and distributed renewable power generation increase the costs in buildings. In the electricity and heat sector, deployment of CCS in coal-fired plants and expansion of bioenergy increase costs by USD 798 billion between the BAU and 2DC. Lifestyle behaviour changes, such as more travel by public transport and ride-sharing, as well as fewer vehicle purchases, are also assumed, which further decrease fuel consumption in transport.

ENERGY TRADE AND SECURITY

Enhancing energy security is one of major targets and strategies in the 13th FYP for energy development—and is likely to garner more attention in subsequent FYPs. The economy's major energy security challenge is that domestic energy production is inadequate to meet fast-growing demand, especially for crude oil and natural gas. To reduce dependence on imported fossil fuels, the government intends to increase the shares of renewable and nuclear power.

Promoting a diversity of supply sources is a key component of China's energy security policy. In 2016, China imported oil and gas from the Middle East, Russia, Central Asia, Africa, Australia and Latin America through pipelines or marine routes. With the international gas price decreasing and the greater flexibility of LNG, China increased its LNG imports significantly between 2010 and 2017, ultimately surpassing Korea in 2017 to become the world's second-largest LNG importer (EIA, 2018) (Figure 5.13). China is also working hard to increase domestic energy production by exploring and utilising domestic unconventional fossil fuels, such as coalbed methane, shale gas and combustible hydrates.

Figure 5.13 • China: Net energy imports and exports in the BAU and 2DC, 2000-50



Source: APERC analysis and IEA (2018a).

By 2050, China's fossil fuel imports are projected to increase in the BAU (942 Mtoe) and the TGT (694 Mtoe), but decrease marginally in the 2DC (566 Mtoe). The 2DC projections offer potential pathways for China to reduce import dependency; as consumption of fossil fuels in the power and transport sectors decline significantly, less imports of thermal coal, crude oil and gas are necessary. This results in a higher primary energy supply self-sufficiency and lower reserve gaps in the 2DC compared with the BAU and TGT Scenarios (Table 5.4).

Table 5.4 • China: Energy security indicators under the BAU, TGT and 2DC

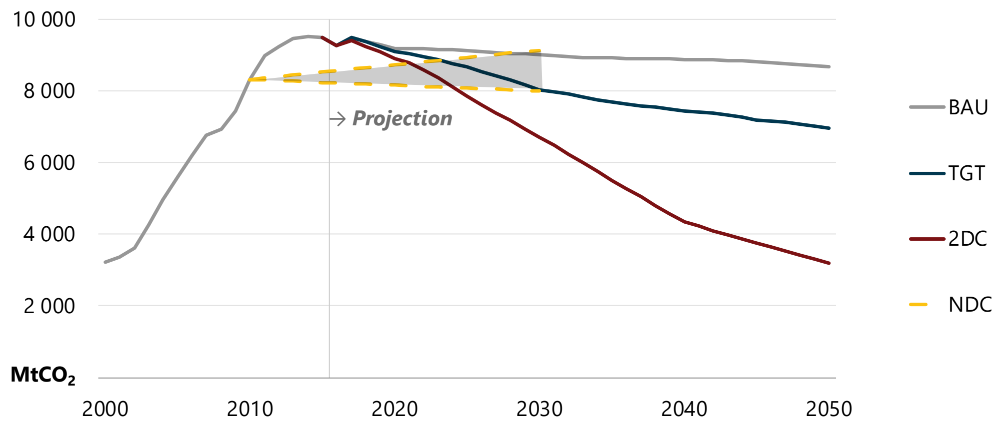
	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	80	78	80	79	74	78	79
Coal self-sufficiency (%)	89	94	93	93	96	96	96
Gas self-sufficiency (%)	68	66	67	58	40	44	47
Crude oil self-sufficiency (%)	36	30	36	41	30	42	43
Primary energy supply diversity (HHI)	0.49	0.32	0.31	0.26	0.24	0.23	0.17
Coal reserve gap (%)	2.3	32	31	29	69	63	48
Gas reserve gap (%)	4.7	104	104	104	313	313	313
Crude oil reserve gap (%)	6.4	86	86	86	204	204	190

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

On 22 April 2016, China signed the COP21 Paris Agreement, which calls for collective international effort to keep the global temperature rise to well below 2°C above pre-industrial levels, and to pursue efforts to limit the increase to 1.5°C. To fulfil its national determined commitment, China has to: achieve peak carbon emissions by 2030 at the latest; lower CO_2 emissions per unit of GDP by 60% to 65% from the 2005 level; increase the share of non-fossil fuels in primary energy consumption to around 20%; and increase the forest stock volume by around 4.5 billion cubic metres on the 2005 level.

Figure 5.14 • China: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the Intergovernmental Panel on Climate Change (IPCC). Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions, and land use, land-use change and forestry (LULUCF) are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018a).

Energy sector CO_2 emissions decrease gently under the BAU scenario, from 9 255 MtCO_2 in 2016 to 8 668 MtCO_2 in 2050 (Figure 5.14). The TGT emissions curve shows a faster-declining trend during the Outlook period, reaching 6 945 MtCO_2 by 2050, some 1 723 MtCO_2 less than in the BAU. Not surprisingly, the 2DC delivers even more impressive results, reaching 3 186 MtCO_2 in 2050, with a cumulative reduction of nearly 100 billion tonnes of CO_2 compared with the BAU. This reflects several assumptions, including more ambitious nuclear deployment and higher energy efficiency across buildings, transport and industry. The largest CO_2 reduction comes from power generation, where nuclear and renewable capacity are deployed more quickly to replace coal-fired capacity under the 2DC. Additionally, in the 2DC, CCS technology is implemented in power generation, industry and refineries after 2030. By 2050, 97 GW of coal-based capacity and 72 GW of bioenergy-based capacity are assumed to have implemented CCS.

OPPORTUNITIES FOR POLICY ACTION

China is moving in the right direction to meet its Nationally Determined Contribution (NDC) to the COP21 Paris Agreement. Further action, however, will be needed to reach peak CO_2 emissions before 2030 and thereby fulfil China's role in the global effort to constrain average global temperature rises to less than 2°C.

Considerable room remains for China to strengthen efforts on energy efficiency improvements. The earlier the transition from energy-intensive industries to high-tech, high-value-added and less intensive activities, the greater the reduction, and the earlier the fulfilment of emission targets. China needs to vigorously promote industrial restructuring and accelerate the reduction of overcapacity in the iron and steel, and non-metallic minerals subsectors. Stricter green building standards are also needed to improve energy efficiency in the buildings sector, while additional policies and measures are also needed to promote public transportation, improve fuel efficiency and accelerate the shift away from fossil fuel to electrified transportation.

China's power sector has enormous potential to reduce CO_2 emissions and make a globally significant contribution towards achieving the goals of the COP21 Paris Agreement. Early retirement of coal-fired power capacity and faster deployment of renewable and nuclear capacity could significantly reduce both fossil fuel consumption and CO_2 emissions, diversify the energy mix, and improve energy security. As coal-fired generation still accounts for a large part of total generation under all three scenarios, policies that encourage existing coal-fired plants to retrofit with CCS are important to the goal of achieving peak CO_2 emissions before 2030 while still allowing China to maintain its energy self-sufficiency rate above 80%. Therefore, additional support for CCS research, development and deployment will also be important. The carbon ETS will likely be the best tool for reducing China's CO_2 emissions, so ensuring careful market design and introduction to other energy sectors is of paramount importance.

Ensuring the integration of new and renewable energy into the power grid is essential to China's energy transition. Policies and measures are needed to improve the flexibility of coal-fired power plants and the development of energy storage technologies. Enhancing the interconnection of power grids, strengthening demand-side management and accelerating electricity market reforms are all needed to improve the integration capacity of the power grids. Continued support to reduce the manufacturing and technology costs of wind and solar power could also stimulate an earlier switch away from coal.

6. HONG KONG, CHINA

KEY FINDINGS

- **The buildings sector accounts for more than half of FED over the Outlook period.** Despite population and GDP growth, demand increases at a moderate 2.4% per year in the BAU Scenario, largely owing to effective energy-saving measures.

- **The economy continues to be a regional shipping and aviation hub.** Energy demand for international aviation and marine transport was almost six times that for domestic transport in 2016 and is projected to be more than eight times by 2050.

- **Reliance on primary energy product imports continues under all scenarios.** However, energy security improves with efforts to replace coal with natural gas, construction of an offshore LNG terminal, and greater deployment of renewables.

- **Energy-related CO_2 emission intensity falls by 67% in the BAU, 73% in the TGT and 89% in the 2DC throughout the Outlook period,** mainly by switching from coal to gas in power generation and by developing renewable energy.

- **Greater deployment of renewable energy—such as offshore wind farms, solar power, waste-to-energy and more electricity imports from mainland China** play an important role in reducing CO_2 emissions and improving energy security.

ECONOMY AND ENERGY OVERVIEW

Hong Kong, China is a global centre of finance, trading and business and is located at the south-eastern tip of China. It has a population of 7.3 million people, and is a special administrative region of the People's Republic of China. In 2016, its per-capita gross domestic product (GDP) was USD 58 325 (2016 USD at purchasing power parity), among the highest in the Asia-Pacific Economic Cooperation (APEC) region.

With an area of 1 106 square kilometres (km^2), of which 40% is designated as Country Parks, the economy's high population density averages 6 780 people per km^2—and the most densely populated district registered more than 57 000 people per km^2 in 2016 (CSD, 2018). Hong Kong, China also has the world's greatest number of buildings above 150 metres high (CTBUH, 2017). These buildings house residences as well as commercial activities, and claim the largest share of the economy's final energy demand (FED).

Table 6.1 · Hong Kong, China: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	242	361	426	481	605	746	913
Population (million)	6.7	7.0	7.3	7.5	8.0	8.2	8.3
GDP per capita (2016 USD PPP)	36 306	51 324	58 325	63 667	75 724	90 994	110 664
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	14	13	13	13	13	12	12
TPES per capita (toe)	2.0	1.8	1.8	1.7	1.6	1.5	1.5
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	56	35	32	27	21	16	13
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	9.4	7.3	7.9	8.0	8.3	8.4	8.6
FED per capita (toe)	1.4	1.0	1.1	1.1	1.0	1.0	1.0
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	39	20	19	17	14	11	9.5
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	39	39	41	39	32	28	29
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

Hong Kong, China has no fossil-fuel energy resources of its own. To sustain economic development, primary energy commodities such as coal, oil and gas as well as electricity are imported to meet transformation needs and for direct use in the residential, services, industry and transport sectors. All energy products except a small portion of renewables are imported.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Government energy policies aim to ensure that energy needs are met safely, efficiently and at a reasonable cost, and that the environmental impacts of energy production are minimised. They also promote the efficient use and conservation of energy to curb growing energy use (ENB, 2018). To further improve air quality, the government has pledged to phase down coal and replace it with natural gas (to account for 50% of the generation mix by 2020) for electricity generation; maintain the current interim measure of importing power from Guangdong Daya Bay Nuclear Power Station so that nuclear imports account for roughly 25% of the total electricity mix; and continue to improve energy efficiency for new and existing buildings and public infrastructure. The government also monitors the financial performance of utility companies as well as the retail prices of automotive fuel and domestic liquefied petroleum gas.

The government's two overarching policy targets are to: a) reduce energy intensity 40% from the 2005 level by 2025 (ENB, 2015) and b) reduce carbon dioxide (CO_2) emissions intensity 65% to 70% from the 2005 level by 2030. (ENB, 2017). In connection with these targets, the government has published two policy documents: *Hong Kong's Climate Action Plan 2030+* and *Energy Saving Plan for Hong Kong's Built Environment 2015~2025+*. These publications provide strategies and measures to achieve the targets by adopting cleaner fuels, promoting energy savings, implementing green commuting and reducing waste.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Hong Kong, China under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 6.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 6.2 · Hong Kong, China: Key assumptions and policy drivers under the BAU

Buildings	Efficiency improves through stricter building energy codes. FED is reduced by extending coverage and improving efficiency standards in appliance energy labelling schemes.
Domestic transport	Public transport, including the train system, develops further. EV development is supported.
Energy supply mix	Coal-based power generation falls, replaced by gas. Electricity imports from mainland China continue.
Power mix	No nuclear plants are installed. No new coal-fired plants are installed. New gas-fired plants replace retiring coal-fired ones.
Renewables	Exploration and promotion of solar, wind and waste-to-energy power continues. Feed-in tariffs and Renewable Energy Certificates are implemented to encourage private-sector investment in renewables.
Energy security	Primary energy imports continue. Electricity and natural gas imports from mainland China continue. New offshore LNG terminal is in operation from 2021.
Climate change	CO_2 emissions intensity falls 65% to 70% from 2005 levels by 2030.

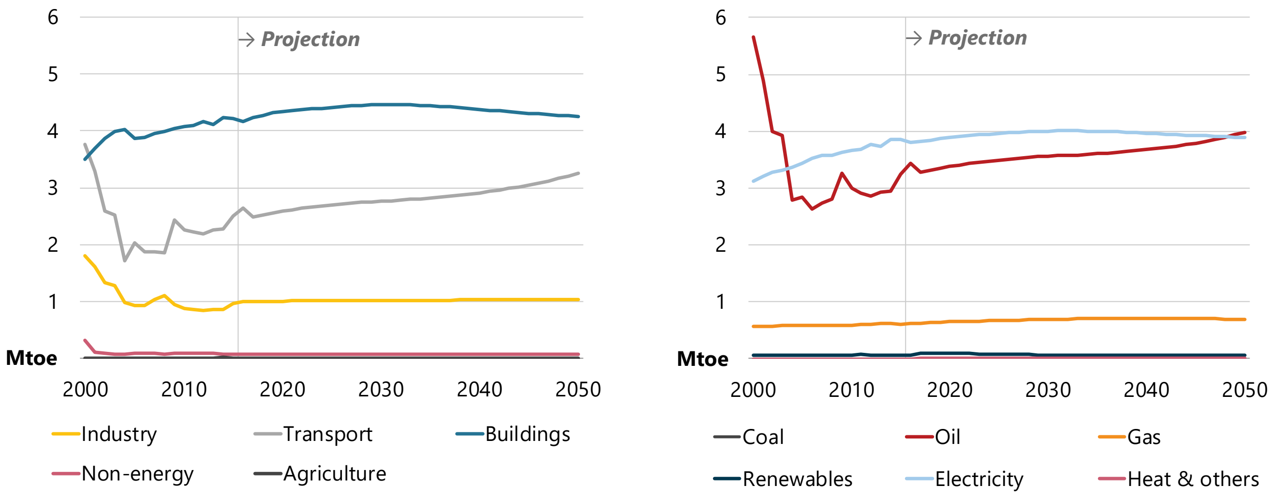
Notes: EV = electric vehicle. LNG = liquefied natural gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

FED in the BAU Scenario increases 9.2% over the Outlook period (2016-50), from 7.9 million tonnes of oil equivalent (Mtoe) in 2016 to 8.6 Mtoe in 2050, at a compound annual growth rate (CAGR) of 0.26% (Figure 6.1). Industry demand remains flat throughout the Outlook period, while that of transport keeps increasing at a CAGR of 0.61% and buildings stalls around 2030 and then declines.

Buildings are the largest energy-consuming sector in Hong Kong, China, accounting for nearly half of FED throughout the Outlook period, even though demand increases by only 0.08 Mtoe to 4.3 Mtoe in 2050. This increase is kept relatively small by stricter building energy codes and appliance labelling schemes. Domestic transport, which accounts for 33% of total demand in 2016 and 38% in 2050, increases from 2.6 Mtoe in 2016 to 3.3 Mtoe in 2050 due to growing transport activity. Better fuel efficiency in new vehicles and policy support for the development of electric vehicles (EVs) moderate this increase. Demand by fuel share is projected to remain relatively stable, with oil and electricity dominant. Oil meets around 46% of FED in 2050 (from 43% in 2016) and electricity meets 45% of FED in 2050 (from 48% in 2016).

Figure 6.1 · Hong Kong, China: Final energy demand by sector and fuel, 2000-50

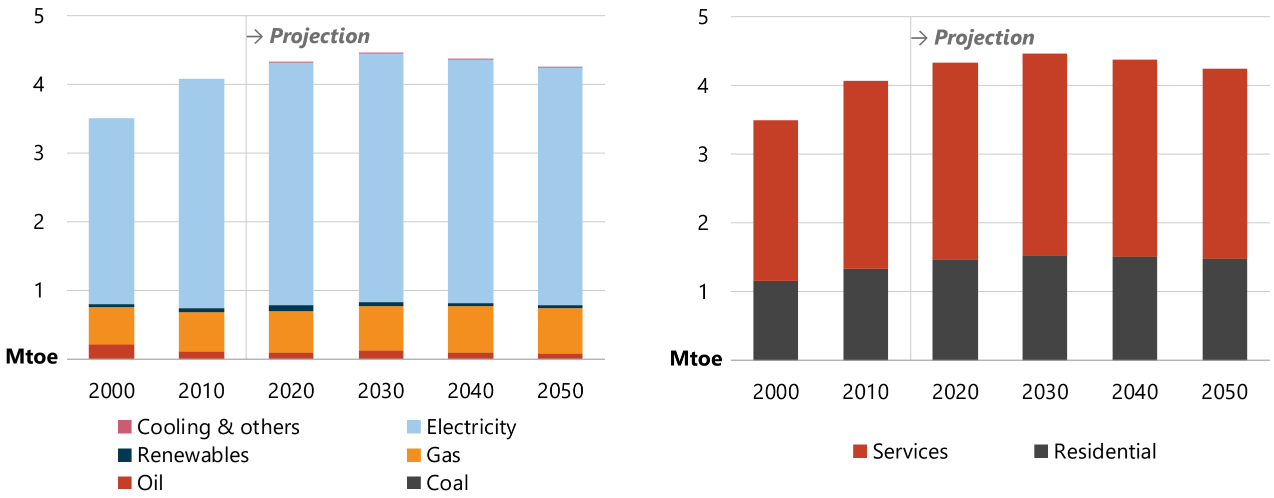


Sources: APERC analysis and IEA (2018a).

BUILDINGS: LARGEST ENERGY CONSUMPTION, BUT DECLINING INTENSITY

The residential and commercial buildings sector accounts for around half of FED throughout the Outlook period. The buildings sector has the highest share of FED among all APEC economies (the APEC average is 26% to 27%). Driven by population and GDP growth, buildings demand rises 1.9%, from 4.2 Mtoe in 2016 to 4.3 Mtoe in 2050 (Figure 6.2). Electricity remains the main fuel for buildings, supplying 83% of energy consumed in 2016 and slightly less (81%) in 2050. Electricity consumed by buildings accounted for 91% of the economy's total electricity demand in 2016; which decreases to 89% in 2050. Gas is the second-most-consumed fuel in buildings, though its share is considerably smaller at 14% in 2016 and 16% in 2050.

Figure 6.2 · Hong Kong, China: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

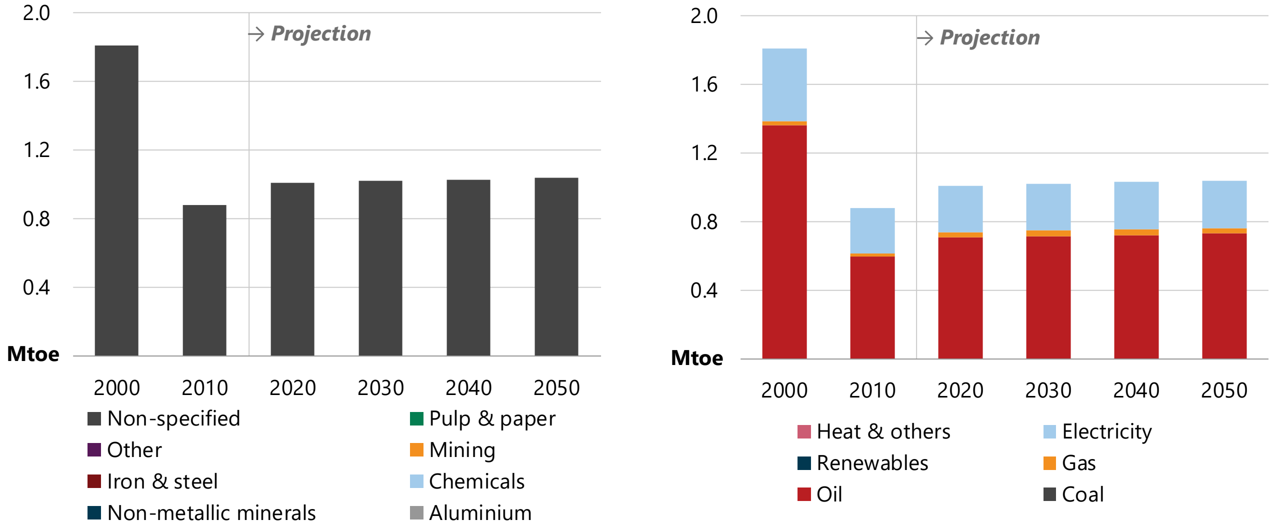
With around 90% of the economy's GDP derived from the services sector, energy demand in service buildings is high at two-thirds of total sectoral demand, whereas the APEC average is only one-third. The floor area of service buildings expands 19% over the Outlook period—from 69 million square metres (m^2) in 2016 to 82 million m^2 by 2050—while energy demand increases only moderately—from 2.75 Mtoe in 2016 to 2.78 Mtoe in 2050. Consequently, energy intensity declines 15%, from 464 kilowatt-hours per square metre (kWh per m^2) in 2016 to 394 kWh per m^2 in 2050.

The government continues to implement measures to enhance energy efficiency in buildings. In addition to promoting more efficient water-cooled air-conditioning systems and implementing a Voluntary Energy Efficiency Labelling Scheme (VEELS), the scope of the Mandatory Energy Efficiency Labelling Scheme (MEELS) was expanded in 2018 to cover more types of electrical appliances. The government is also reviewing the Building Energy Codes (BECs) issued under the Buildings Energy Efficiency Ordinance to enhance the energy performance standards for installations such as air conditioning, lighting, other electrical appliances and escalators.

INDUSTRY: ENERGY CONSUMPTION REMAINS LOW

Through economic restructuring in recent decades, most labour-intensive operations have been moved to mainland China or other overseas destinations. The economy has no heavy industries, and local industrial activities are generally high value-added or knowledge-intensive, with low energy demand. Consequently, industry energy demand remains largely unchanged around 1.0 Mtoe (a 12%~13% share of FED) through the Outlook period and is smaller than buildings and transport (Figure 6.3). Oil remains the major fuel used in this sector, meeting 70% of total energy demand throughout the Outlook period, followed by electricity (27%) and gas (3.2%).

Figure 6.3 · Hong Kong, China: Industry final energy demand by subsector and fuel, 2000-50

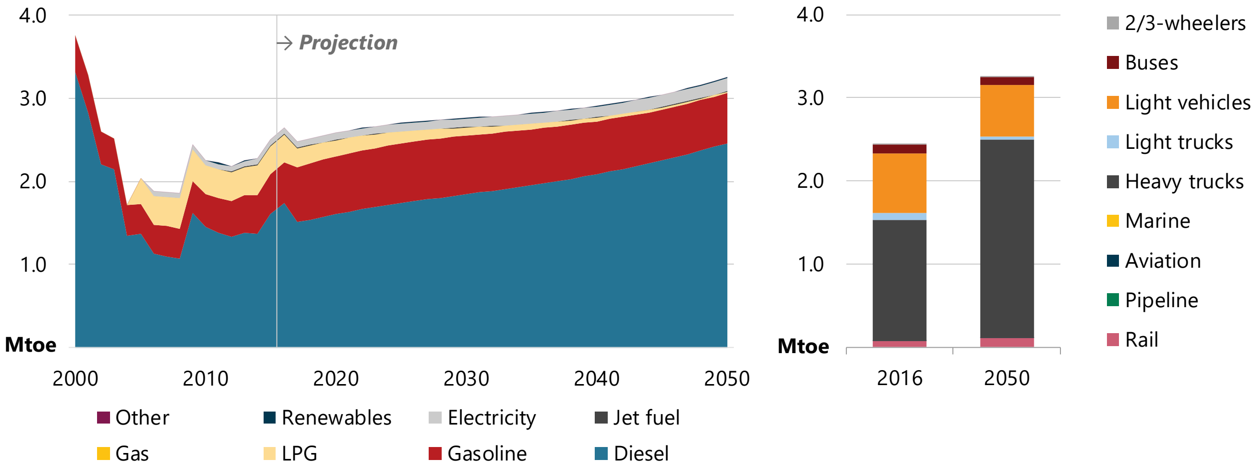


Sources: APERC analysis and IEA (2018a).

TRANSPORT: DEMAND INCREASES GRADUALLY

After the buildings sector, domestic transport is the second-largest energy consumer, with a 33% share of FED in 2016 and 38% in 2050. Domestic transport demand increases from 2.6 Mtoe in 2016 to 3.3 Mtoe in 2050 (Figure 6.4). Freight transport accounts for 74% of domestic transport energy demand, and passenger transport accounts for 26% in 2050, these mainly due to transport activity expansion. During the Outlook period, freight transport activity more than doubles, expanding from 236 million tonne kilometres (tkm) to 578 billion tkm. Passenger transport activity also expands from 45 billion passenger kilometres (pkm) to 66 billion pkm. Fossil fuels, mainly diesel and gasoline, remain the major fuel types, supplying over 95% of total demand throughout the Outlook period. The share of electricity demand increases from 2.7% to 4.7%, partly due to the sharp increase in advanced light duty vehicles (LDV) stock.

Figure 6.4 · Hong Kong, China: Domestic transport FED by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

To curb transport energy demand, the government is promoting EVs by continuing to waive the first registration tax. It is also launching a 'one-for-one' replacement scheme that allows eligible private car owners who buy a new electric car and scrap an eligible private car they own to benefit from first-registration tax concession. The government is also enhancing the development of charging networks for EVs (Hong Kong Government, 2018).

The public transport system, comprising the Mass Transit Railway (MTR), buses and ferries, had a total average patronage of over 12 million per day in 2016. The MTR is the backbone of the system, with the largest share of passenger journeys in 2016 (41%, up from 35% in 2007), while that of franchised buses fell from 34% to 31% in the same period (TD, 2017). MTR network expansion is ongoing: two major projects were completed in 2016 and three others are under construction. The network is set to expand by 25% when all projects are completed in 2021 (MTR, 2016), making the MTR an important element in curbing domestic transport energy consumption growth.

As a regional shipping and aviation hub, the economy's international aviation and marine demand far exceeds domestic FED. In 2016, 15 Mtoe of fuel was consumed for international transport, six times that for domestic transport. As globalisation of economic activities continues to raise air and marine freight volumes, international aviation energy demand rises from 6.5 Mtoe in 2016 to 11 Mtoe by 2050, and that of marine jumps from 8.9 Mtoe to 17 Mtoe.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

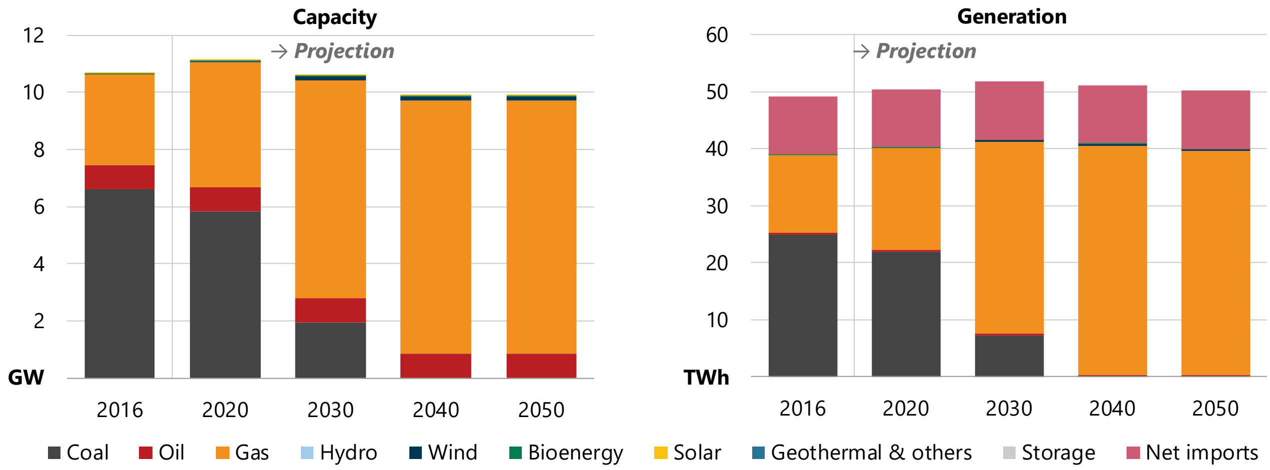
Hong Kong, China has no refineries so the transformation sector is dominated by power generation, which remains flat over the Outlook. Almost all primary energy is imported (apart from a small amount of renewable generation) and a significant amount of secondary energy (mainly oil products and electricity) is also imported. The majority of total primary energy supply (TPES) comes from fossil fuels, which remain relatively flat to 2050.

POWER SECTOR: COAL REPLACED BY GAS

Total electricity generation capacity in 2016 was 11 gigawatts (GW), generating 39 terawatt-hours (TWh) of electricity (Figure 6.5). Almost all locally generated electricity is thermal-powered and produced by CLP Power Hong Kong Limited (CLP) and the Hong Kong Electric Company Ltd. (HKE); there are also some small wind turbines and solar photovoltaic (PV) systems (HKE, 2015). Since 2009, CLP has purchased 80% of the electricity generated at the Guangdong Daya Bay Nuclear Power Station in mainland China, which satisfies around 25% of the economy's total electricity demand.

Electricity demand remains around 50 TWh throughout the Outlook period with 12 TWh continuing to be met by imports from China. The generation mix changes significantly, however, as the government plans to raise the share of natural gas in the electricity generation to 50% by 2020 to replace coal. In the BAU, coal-fired generation is phased out by 2035, and gas-fired expands from 35% in 2016 to 78% in 2050. CLP is currently constructing a 550 megawatt (MW) gas-fired generation unit at its Black Point Power Station, to be commissioned before 2020 (CLP, 2017a). HKE is building two 380 MW gas-fired units at Lamma Power Station, scheduled for commissioning in 2020 and 2022 (HKE, 2018). A small amount of backup oil capacity (0.85 GW) remains through the Outlook but supplies only a negligible amount of electricity.

Figure 6.5 · Hong Kong, China: Power capacity and electricity generation by fuel, 2016-50

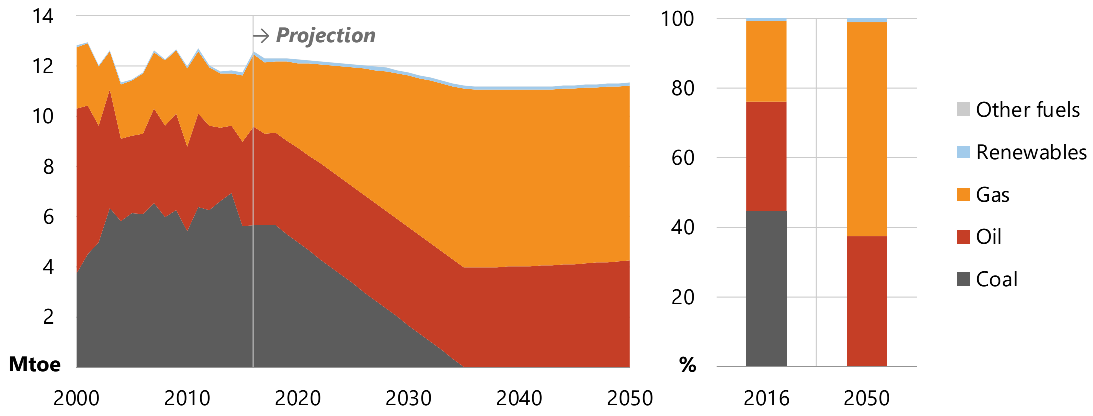


Sources: APERC analysis and IEA (2018a).

TOTAL PRIMARY ENERGY SUPPLY: GAS CONTINUES TO INCREASE SHARE

TPES decreases by 9.5% over the Outlook period, from 13 Mtoe in 2016 to 12 Mtoe by 2050 (Figure 6.6). The fuel mix changes dramatically under the BAU, with coal losing dominance: its share plummets from 42% in 2016 to 0% by 2035, whereas the share of gas expands from 22% in 2016 to 57% by 2050. The switch from coal to gas occurs as new gas-fired plants replace retiring coal-fired ones. Oil increases slightly, from 3.8 Mtoe in 2016 to 4.3 Mtoe in 2050. Renewables make up only a small portion of primary supply, with 0.79%~1.1% share (between 0.11 Mtoe and 0.14 Mtoe) throughout the Outlook period.

Figure 6.6 · Hong Kong, China: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: ALL PRIMARY ENERGY IMPORTED

Domestic fossil fuel resources are unavailable in Hong Kong, China. Aside from a small portion of renewables, it imports all its energy supplies from a handful of neighbouring economies. Refined oil products come mainly from Singapore, coal products from Indonesia, and all natural gas is imported from mainland China. The economy also imports electricity through a joint venture and supply contract with China Southern Power Grid, which operates the Guangdong Daya Bay Nuclear Power Station in the Guangdong province of China.

The economy's net energy imports therefore expand from 30 Mtoe in 2016 to 40 Mtoe by 2050. Most of the increase is in oil (20 Mtoe to 32 Mtoe) to meet greater international aviation and marine transport demand. The substitution of natural gas for coal in the power sector sees coal imports disappear by 2035 (from 6.9 Mtoe in 2016), and gas imports increase from 2.7 Mtoe to 7.0 Mtoe over the Outlook period.

Box 6.1 • Hong Kong, China: Recent developments in renewables

Despite constraints to renewable development, particularly a lack of land, the government has devised schemes to develop renewable energy potential. Government investments to promote the installation of renewable energy facilities on its premises rose from 200 million Hong Kong Dollars (HKD) in 2017 (USD 26 million) to HKD 800 million (USD 103 million) in 2018 (Hong Kong Government, 2018). The government also supports offshore wind farm development, and HKE plans to install offshore wind turbines with a total generating capacity of 100 MW to produce 175 gigawatt-hours of electricity per year (equivalent to the annual demand of 50 000 four-person households; HKE, 2015). In addition, CLP is studying the feasibility of developing a 200 MW offshore wind farm in the south-eastern waters of Hong Kong, China (CLP, 2018).

In 2017, the government commissioned two pilot floating PV systems in reservoirs, each capable of delivering 120 megawatt-hours of electricity per year. It is also exploring the feasibility of installing large-scale floating solar farms on the surfaces of impounding reservoirs (WSD, 2017). To promote renewables in the community, in 2018 the government introduced a feed-in tariff under the post-2018 Scheme of Control Agreement with CLP and HKE (Hong Kong Government, 2018).

A sludge treatment plant, which began operating in April 2015 and can incinerate 2 000 tonnes of sludge per day, generates enough electricity to sustain its own operations plus 2.0 MW surplus (equivalent to the annual demand of 4 000 households) (T-Park, 2018). In addition, an Organic Resources Recovery Centre (ORRC) was commissioned in 2018 to treat 200 tonnes of organic waste per day. The Centre also generates 14 million kilowatt-hours of electricity from biogas (equivalent to the annual demand of 3 000 households), and the government is planning new phases of the ORRC to treat 1 300 tonnes to 1 500 tonnes of organic waste per day (EPD, 2018).

Note: HKD are converted to USD at a rate of 7.76:1, which was the average exchange rate for 2016 (OFX, 2019).

ALTERNATIVE SCENARIOS

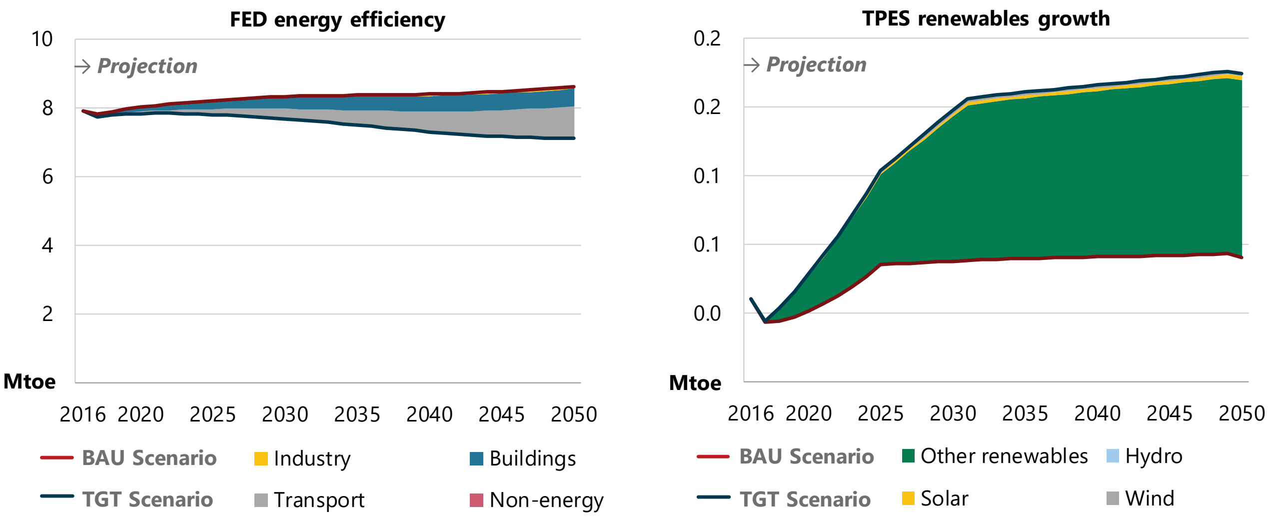
While the BAU Scenario is intended to be representative of current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increased renewables deployment, and reduced energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Under the TGT in Hong Kong, China, FED is 18% lower while CO_2 emissions are 19% lower, compared to the BAU. Under the 2DC, FED is 35% lower and CO_2 emissions are 63% lower. The share of renewables in TPES is 1.5% higher in the TGT and 24% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTESITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. FED in the TGT is 1.5 Mtoe lower in 2050 at 7.1 Mtoe—compared with 8.6 Mtoe under the BAU Scenario (Figure 6.7). Most of the reduction occurs in buildings (34% of the total) and transport (62%), which nevertheless remain the two largest-consuming sectors.

Over the TGT, buildings sector demand drops 0.51 Mtoe (equivalent to 12% of its demand in 2050 under the BAU) owing to stricter appliance efficiency and building code standards. Transport demand falls 0.94 Mtoe by 2050 (29% of demand under the BAU) with higher vehicle fuel efficiency standards and greater expansion of the highly efficient rail transport system. The industry sector demands only 0.071 Mtoe less energy in 2050 due to its small size and because no energy policy specifically addresses this sector.

Figure 6.7 · Hong Kong, China: Energy efficiency and renewables, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Renewables demand increases in the TGT, from 0.063 Mtoe in 2016 to 0.12 Mtoe in 2050 (compared with 0.058 Mtoe in 2050 in the BAU). This growth results mainly from the buildings and transport sectors and is underpinned by stronger government support. Renewables demand in buildings increases from 0.055 Mtoe in 2016 to 0.083 Mtoe in 2050 in the TGT, and in transport from 0.005 Mtoe to 0.036 Mtoe. Renewables demand in the electricity sector increases marginally (to 0.83 TWh in 2050, compared with 0.48 TWh in the BAU) as the deployment of wind, solar and biofuel energy expands.

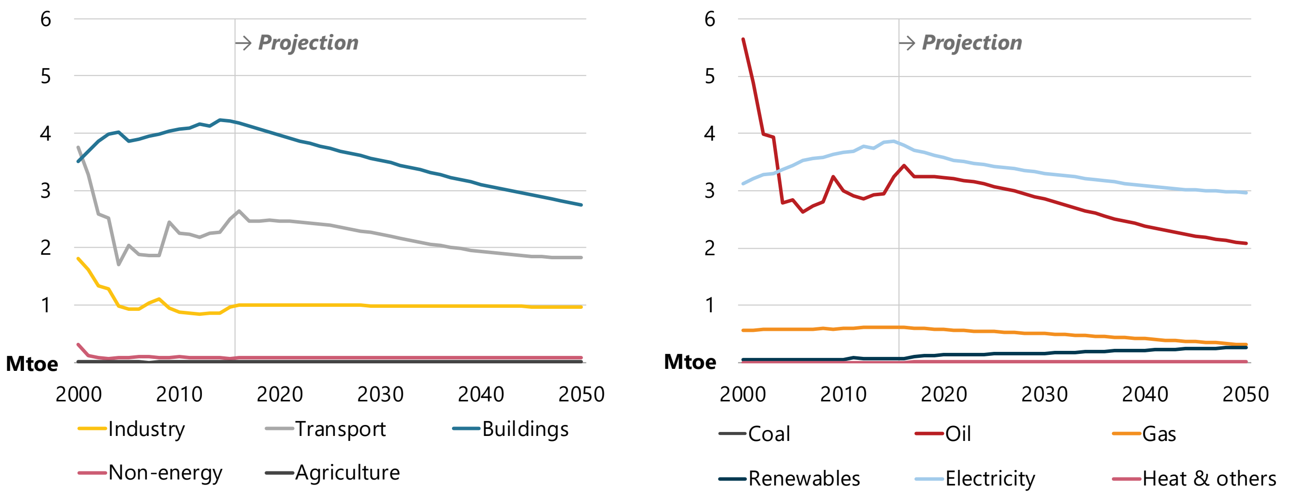
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors will have to undergo some degree of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

FED in 2050 in the 2DC is 1.5 Mtoe (or 21%) lower than the 7.1 Mtoe projected in the TGT. Compared with the TGT, the greatest reduction occurs in the buildings sector (0.99 Mtoe), followed by domestic transport (0.48 Mtoe). FED declines to 5.6 Mtoe in 2050 in the 2DC, 2.3 Mtoe lower than in 2016 (as opposed to a 0.73 Mtoe increase in the BAU), with oil and electricity use both moderating significantly (Figure 6.8).

Figure 6.8 · Hong Kong, China: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

With the introduction of stricter appliance efficiency and building code standards and more efficient use of service floor area under the 2DC, energy demand for buildings falls from 4.2 Mtoe in 2016 to 2.7 Mtoe by 2050—only 65% of the demand projected in the BAU and 1.0 Mtoe less than under the TGT. Greater renewables use under the 2DC results in its share in buildings FED growing to 8.0% over the Outlook period, compared with 1.1% in the BAU. This larger share of renewables displaces electricity somewhat, causing its share to decline slightly to 80% by 2050 (compared with 81% in the BAU and 83% in the TGT). As electricity remains the dominant fuel in all scenarios, the effect of fuel switching is not significant even though the share of oil in buildings energy demand declines from 1.9% in the BAU to 1.0% in the 2DC.

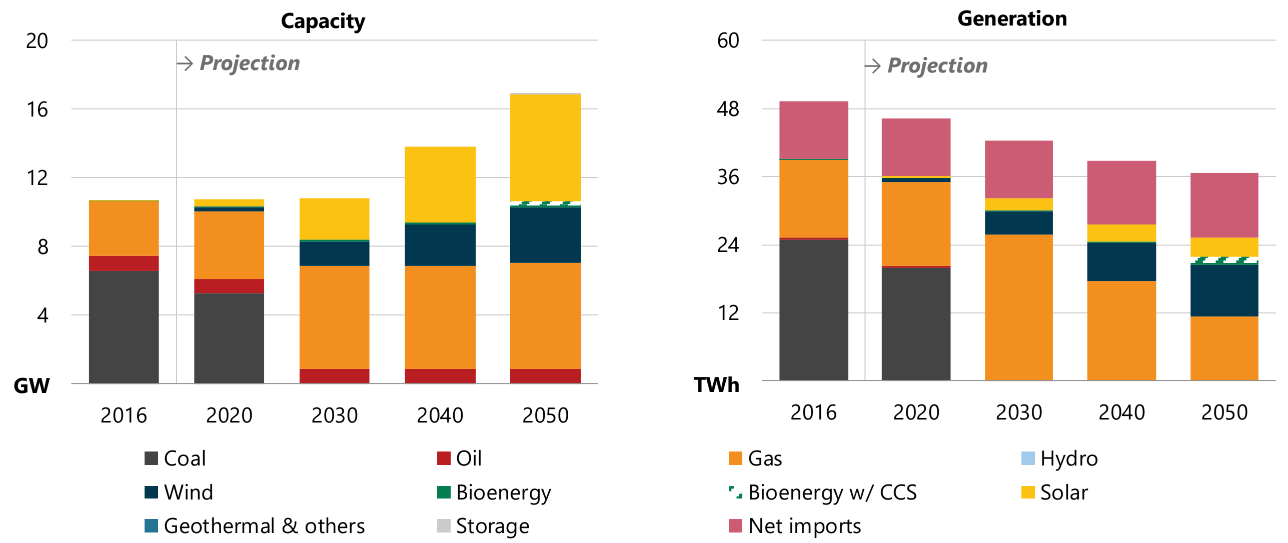
Domestic transport demand falls from 2.6 Mtoe in 2016 to 1.8 Mtoe by 2050 (56% of the BAU) under the 2DC owing to further vehicle fuel efficiency improvements and even greater expansion of the rail system. While oil remains dominant for domestic transport, a marked shift to cleaner fuels in the 2DC results in the share of fossil fuels falling to 71% (compared with 95% in the BAU and 86% in the TGT) as the use of electricity and renewables expands. Low shares of electricity (2.7%) and renewables (0.20%) in 2016 grow substantially in the 2DC, to 27% (electricity) and 2.5% (renewables) by 2050.

In the industry sector, demand is marginally lower in the 2DC than in the BAU owing to technological improvements to industrial machinery and processes. Demand under the 2DC decreases from 1.01 Mtoe in 2016 to 0.97 Mtoe by 2050, 93% of demand under the BAU. Fuel shares remain relatively stable under the 2DC throughout the Outlook period, with oil continuing to be the primary fuel (70% share).

TRANSFORMATION AND SUPPLY IN THE 2DC

With lower demand in the 2DC, electricity generation drops to 25 TWh in 2050, only 63% of the BAU level (and 70% of the TGT). The fuel mix is also significantly different under the 2DC by 2050, with renewables accounting for 55% of generation and gas 45% (Figure 6.9). In the medium term, coal-fired generation is completely phased out and replaced with gas by 2030. After 2030, renewable capacity expands rapidly so that renewables then begin to replace gas in the generation mix. Renewable capacity reaches 9.8 GW in 2050 (58% of total) from 0.030 GW (0.28%) in 2016.

Figure 6.9 · Hong Kong, China: Power and electricity in the 2DC by fuel, 2016-50

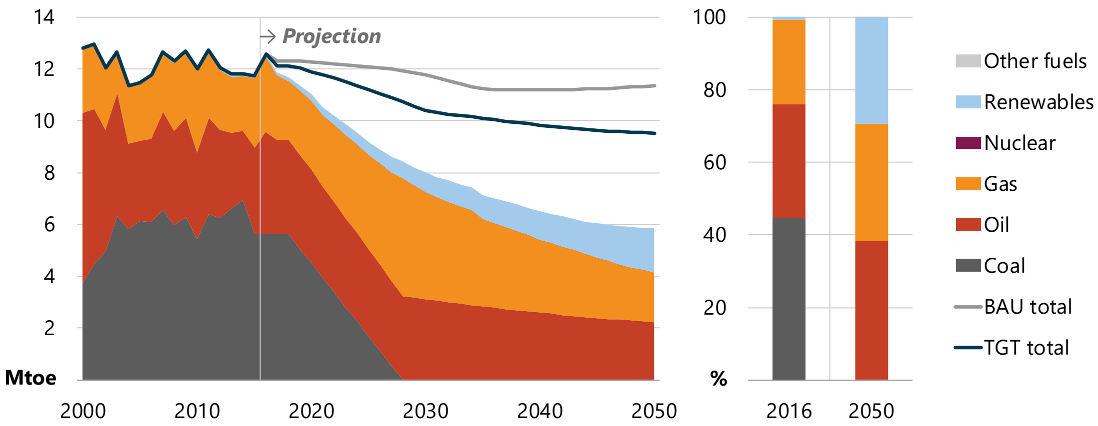


Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

With the widespread development of offshore wind farms in the 2DC, the amount of wind-generated electricity in 2050 (35% share) is about 25 times that projected in the BAU Scenario (0.90% share). Solar generation increases even more strongly, with significant floating capacity, to account for 14% of the fuel mix. To further reduce CO_2 emissions, bioenergy generation plants are designed to be equipped with carbon capture and storage (CCS) facilities under the 2DC. It is assumed that the captured CO_2 will be piped to gas and oil fields in mainland China to enhance production. The policy of importing electricity from mainland China also continues under the 2DC, with the import share increasing as total demand shrinks. By 2050, electricity imports account for 34% of total electricity supply, up from 25% in 2016.

In the 2DC, TPES declines from 13 Mtoe in 2016 to 7.0 Mtoe in 2050, only 57% of the BAU and 67% of the TGT by the end of the Outlook period (Figure 6.10). Coal, oil and gas supply all decrease, due to lower demand in the 2DC, while renewables expand considerably from 0.11 Mtoe in 2016 to 1.7 Mtoe in 2050, thanks to the widespread deployment of offshore wind farms, waste-to-energy and solar power. The fuel mix changes most dramatically for coal and renewables under the 2DC, with the share of the former plummeting from 42% in 2016 to 0% by 2050, and the latter expanding from 0.79% in 2016 to 25% in 2050.

Figure 6.10 · Hong Kong, China: TPES in the 2DC compared with BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Renewable production increases in line with primary energy supply (from 0.11 Mtoe in 2016 to 1.7 Mtoe in 2050) in the 2DC. Net energy imports decrease slightly from 30 Mtoe in 2016 to 29 Mtoe by 2050 in the 2DC with lower demand because of energy efficiency improvements. Electricity imported from mainland China grows slightly from 1.0 Mtoe to 1.1 Mtoe throughout the Outlook period.

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[32]

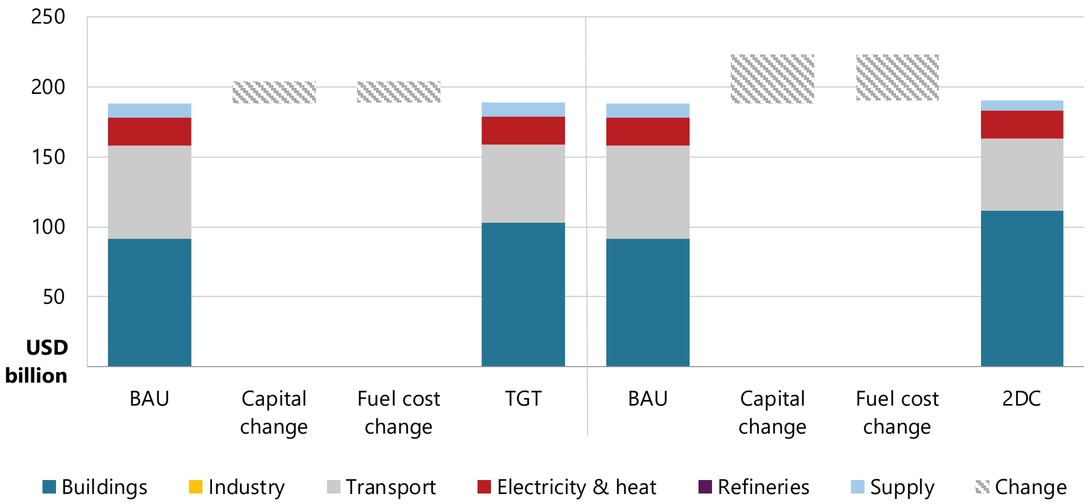
Energy investment comprises two parts: capital investments and fuel costs. In the BAU, total investment reaches USD 188 billion over the Outlook period (Figure 6.11), of which only USD 23 billion is for capital investments, mostly in the supply (USD 10 billion, mainly in gas-related infrastructure) and electricity generation sectors (USD 9.7 billion to replace coal-fired generation with gas). The transport sector sees USD 2.0 billion in capital investment for more efficient vehicles and a higher penetration of EVs. Fuel costs in the BAU reach USD 165 billion over the Outlook period, with the majority accounted for by buildings (USD 90 billion) and transport (USD 64 billion).

Total energy investment is marginally higher in the TGT (USD 0.60 billion) and in the 2DC (USD 2.56 billion). The greatest increase in capital investment comes from the buildings sector—USD 17 billion in the TGT Scenario and USD 38 billion in the 2DC Scenario (compared with USD 1.1 billion in the BAU)—for the installation of more efficient and costly building envelope elements and appliances. Transport sector capital investment, which amounts to USD 2.0 billion in the BAU Scenario, increases to USD 2.1 billion in the TGT and USD 3.0 billion in the 2DC, primarily owing to increased investment in advanced vehicle infrastructure such as EV charging stations. Transport fuel costs fall, from USD 64 billion in the BAU to USD 54 billion in the TGT and USD 49 billion in the

[32] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

2DC, due to a more efficient vehicle fleet and lower stock. In energy transformation, more aggressive replacement of coal-fired power capacity, as well as more renewables and CCS, result in USD 0.30 billion higher capital investment and USD 0.66 billion lower fuel costs in the 2DC, compared with the BAU.

Figure 6.11 · Hong Kong, China: Energy sector capital and fuel costs, 2016-50

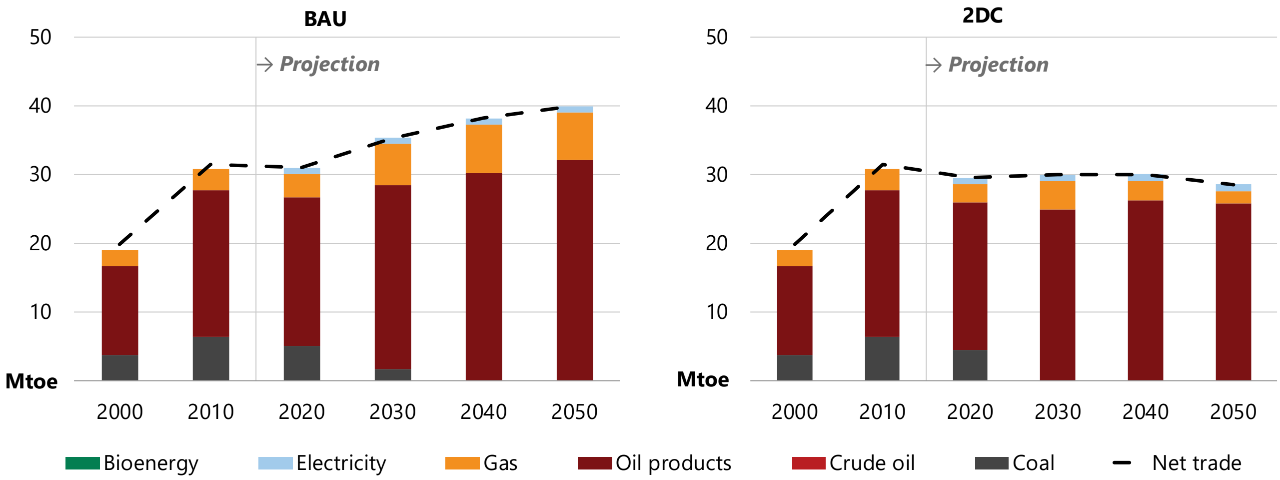


Source: APERC analysis and IEA (2018a).

ENERGY TRADE AND SECURITY

Hong Kong, China continues to import all its coal, oil and gas supplies under all scenarios. Oil remains the dominant energy import through the Outlook, increasing steadily in the BAU (from 20 Mtoe to 32 Mtoe), but more slowly in the 2DC (to 26 Mtoe). Dependence on gas imports rises and coal shrinks over the Outlook period (Figure 6.12). All gas is currently imported from mainland China, but the installation of an offshore liquefied natural gas (LNG) terminal has been proposed to enable direct access to competitive LNG supplies from other parts of the world (CLP, 2017b). Diversifying supply sources would enhance the economy's long-term energy security.

Figure 6.12 · Hong Kong, China: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Constrained by having no natural energy resources of its own, the expanding use of renewables makes primary energy supply self-sufficiency improve over the Outlook period—but only very slightly (Table 6.3). The Herfindahl-Hirschman Index (HHI) value for primary energy supply diversity worsens from 0.32 in 2016 to 0.45 in 2050, due to the switch from coal to gas, while the HHI values in the TGT and 2DC improve against the BAU (0.45 in the BAU, 0.43 in the TGT and 0.24 in the 2DC), mainly owing to renewable energy development.

Table 6.3 · Hong Kong, China: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	1	1	2	8	1	3	25
Primary energy supply diversity (HHI)	0.32	0.33	0.40	0.36	0.45	0.43	0.24

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

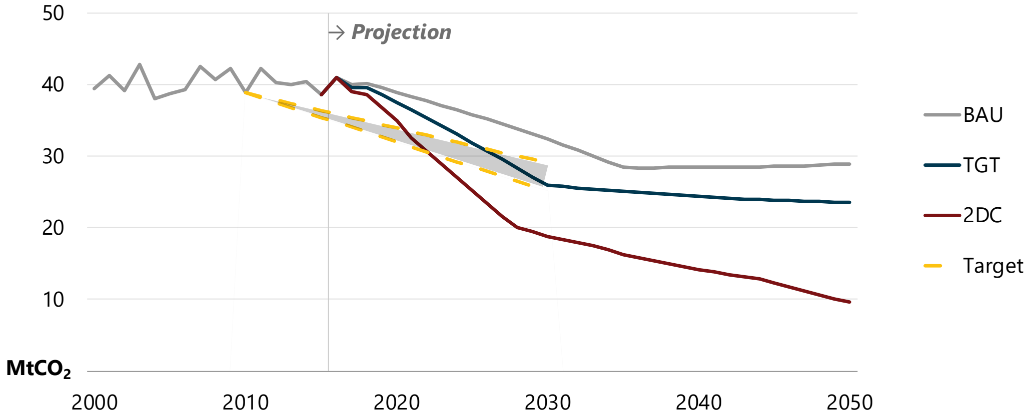
SUSTAINABLE ENERGY PATHWAY

The economy has set a goal to reduce CO_2 emissions intensity by 65% to 70% from the 2005 level by 2030, which will contribute towards China's NDC under the COP21 Paris Agreement (ENB, 2017). This goal will be met by 2034 in the BAU Scenario, by 2030 in the TGT and by 2026 in the 2DC. There are also official targets to reduce energy intensity 40% from the 2005 level by 2025 (ENB, 2015). The target is met by 2030 in the BAU, by 2027 in the TGT and by 2024 in the 2DC (Figure 6.13).

Energy-use CO_2 emissions in the BAU drop by 29% from 2016 to 2050 and by 43% in the TGT due mainly to a sharper decline in primary energy demand driven by efficiency improvements in the buildings and transport sectors. Reducing energy demand alone, however, is insufficient to reduce total CO_2 emissions to the 2DC pathway. Shifting away from coal for electricity generation, as well as increasing renewables penetration, significantly reduces CO_2 emissions in all scenarios.

In the 2DC, energy-related CO_2 emissions fall even more rapidly than the other scenarios (by 77%) due to quicker adoption of higher efficiency appliances, more efficient use of service building floor area, and building code standards that are assumed to further raise end-use energy efficiency and curb demand in the buildings sector. Besides wider EV deployment, additional fuel efficiency improvements and the extension of the electric rail network cuts emissions in the transport sector. The transformation sector is also projected to adopt significantly more renewables and to entirely replace coal-fired plants by 2030.

Figure 6.13 · Hong Kong, China: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional targets, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

To achieve its aims of reducing energy and CO_2 emissions intensities, Hong Kong, China must take advantage of opportunities to implement additional policies or make existing ones stricter. In the demand sectors, continuing to raise appliance efficiency standards, BECs and building thermal transfer standards will be instrumental in tempering demand growth in the building sector. Similarly, expanding public transport use (particularly the MTR, which has grown rapidly in recent years) and maintaining or increasing support for EVs can moderate population- and GDP-driven demand growth in the transport sector.

In the electricity generation sector, continuing to promote renewables and seek innovative solutions to land constraint issues (such as using reservoirs for solar PV or developing offshore wind farms) is essential to moving towards decarbonisation. Exploring CCS options for gas-fired power plants, as well as closer grid integration with mainland China to tap into more nuclear and renewable energy, could also be beneficial.

Among other challenges to attaining a more sustainable low-carbon future are technical barriers, low market availability of appliances, a lack of skilled specialists to develop and implement efficient energy systems, low investor availability, and inadequate public awareness and participation. The government must therefore work closely with various stakeholders and the public, as well as with trade, investment and technical professionals, to overcome these obstacles.

7. INDONESIA

KEY FINDINGS

- **As one of the world's leading coal and LNG exporters,** Indonesia must balance its energy resources between exports and rapidly growing domestic demand.

- **Over the projection period, GDP grows at a CAGR of 5.1% while FED grows at 2.5% under the BAU,** mainly due to rising fossil fuel consumption in industry, natural gas and electricity demand in residential buildings, and oil demand in the transport sector.

- **Renewable energy accounts for the largest share of TPES in the BAU in 2050** as geothermal power generation expands and the mandatory transport sector biodiesel blend rate increases.

- **The share of coal in primary energy production in the BAU scenario increases by 34% over the Outlook period to meet export demand as well as rising electricity demand.** Without additional policy action, this leads to growing CO_2 emissions and environmental concerns.

- **Indonesia's energy security weakens as oil production continues to decline while consumption rises at 2.3% CAGR.** Greater use of renewables, biofuels and clean energy sources can mitigate these effects.

- **CO_2 emissions increase under all three scenarios, although growth is much more moderate in the 2DC.** The NDC is achieved under all three scenarios.

ECONOMY AND ENERGY OVERVIEW

Indonesia is a large archipelago south-east of mainland Asia, between the Pacific and Indian Oceans. Its exclusive economic zone of 7.8 million square kilometres (km^2) encompasses 17 508 islands as well as large bodies of water around the equator, and its total land area is 1.9 million km^2 (World Bank, 2018c). The population in 2016 was 261 million, and it is projected to increase at a compound annual growth rate (CAGR) of 0.61% over the Outlook period (2016-50), to 322 million in 2050 (Table 7.1).

Indonesia had a gross domestic product (GDP) of USD 3 000 billion (and a per-capita GDP of USD 11 488) in 2016, the largest in south-east Asia owing to its robust economic growth following the Asian financial crisis of the late 1990s. The Indonesian government has been making progress in deregulating the economy and removing barriers to investment, indicated in its ranking of 72nd place in the World Bank's 2018 ease of doing business index, a significant improvement from 91st place in 2017 (World Bank, 2018d).

Oil, gas and coal reserves have been important to Indonesia's economy as sources of energy, industrial raw materials and foreign exchange. Recent development of industrial and manufacturing capacity has raised the share of manufacturing revenue in total GDP. Consequently, the share of oil and gas revenue in GDP is projected to continue declining over the Outlook period as more gas is allocated for domestic use in manufacturing and oil demand outpaces domestic oil production. The coal industry continues to play an important role in economic growth as production expands to meet local and international demand.

Table 7.1 · Indonesia: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	1 310	2 182	3 000	3 740	6 588	10 860	16 417
Population (million)	212	243	261	272	296	312	322
GDP per capita (2016 USD PPP)	6 195	8 998	11 488	13 740	22 286	34 792	51 057
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	158	209	233	259	340	447	543
TPES per capita (toe)	0.75	0.86	0.89	0.95	1.2	1.4	1.7
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	120	96	78	69	52	41	33
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	121	144	166	192	249	316	388
FED per capita (toe)	0.57	0.59	0.64	0.70	0.84	1.0	1.2
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	92	66	55	51	38	29	24
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	262	395	476	548	703	1 003	1 241
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	0	0	91	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

Indonesia has substantial and diverse oil, natural gas, coal and renewable energy resources. In 2016, proved fossil energy reserves comprised 3.2 billion barrels (bbl) of oil, 2.9 trillion cubic metres of natural gas and 23 billion tonnes of coal (Table 7.2). Most oil and gas resources are in western and eastern Indonesia, with deep-water technology required to exploit those in the east. Recent liquefied natural gas (LNG) projects include Dongi-Senoro, Tangguh and Abadi Masela, all located in eastern Indonesia. Crude oil is produced mostly from mature oil reservoirs, and although new projects have been developed (such as the Exxon Banyu Urip oil field in East Java and the Bass Oil Tangai-3 in South Sumatera), domestic oil production is declining.

Indonesia is one of the largest thermal coal producers in the world. Of the 528 million tonnes (Mt) produced in 2018, 78% was exported (MEMR, 2019a). The Indonesian coal industry is actively increasing thermal coal production to keep pace with domestic demand and secure export revenues. The shorter project gestation periods, lower freight rates and diverse vessel options to transport coal to Asian markets offered by Indonesia's geographic location give it a competitive advantage. Most coal is mined in South Sumatra and Kalimantan.

Table 7.2 · Indonesia: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	22 598	49	2.2	10	5
Oil (billion bbl) [a]	3.2	9	0.2	30	9
Natural gas (tcm) [a]	2.9	43	1.5	14	5
Uranium (tU) [b]	5 300	0	0.1	25	8

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. tU = tonnes of uranium. a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kgU.
Sources: NEA (2018) for uranium, BP (2018) for coal, oil and natural gas.

Indonesia also has abudant renewable energy resources, with significant potential for geothermal (29 gigawatts [GW]), hydro (75 GW), wind (61 GW of commercial potential) and biomass for electricity (33 GW) (DGNREEC, 2016). Theoretical potential also exists for ocean wave energy (18 GW), while solar irradiation potential is between 2.6 kilowatt-hours per square metre (kWh per m^2) and 5.8 kWh per m^2 (DGNREEC, 2016). Commissioning of the 330 megawatt (MW) Sarulla geothermal plant in May 2018 increased total geothermal capacity to 1 948 MW (the world's second-largest). The geothermal power industry continues to attract private-sector investment and receives support from international development agencies: in March 2018, the Asian Development Bank signed a loan agreement for USD 175 million with a private Indonesian developer for Phase II of the 90 MW Rantau Dedap Geothermal Power Plant in South Sumatra (ADB, 2018).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Indonesia's policies on energy and natural resources are governed by Oil and Gas Law No. 22/2001, Energy Law No. 30/2007, Electricity Law No. 30/2009 and Geothermal Law No. 21/2014. Government Regulation No. 79 of 2014 about the National Energy Policy (NEP) provides guidelines for formulating energy management policies to promote energy self-sufficiency and strengthen energy security by making energy production equitable, sustainable and environmentally friendly. Presidential Regulation No. 22/2017 on the General Plan of National Energy contains government policies on managing the NEP.

To encourage the use of domestic resources to meet energy needs, the government uses policy instruments such as energy pricing, subsidies and incentives, particularly for renewables. It also supports R&D to help commercialise specific energy technologies. To ensure domestic energy needs are met, the government implements policies to gradually increase domestic use of fossil fuels (particularly coal and gas) and adjusts quotas for fossil energy exports accordingly. Mandatory blend rates for biofuels used in the transport and electricity sectors have also been introduced to improve energy security and support renewable energy.

The NEP also sets development priorities for domestic energy resources, encouraging the development and use of renewables and coal as well as optimising gas consumption while minimising the use of oil; it identifies nuclear as the last energy option due to safety concerns. The NEP aims to transform the primary energy supply mix by mandating the following shares:

- New low-carbon energy sources[33] and renewables at least 23% in 2025 and 31% in 2050.
- Oil less than 25% in 2025 and less than 20% in 2050.
- Coal at least 30% in 2025 and 25% in 2050.
- Gas at least 22% in 2025 and 24% in 2050.

In addition, the NEP establishes numerous economy-wide targets, including to: reduce energy elasticity[34] to less than 1 in 2025; reduce final energy intensity by 1% per year to 2025; achieve an electrification rate approaching 100% in 2022; and increase per-capita electricity consumption to 2 500 kilowatt-hours (kWh) in 2025 and 7 000 kWh by 2050. In 2018, the electrification rate was 98% and per-capita electricity consumption was 1 064 kWh (MEMR, 2019b). Presidential Regulation No. 22/2017 on the General Plan of National Energy mandates 167 GW of installed renewable power capacity by 2050, made up of 23% hydro power and 11% geothermal. The MEMR Regulation No. 49/2018 on Rooftop Solar Panels was issued in November 2018 to increase residential solar photovoltaic (PV) in Indonesia. In late 2017, the Indonesian government began streamlining energy regulations and permits to encourage public- and private-sector investment in the energy sector. By end-2018, 186 regulations and permits deemed to introduce barriers to energy sector investment had been revoked or annulled.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Indonesia under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 7.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere, such as in the National Energy Council's *Indonesia Energy Outlook*, the General Plan of National Energy, and BPPT's (Agency for the Assessment and Application of Technology) *Indonesia Energy Outlook*.

[33] Such as hydrogen and ocean thermal energy conversion.
[34] An elasticity of less than 1 indicates that for an additional 1% of GDP growth, energy demand grows by less than 1%.

Table 7.3 · Indonesia: Key assumptions and policy drivers under the BAU

Buildings	Building stock grows, consistent with GDP and population growth. Higher energy efficiency standards and more comprehensive appliance energy labelling schemes enforced to moderate demand growth.
Domestic transport	Expansion of road network, including toll roads. Further development of the public transport system, including the train system, buses and marine transport. Support in place for biofuels and electric vehicles (EVs) development.
Energy supply mix	Coal production remains strong over the Outlook period. Crude oil production continues to decline. Oil refinery development peaks in 2025.
Power mix	Newly built coal-fired plants employ super-critical or ultra-supercritical technologies. Rapid expansion of renewable energy power plants, including hydro, geothermal, biomass and variable renewable energy (solar PV and wind power). Existing subcritical coal-fired plants retire upon reaching end of design lifespan. No nuclear plants introduced over the Outlook period.
Renewables	Continued exploration and promotion of hydro, geothermal, solar, wind, waste-to-energy and biofuel technologies.
Energy security	Continued crude oil imports. Domestic coal and gas resources used to meet energy demand. Refinery capacity built to improve oil product self-sufficiency.
Climate change	Climate change policy supported to achieve 23% share of renewable energy in the final energy mix by 2025 and 30% share by 2030.

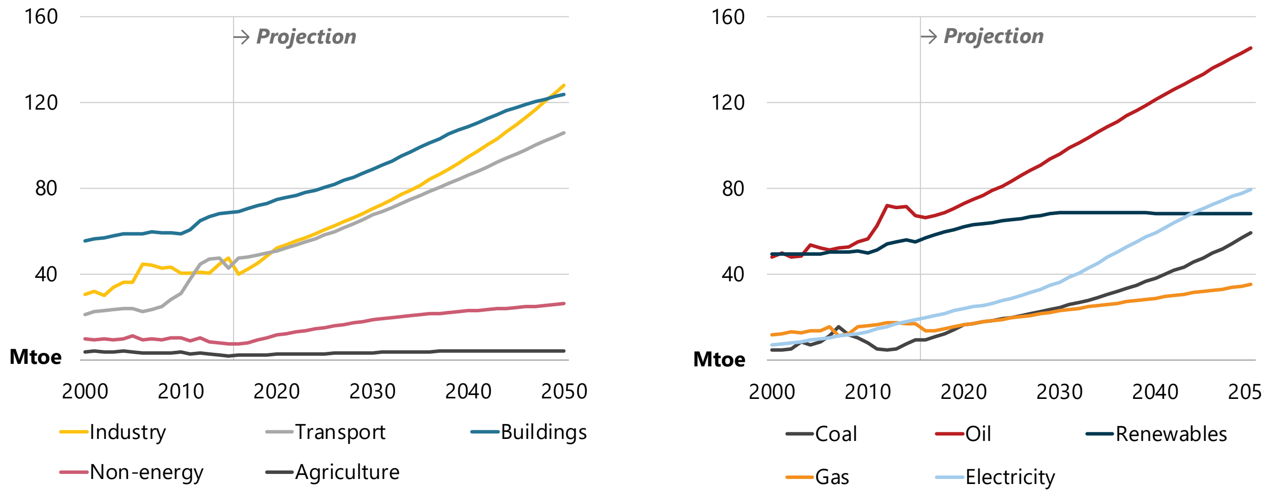
Note: This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Indonesia's energy sector is the largest in south-east Asia, accounting for 42% of the total final energy demand (FED) of APEC's south-east Asian economies when averaged over the Outlook period. FED is projected to grow steadily to reach 388 million tonnes of oil equivalent (Mtoe) in 2050—a significant increase of 133% from 166 Mtoe in 2016. Growth occurs in all sectors, with buildings retaining the dominant share of FED until 2049 when it is overtaken by industry (33%) (Figure 7.1). Industry demand grows quickest at a CAGR of 4.1% from 2016 to 2030 before moderating slightly to grow at 3.5% CAGR afterwards to reach 128 Mtoe by 2050. Transport energy demand also increases rapidly at 2.4% CAGR, to reach 106 Mtoe in 2050 (more than doubling from 48 Mtoe in 2016).

Rising energy demand in buildings is particularly noticeable, since it was projected to grow only modestly (1.0% CAGR) in the 6th edition of the APEC *Energy Demand and Supply Outlook*. However, the rapid expansion of access to electricity, rising population and stable economic growth over the projection period are key drivers of a greater increase in buildings energy demand.

Figure 7.1 · Indonesia: Final energy demand by sector and fuel, 2000-50



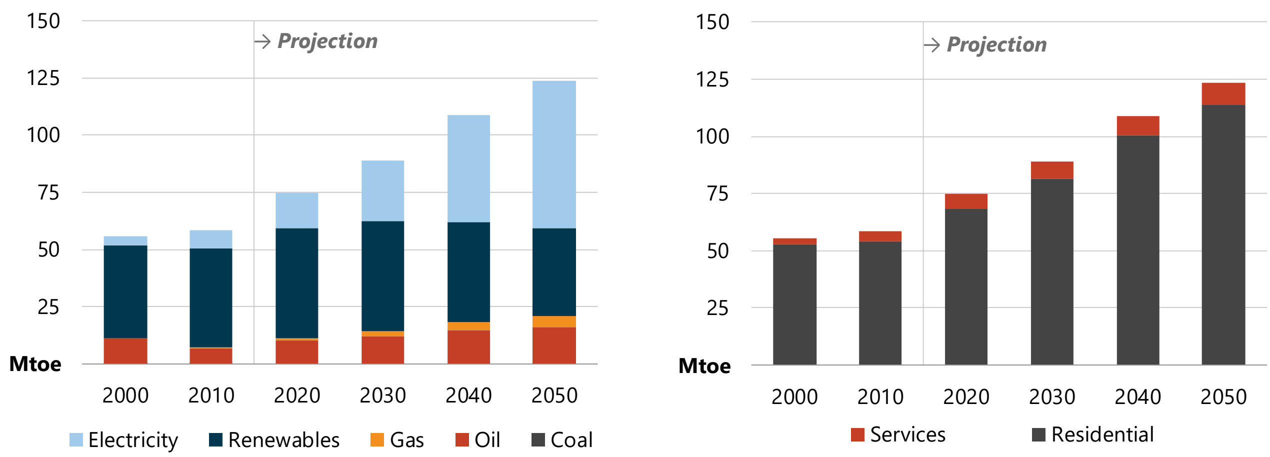
Sources: APERC analysis and IEA (2018a).

The share of oil in FED is stable around 39% from 2000 to 2050, but the actual volume more than doubles from 67 Mtoe in 2016 to 145 Mtoe in 2050. Electricity contributes the second-largest share by 2050, increasing from 12% (20 Mtoe) in 2016 to 21% (80 Mtoe) in 2050. Rapid renewable energy development in the electricity and transport sectors as well as the transition from the traditional use of biomass to modern biomass and other fuels causes the share of renewables in FED to increase at 0.53% CAGR.

BUILDINGS: ECONOMIC AND POPULATION GROWTH DRIVE ENERGY DEMAND

Economic and population growth over the Outlook period raise energy demand for buildings from 69 Mtoe to 124 Mtoe, an increase of 79% (Figure 7.2). BAU projections of buildings sector energy demand reflect fuel demand changes resulting from energy sector policies introduced since 2015. These include switching from kerosene to liquefied petroleum gas (LPG) in the residential subsector, oil and electricity subsidy restrictions, and the mandatory use of biofuels (especially biodiesel) in the transport and electricity sectors.

Figure 7.2 · Indonesia: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy demand for residential buildings rises at a CAGR of 1.7% and accounts for more than 90% of buildings sector energy demand over the projection period. Energy consumption by service buildings increases at a lower rate (1.6% CAGR), from 5.8 Mtoe (8.4% of total buildings demand) in 2016 to 8.6 Mtoe (8.1%) in 2050. Electrification in Indonesia is projected to reach nearly 100% by 2020, raising electricity consumption and reducing demand for traditional biomass. Residential renewables consumption drops as a result, from 48 Mtoe (76%) in 2016 to 38 Mtoe (34%) in 2050.

Cooking accounts for the largest share of end-use energy demand in residential buildings but grows modestly at a CAGR of 0.10% from 47 Mtoe (accounting for 74% of the total) in 2016 to 48 Mtoe (43%) in 2050. Minimal cooking energy demand growth is the result of a large-scale fuel switching program to phase out kerosene and replace it with more efficient LPG, as well as natural gas network expansion, which reduces oil consumption in urban areas.

Energy demand for residential space cooling increases 12-fold over the Outlook period from 2.7 Mtoe (4.4% of total residential demand) to 37 Mtoe (32%). Population and economic growth lead to increased floor area and greater space-cooling demand. The average floor area per household doubles to 188 m^2 by 2050. Although Indonesia already applies mandatory labelling and minimum energy performance standards (MEPS) for end-use appliances including air conditioners, it plans to raise the standards for space cooling through the Association of Southeast Asian Nations (ASEAN) Standards Harmonisation Initiative for Energy Efficiency (SHINE) program. Under the SHINE program, air conditioners must meet the 2.9 Energy Efficiency Ratio[35] by 2020 (IEA, 2017).

In service buildings, electricity accounts for more than 80% of total demand throughout the Outlook period, rising at a 1.7% CAGR from 4.7 Mtoe in 2016 to 8.3 Mtoe in 2050. Businesses and services are more concentrated in cities, so electricity demand for service buildings rises with greater urbanisation. Space cooling accounts for the largest share of end-use energy demand, climbing from 1.9 Mtoe (33% of total demand) in 2016 to 3.2 Mtoe (32%) in 2050, a 66% increase. Space cooling consumption in service buildings includes commercial centrifugal chillers and rooftop air conditioners.

As the economy develops and GDP per capita continues to grow, more sophisticated appliances will be introduced (in hospitals, hotels, offices, schools, etc.), raising energy demand and energy intensity. With the adoption and tightening of building energy codes at the central government and city levels, however, buildings become more energy efficient as envelopes improve. Jakarta was the first city in Indonesia to apply building codes and standards for new service buildings in 2012, followed by Bandung in West Java in 2016. Also in 2016, the Ministry of Energy and Mineral Resources (MEMR) Regulation on the Establishment of Energy Services Companies (ESCOs) provided the legal basis for ESCOs to conduct investment-grade audits. Reducing space-cooling energy demand is one of key ways ESCOs aim to improve energy efficiency in service buildings, resulting in the deployment of more efficient technologies for space cooling over the Outlook period (energy intensity is assumed to decrease by 19% from 40 kWh per m^2 in 2016).

INDUSTRY: RAPID GROWTH IN ENERGY DEMAND

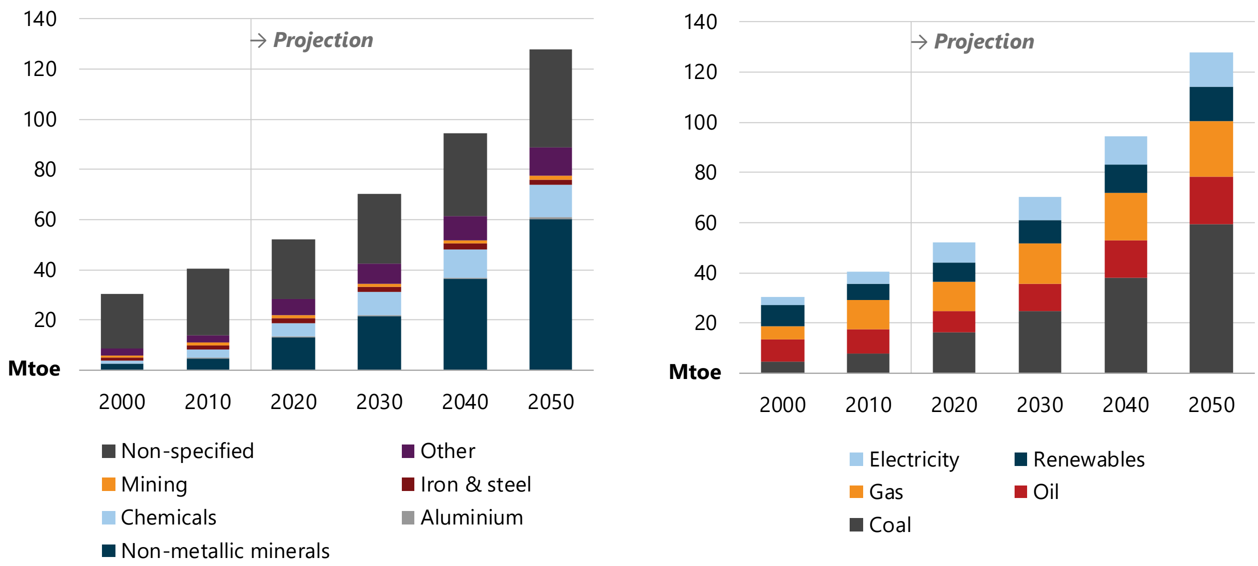
Industrial energy demand is projected to grow rapidly, from 40 Mtoe in 2016 to 128 Mtoe in 2050, at a CAGR of 3.5% (Figure 7.3). With significant recent infrastructure development and steady GDP growth, energy demand in the non-metallic minerals and chemicals subsectors is projected to increase more than eight times over the Outlook period, from a combined 9.0 Mtoe in 2016 to 73 Mtoe by 2050.

Energy demand in non-metallic mineral production has the highest growth rate over the Outlook period (7.2% CAGR), driven mainly by rapid infrastructure development, building construction and growing export markets. In 2018, Indonesia exported cement and clinkers to neighbouring economies, including Bangladesh, Malaysia

[35] The energy efficiency ratio (EER) measures how many British thermal units per hour are removed for each watt of power that an air conditioner draws from an electricity supply; the higher the EER, the more efficient the air conditioner.

and Viet Nam. Energy demand in the chemical sector grew at a CAGR of 8.5% between 2000 and 2016 and more than triples over the Outlook, from 3.4 Mtoe (8.5% of total industrial demand) in 2016 to 13 Mtoe (10%) in 2050. Major demand for chemical production comes from olefin plant steam crackers and plants that produce ammonia and other compounds to manufacture fertilisers which are used by the domestic agriculture and plantation industries.

Figure 7.3 · Indonesia: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

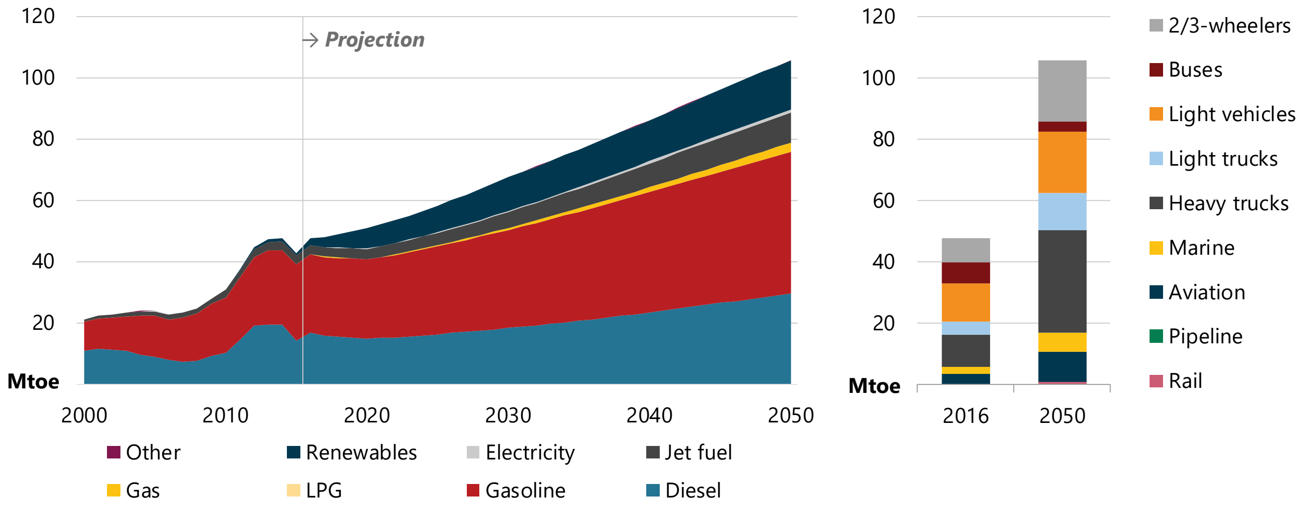
Industrial demand for coal rises the most quickly of all fuels at a 5.5% CAGR from 9.5 Mtoe in 2016 to 59 Mtoe in 2050 (46% share of total fuel demand). Coal consumption is driven by higher demand from cement plants and the operation of additional blast furnaces in iron- and steelmaking. Two blast-furnace plants with a total production capacity of 4.2 Mt per annum, owned by Krakatau Steel, commenced operations in 2018, with a number of others currently under construction. Gas consumption, which almost doubled between 2000 and 2016, increases 125% over the projection period to 22 Mtoe (17% share of total industrial fuel demand) in 2050.

The chemical and petrochemical subsector is the largest gas consumer (98% share of total industrial gas demand) as new petrochemical plants are being constructed or under planning. Construction of the USD 3.5 billion Lotte Chemical Indonesia new ethylene (LINE) project began in December 2018, and it will produce ethylene cracker and other chemical products when it commences operation in 2023 (Tani, 2018). Energy demand for the ammonia industry also grows rapidly to meet the increased demand for chemicals and fertilisers in domestic and export markets.

TRANSPORT: ROAD ENERGY DEMAND CONTINUES TO DOMINATE

Domestic transport accounts for the third-largest share of FED after buildings and industry over the Outlook period. Transport demand more than doubled between 2000 and 2016 and continues rising at a CAGR of 2.5% to 106 Mtoe (27% of FED) in 2050 (Figure 7.4). Road transport accounts for the majority of domestic transport consumption: 42 Mtoe (88% of the total) in 2016 and 89 Mtoe (84%) in 2050. Energy demand for air and rail transport are small in comparison (9.7 Mtoe for air and 0.90 Mtoe for rail in 2050), but growth is strong over the Outlook period at a CAGR of 3.5% for air and 3.3% for rail.

Figure 7.4 · Indonesia: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Accelerated transport infrastructure development between 2015 and 2019, to improve connectivity between western and eastern Indonesia and reduce logistics costs, underpins near-term energy demand growth. Notable transportation projects over that time include a 4 000 kilometre (km) trans-Papua highway; a 304 km trans-Sumatra toll road; 3 258 km of railway expansions; 81 new and expanded sea ports; 15 new airports; and the revitalisation of 10 existing airports (PUPR 2015).

Demand for gasoline rises at a strong 9.3% CAGR and remains the most-used fuel in the transport sector at 26 Mtoe (54% of total fuel consumption) in 2016 and 46 Mtoe (44%) in 2050. The second-fastest increase is in renewables (6.2% CAGR) owing to policies aimed at raising biofuel blend rates and increasing trans-national road connectivity. To diversify fuels and stimulate renewable energy demand in the transport sector, the Indonesian government's policies to promote, produce and consume biofuels include minimum biofuel blend rates and targets. Indonesia's biodiesel blending mandate is supported by the Oil Palm Estate Fund agency, which manages funds from levies charged on palm oil exports.

Of the 3 656 million litres (L) of biodiesel produced in 2016, 477 million L (13%) were exported. The share of bioethanol for gasoline blending is relatively small compared with that of biodiesel, as local ethanol production from molasses is uneconomical given the current price of gasoline, and fuel stocks from sugarcane and corn plantations for fuel-grade ethanol production are limited (USDA, 2017).

The government is also encouraging domestic electric vehicle (EV) production with the aim of reducing oil consumption, local air pollution and carbon dioxide (CO_2) emissions in the transport sector. An Electric Vehicles Development Plan and Targets have been outlined in the General Plan of National Energy (Table 7.4) (Government of Indonesia, 2017). As a result, the transition from gasoline to electricity for 2-wheelers and light vehicles increases electricity consumption in the transport sector at a 13% CAGR over the Outlook period, but EVs account for only 1.0% (1.1 Mtoe) of total transport fuel demand in 2050.

Table 7.4 · Indonesia: Electric vehicles development plan and targets

EV development target	2025	2050
Light-duty vehicles (LDVs)	2 200	4 200 000
Hybrid/dual-fuel LDVs	711 900	8 050 000
2-wheelers/motorcycles	2 130 000	13 300 000
EV charging stations	1 000	10 000

Source: Government of Indonesia (2017).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Energy use has grown rapidly in Indonesia's transformation sectors since 2000 and is projected to more than double over the Outlook. Refinery developments can potentially see Indonesia switch from being a net importer to a net exporter of oil products between 2023 and 2035. Although primary energy supply, trade and production continue to be dominated by fossil fuels, the share of renewables increases, mainly displacing oil and coal.

ENERGY INDUSTRY OWN-USE: STRONG GROWTH IN REFINING ACTIVITIES

The Indonesian government is boosting liquid fuel production to keep pace with demand and reduce imports. According to the Refinery Development Master Plan, six oil refineries will be built or upgraded by 2025 with a total production capacity of 2 600 thousand barrels (0.36 Mtoe) per day (133 Mtoe per year)[36] (MEMR, 2016). To stimulate investment and improve returns, a recent Ministry of Finance regulation (No. 35/2018) stipulates that refinery development is entitled to a tax holiday of 5 to 20 years depending on the type and size of the project.

Overall own-use energy consumption increases at 2.2% CAGR from 10 Mtoe in 2016 21 Mtoe in 2050, owing to a strong rise in electricity generation and refining activities. Energy own-use in refining activities accounts for the highest share in 2050 (37% at 7.8 Mtoe), followed by oil and gas extraction (31% at 6.4 Mtoe), and electricity generation (16% at 3.4 Mtoe). Energy sector losses increase rapidly at 7.3% CAGR from 0.63 Mtoe (0.27% of TPES) in 2016 to 6.9 Mtoe (1.3%) in 2050 even though the government aims to reduce electricity sector transmission and distribution losses to below 10% of total electricity produced from 2018 onwards.

POWER SECTOR: COAL REMAINS ON TOP BUT RENEWABLES GROW RAPIDLY

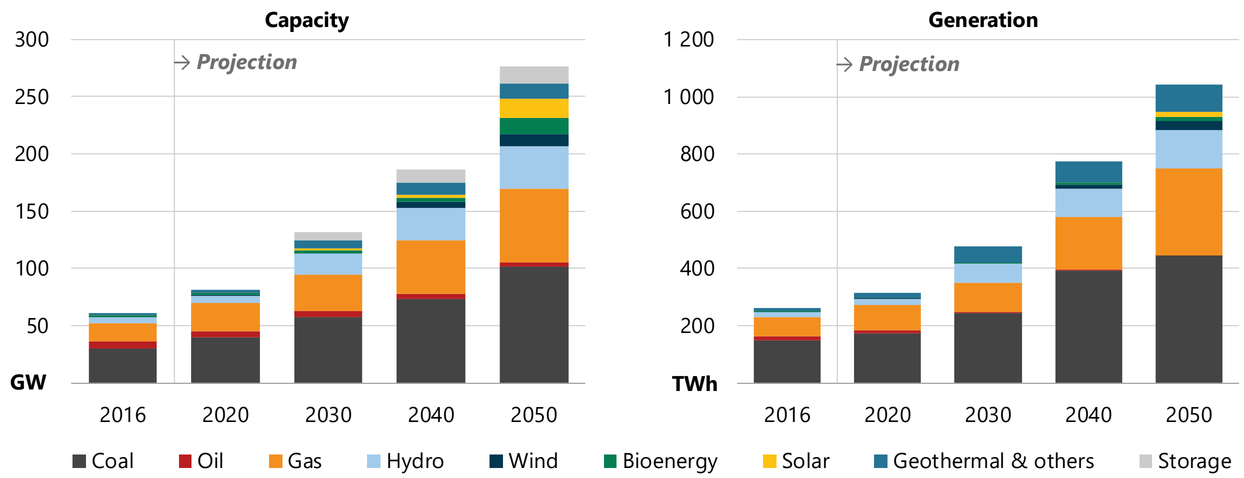
Indonesia's electricity generation mix is currently dominated by fossil fuels, but consumption gradually shifts away from coal and oil towards renewables and natural gas over the Outlook period (Figure 7.5). In 2016, coal and oil together accounted for 63% of generation, but this shrinks to 43% in 2050 as electricity generation from renewables expands rapidly, at a CAGR of 7.1%. Wind increases at the fastest pace (29% CAGR), followed by solar (21% CAGR), hydro (5.9% CAGR) and geothermal (6.4% CAGR).

Electricity generation from wind grows from a relatively small 6 gigawatt-hours (GWh) (less than 1% of the electricity generation mix) in 2016 to 32 terawatt-hours (TWh) (3.0%) in 2050. Commissioned in July 2018, the 75 MW Sidrap Wind Power project in South Sulawesi Province was the first project to demonstrate the potential for large-scale wind power generation in Indonesia. Solar generation expands at a 21% CAGR from just 2.1 GWh in 2016 (a negligible share of total electricity generation in Indonesia) to 15 TWh (1.4% of total generation) in 2050. The 200 MW floating solar PV in Cirata dam in the West Java province, which is currently under construction, is expected to be the world's largest floating solar PV when completed in 2019. The introduction

[36] Annual total production is based on refineries' operations at full capacity in 365 days.

of MEMR regulation No. 49/2018 regarding rooftop solar PV in December 2018 is also expected to increase electricity generation from residential solar PV. Two other power development programs have been implemented to construct more renewable power plants: the Fast-Track 10 000 MW Phase II (2009) and the 35 000 MW Program (2015). Indonesia has the second-highest total installed capacity of geothermal power plants in the world after the United States. The 330 MW Sarulla geothermal power plant, commencing operations at the end of 2018 (at a cost of USD 1.7 billion), is followed by another three small- and medium-scale projects which bring total geothermal capacity to 2.1 GW (MEMR, 2018c).

Figure 7.5 · Indonesia: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

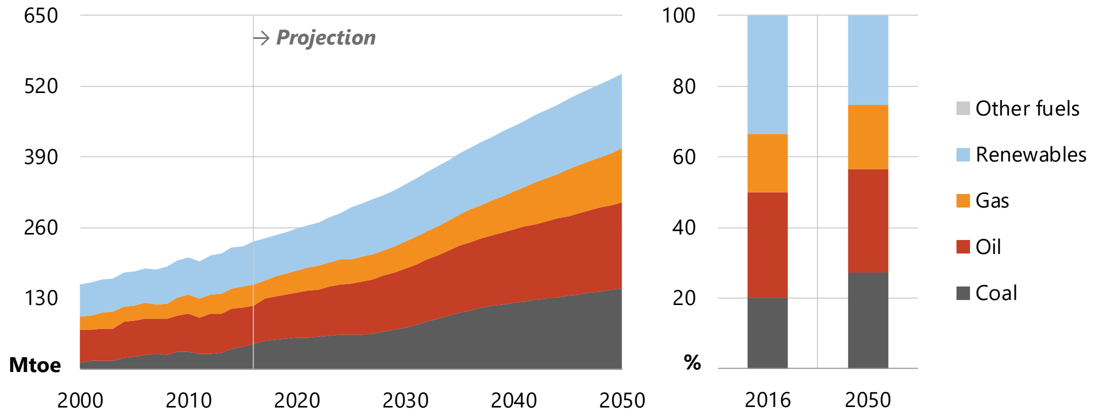
Electricity consumption per capita varies across Indonesia, and is currently highest in the most economically developed regions of Java and Bali (1 170 kWh per capita in 2017) (BPS, 2018; Directorate General of Electricity, 2018). Electricity consumption per capita grows more slowly than GDP over the Outlook period, reaching 3 268 kWh in 2050 from 1 005 kWh in 2016. In the medium term, the government aims to increase per-capita electricity consumption to 2 500 kWh by 2025, primarily through achieving 100% electrification by 2020. The rate of electrification rose rapidly from 88% in 2015 to 98% in 2018, mainly owing to improvements in eastern Indonesia (MEMR, 2019b).

The Indonesian government is also conducting a pilot waste-to-electricity project in 12 major cities in 2018. Presidential Regulation No. 35/2018 on the Acceleration of Waste-to-Electricity Power Plant Development Based on Environmentally Sustainable Technology provides opportunities for public- and private-sector investment in waste-to-electricity power generation. The government has streamlined the procurement process and is offering an electricity tariff of USD 0.13 per kWh for waste-to-electricity power plants of up to 20 MW. The first project to benefit from this scheme is a 10 MW waste-to-electricity plant in Solo that reached a power purchase agreement in December 2018 and is expected to begin operations in 2020 (PwC Indonesia, 2018).

TOTAL PRIMARY ENERGY SUPPLY: COAL AND GAS GROW RAPIDLY

Indonesia's total primary energy supply (TPES) in 2016 was dominated by renewable energy—78 Mtoe (34%)—and oil—74 Mtoe (32%)—followed by coal at 47 Mtoe (20%) and gas at 39 Mtoe (17%) (Figure 7.6). TPES more than doubles to 543 Mtoe over the Outlook period. All fuel types are projected to expand, with coal demonstrating the highest CAGR (3.4%), driven mainly by the electricity and industry sectors. Oil increases more slowly, at a CAGR of 2.3% (to 160 Mtoe in 2050), but it becomes the largest fuel source in TPES, mainly owing to rapid demand growth in the transport and industry sectors. Renewable energy rises at a 1.7% CAGR (to 137 Mtoe in 2050) as the state power utility enlarges geothermal, hydro, solar PV and wind power development.

Figure 7.6 · Indonesia: Total primary energy supply by fuel, 2000-50

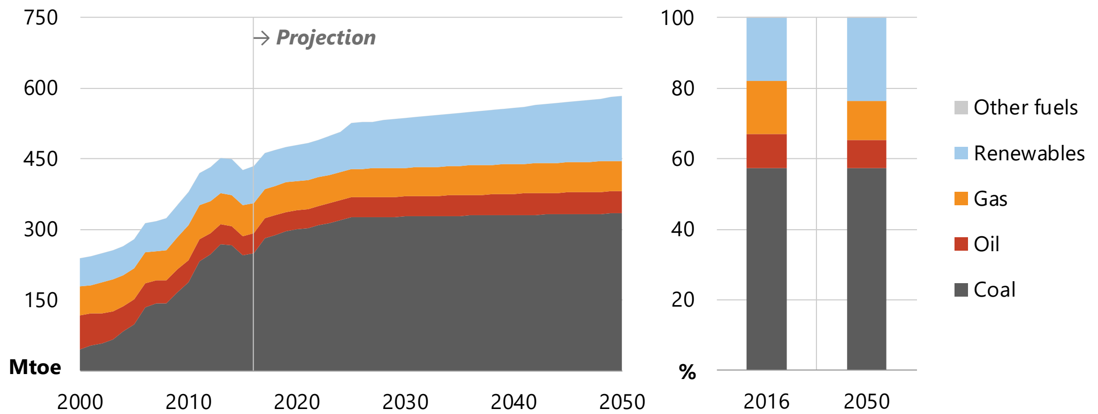


Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: RENEWABLES INCREASE AS OIL AND GAS SHRINK

Over the Outlook period, Indonesian energy production and trade is mostly dominated by coal, but rapidly increasing renewable energy production helps to meet growing domestic energy demand. Coal production, driven by high domestic and international demand, grows at a moderate 0.87% CAGR over the Outlook, reaching 334 Mtoe in 2050 (from 249 Mtoe in 2016) (Figure 7.7). Gas production is almost unchanged over the Outlook period at 64 Mtoe per year, but renewable energy grows the most quickly at 1.7% CAGR, reaching 137 Mtoe by 2050 (from 78 Mtoe in 2016).

Figure 7.7 · Indonesia: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Indonesia's gas supply under the BAU continues to be adequate to meet domestic market and export demands until 2040. Three major natural gas projects (BP's Tangguh Train-3, Inpex's Abadi-Masela, and Eni's Merakes) are currently being developed and are projected to add a total of 30 Mtoe per year of production between 2020 and 2027 (which compensates for declining output at existing projects). On 19 February 2019, the Repsol-Mitsui-Petronas joint venture discovered 2 trillion cubic feet (50 Mtoe) of recoverable resources of natural gas in South Sumatera, the largest discovery in Indonesia over the past 18 years (Repsol, 2019).

To raise natural gas consumption in power generation and industry, Indonesia continues expanding its gas pipeline network and builds LNG facilities, including floating storage and regasification units (FSRU). The Nusantara Gas FSRU, the first of its kind in south-east Asia, has a capacity of 13 Mtoe and supplies natural gas-fired power plants and the chemical industry in West Java. In late 2018, Indonesia began construction of a 1 760 MW FSRU-to-power project, the first of its kind in Asia (MOL, 2018).

Coal production is scaling up rapidly to keep pace with domestic demand while maintaining export revenues. Of the 528 Mt of coal produced in 2018, 413 Mt (78%) was exported, mainly to China, India, Japan, Korea, and Chinese Taipei (MEMR, 2018a and 2019a). In 2018, Indonesia's state energy enterprises formed a partnership with Air Products and Chemicals, a chemical company from the United States, to produce coal derivative products such as dimethyl ether and synthetic natural gas from an Indonesian coal mine to reduce Indonesia's imports of LPG (Pertamina, 2019).

Indonesia's oil demand remains higher than domestic production over the Outlook period. Crude oil imports increase at a CAGR of 3.5% from 26 Mtoe in 2016 to 84 Mtoe in 2050. The economy aims to increase oil production by using advanced technologies such as enhanced oil recovery (EOR) and deepwater exploration. The Rokan oil field in Sumatra plans to implement full-scale EOR in 2024 to raise production to 500 000 barrels of oil per day (25 Mtoe per year) (MEMR, 2018d). To attract more investment in upstream oil development, the government has introduced new regulations, including gross split production sharing contracts (PSCs) to replace traditional PSCs. Presidential Regulation No. 53/2017 offers tax incentives and allowances for oil and gas gross split PSCs.

ALTERNATIVE SCENARIOS

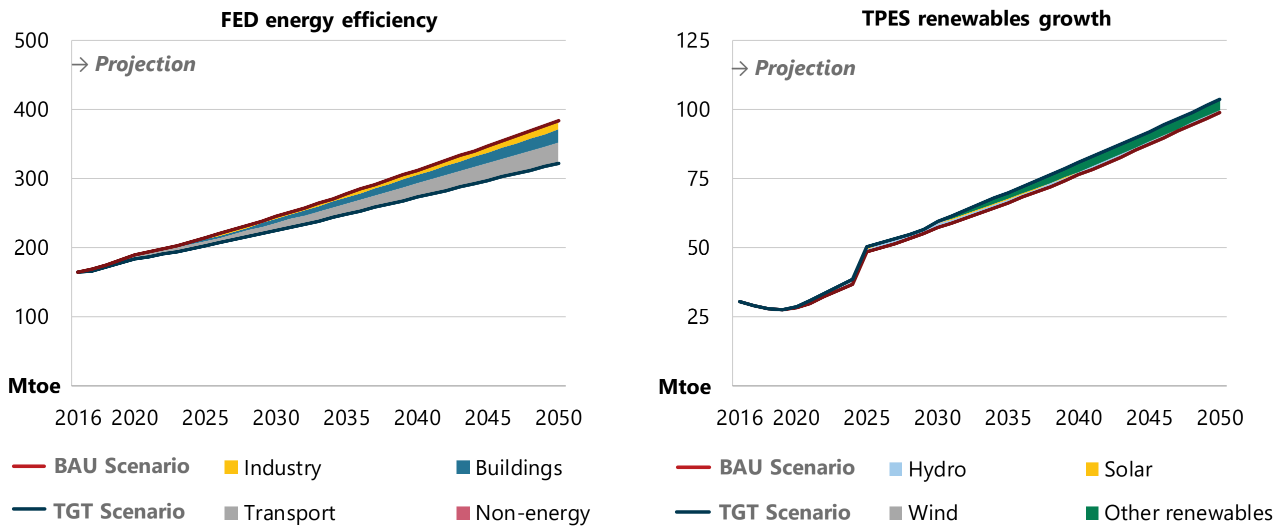
While the BAU Scenario is intended to be representative of Indonesia's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050.

Relative to the BAU, FED is 16% lower while CO_2 emissions are 15% lower in the TGT in 2050. Under the 2DC, Indonesia's FED is 29% lower and CO_2 emissions are 58% lower. The share of renewables in TPES is 2.0% higher in the TGT, due to a stronger shift away from traditional uses of biomass, towards electricity and more efficient modern renewables, mostly in the transport and electricity sectors. The share of renewables is 18% higher in the 2DC because of accelerated development of renewables in all energy sectors, particularly power.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. In the TGT, FED reaches 326 Mtoe in 2050, which is 16% lower than under the BAU, and the cumulative FED's difference over the entire Outlook period is 959 Mtoe (a 10% reduction compared with the BAU) (Figure 7.8). The greatest cumulative energy demand reduction is in the transport sector (18%), followed by buildings (8.5%) and industry (6.5%). Higher efficiency in the transport sector results from a wider adoption of fuel efficiency regulations for internal combustion engines (ICEs) (gasoline and diesel engines) and an improved public transport system. EV adoption also reduces transport sector energy consumption.

Figure 7.8 · Indonesia: Energy efficiency and renewables, TGT compared with BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewable growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Demand reductions in the buildings sector result from the rapid transition from traditional use of biomass to modern biomass and electricity; adoption of energy efficient appliances such as air conditioners, refrigerators and electric pumps; and LED lighting. Reduced demand in industry can be attributed to wider adoption of best available technologies (BATs) for new plant developments in key subsectors such as non-metallic minerals, iron and steel, and pulp and paper. Further efficiency results from a higher steel recycling rate for electric arc furnaces in the iron and steel industry, more efficient clinker production for cement, and fuel switching from coal to gas and renewables in the chemical industry.

Renewables demand in the TGT Scenario gradually increases at a 0.35% CAGR, owing to renewable capacity additions in the electricity sector, biomass in the industry fuel mix and biofuel blending in transport. However, the share of renewables in FED drops from 34% (57 Mtoe) in 2016 to 20% (64 Mtoe) in 2050 as a result of rapid growth of other fuels, and the shift from traditional biomass to electricity for cooking in the residential buildings subsector.

Installed renewable electricity capacity increases strongly from 2016 to 2030 to support the APEC goal of doubling renewable energy from the 2010 level. Electricity generated from renewable sources was 16% in 2010, and under the BAU it increases substantially to 27% by 2030. In the TGT, however, hydro power installations expand by 17 GW, biomass by 3.5 GW, and solar PV and wind power by 1.1 GW each by 2030, so that renewable electricity accounts for 30% of total generation by 2030. In 2050, electricity generation from coal and gas is 32 TWh (7.2%) and 28 TWh (9.1%) less than under the BAU.

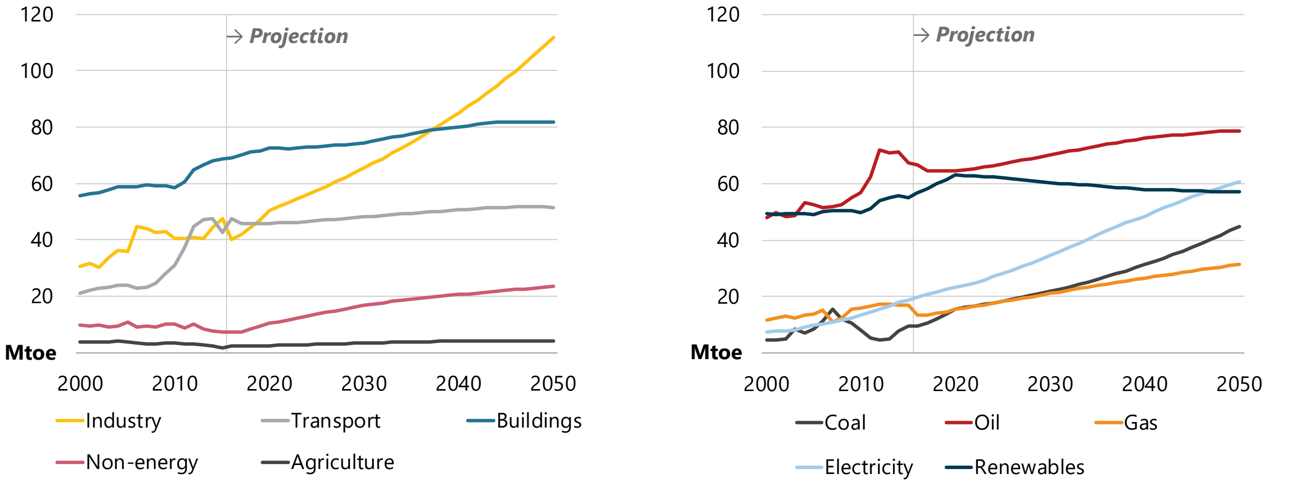
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Indonesia will have to undergo significant decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Reducing CO_2 emissions in FED under the 2DC is achieved mainly through decarbonisation of the transport sector by rapidly improving the fuel efficiency of ICEs and accelerating the deployment of EVs. Greater energy efficiency improvements and fuel switching in buildings also makes a significant contribution, with a smaller reduction in industry resulting from the deployment of BATs and greater switching from fossil fuels to renewable energy (Figure 7.9).

Figure 7.9 · Indonesia: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Cumulative domestic transport energy demand over the Outlook period falls 34% in the 2DC compared with the BAU. Road transport has the largest reduction (60%), consuming 35 Mtoe in 2050 compared with 89 Mtoe in the BAU. Demand is curtailed mainly through electrification of 2/3-wheelers and light-duty vehicles (LDVs), reducing cumulative consumption to 560 Mtoe (48% less than under the BAU). A further reduction (32%) is achieved through more efficient combustion engines in trucks and bus. Air transport, water and rail together account for a modest energy demand reduction of 0.42% in 2050 in 2DC compared with the BAU since increased efficiency is partially offset by mode shifting (from LDVs to rail, for example).

Buildings sector energy demand peaks in 2047 at 82 Mtoe and slightly decreases over the remainder of the projection period. The largest demand reduction occurs in residential buildings with rapid deployment of more energy efficient air conditioners, refrigerators and electric appliances as well as LED lighting, resulting in a 33% greater reduction than in the BAU Scenario. Building envelope improvements and transitioning from oil and gas to electricity and renewables reduce energy consumption in service buildings such that energy demand of 5.2 Mtoe in 2050 under the 2DC is 49% lower than under the BAU.

Industry sector demand in the 2DC remains strong and continues to increase from 40 Mtoe in 2016 to 112 Mtoe in 2050, 13% less than in the BAU. The non-metallic minerals subsector accounts for the largest reduction (5.1%), followed by chemical and petrochemical (1.8%), and non-energy (1.6%). Energy demand reductions in industry are achieved through more aggressive deployment of electric arc furnaces for new iron and steel plants, and to replace blast furnaces in older plants. For blast furnaces that are not replaced, using biomass cuts coal consumption. In the non-metallic minerals subsector, the installation of six-stage preheaters and pre-calciners reduces the clinker-to-cement production ratio, and in petrochemicals, carbon capture and storage (CCS) is deployed to reduce CO_2 emissions from ammonia production.

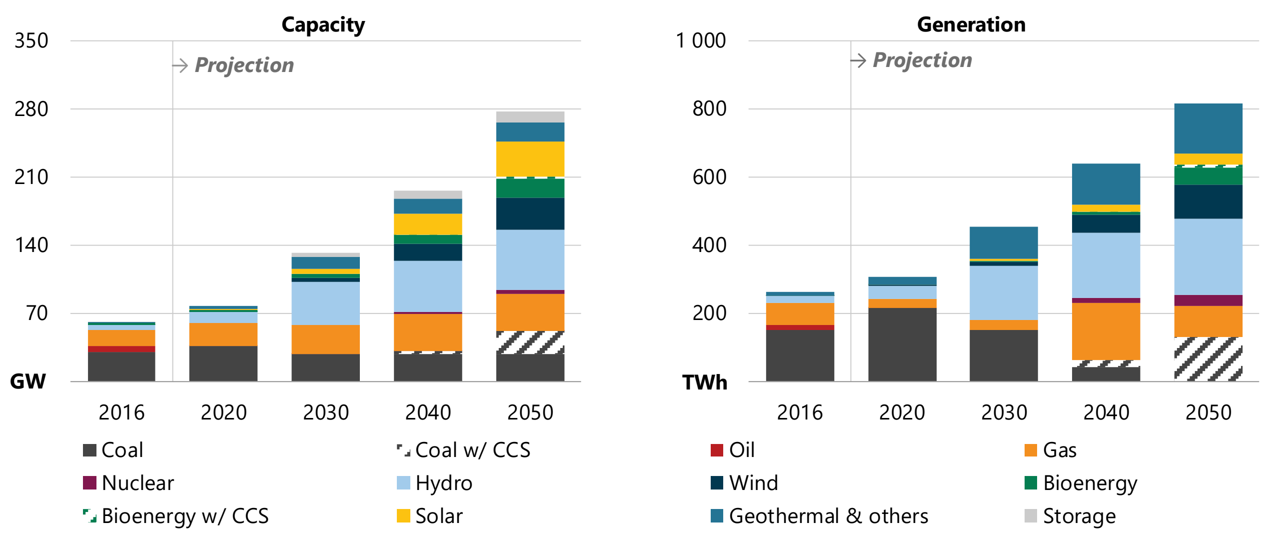
TRANSFORMATION AND SUPPLY IN THE 2DC

Electricity sector decarbonisation is essential to reducing CO_2 emissions in the 2DC and requires rapid deployment of renewables and gas-based power generation, and the introduction of nuclear power technology. In addition, biomass-fuelled power plants are fitted with CCS technology to create 'negative emissions'.[37] Many coal-fired power plants without CO_2 capture must be retired early, as only 28 GW of coal capacity can continue operating to 2050 under the 2DC—a 73% capacity reduction compared with the 102 GW of coal-fired power in the BAU Scenario (Figure 7.10). Gas-fired capacity is also cut significantly to 38 GW in 2050, 41% less than in the BAU. The stringent carbon budget requirements see regular gas turbine and combined-cycle gas turbine (CCGT) power plants to operate at lower capacity factors than in the BAU.

In addition, renewable energy expands more rapidly in the 2DC than in the BAU and TGT. Solar PV capacity is more than double the BAU at 36 GW by 2050, and geothermal power capacity reaches 19 GW by 2050 (a 39% increase from the BAU). Hydropower accounts for the largest share of renewable energy (63 GW and 36% of installed capacity in 2050), and there are 57% more biomass power plants than under the BAU (14 GW installed capacity), including 2.2 GW of biomass-fuelled power plants fitted with carbon capture technology, which is considered the most cost-effective option given Indonesia's abundant biomass resources.

In order to remain on the CO_2 emissions trajectory while continuing to meet electricity demand in the 2DC, Indonesia installs 4 GW of nuclear power by 2050. Nuclear power offers the least costly power generation solution after 2040, but other higher-cost solutions may be applicable if government policy restricts the installation of nuclear power plants due to public opposition. One higher-cost alternative is to completely retire coal-fired power plants without CCS and replace them with renewable energy.

Figure 7.10 · Indonesia: Power capacity and electricity generation in the 2DC by fuel, 2016-50



Notes: CCS = carbon capture and storage.

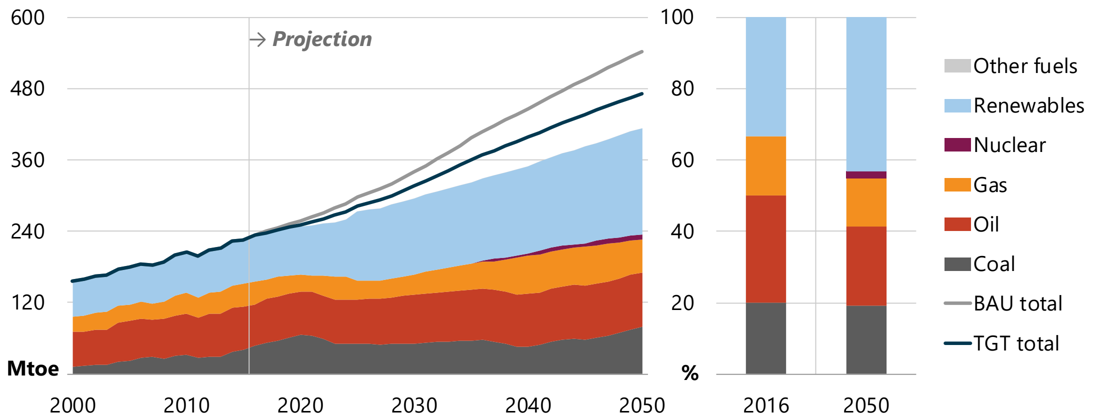
[37] Since the biomass being combusted has absorbed CO_2 from the atmosphere, storing it represents a net reduction.

Sources: APERC analysis and IEA (2018a).

Indonesia's coal production is 67% lower in the 2DC than in the BAU and 60% lower than in the TGT by 2050, but oil and gas production are similar (Figure 7.11). As the low-carbon budget in the 2DC results in substantially less coal consumption for electricity generation across the APEC region, coal exports drop considerably after 2030 when stronger CO_2 emissions restrictions are applied in the 2DC Scenario. By 2050, total coal exports amount to 29 Mtoe—84% less than in the BAU and 78% lower than in the TGT Scenario.

The 2DS also results in lower natural gas consumption in power generation as renewable energy and high-efficiency CCGTs gradually replace regular low-efficiency gas turbines. As gas production remains unchanged in the 2DC, there is enough to meet domestic demand with some left for export. Indonesia may sell its excess gas production in LNG spot markets. Crude oil imports drop to 39 Mtoe by 2050 under the 2DC, 41% less than in both the BAU and TGT Scenarios because of lower oil demand, mainly in the transport sector.

Figure 7.11 · Indonesia: Total primary energy supply in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

SCENARIO IMPLICATIONS

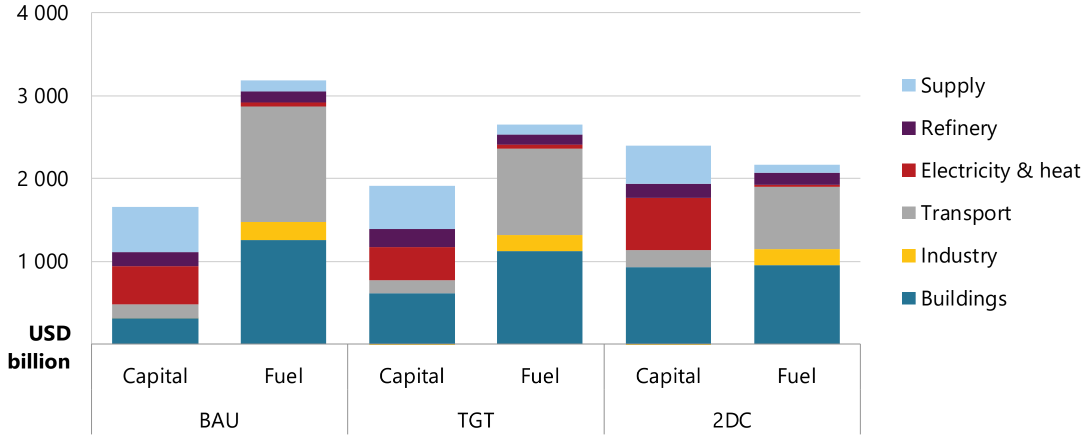
ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[38]

Indonesian energy investments are dominated by transport and buildings in all three scenarios—mostly for fuel expenditures (Figure 7.12). Total investment in the TGT and 2DS is marginally lower than in the BAU (USD 4.5 trillion in both compared with USD 4.8 trillion) as increased capital expenditure on transport and buildings is partially offset by fuel savings, due to less energy demand from domestic road transport vehicles. Increased buildings expenditure goes mainly towards improved building envelopes, space cooling, and appliances efficiency, all of which reduce energy demand.

[38] A more detailed description of the investment boundaries is provided in the Annex I Investment Methodology section.

Figure 7.12 · Indonesia: Energy sector total capital investment and fuel costs, 2016-50



Source: APERC analysis.

Of total capital investments under the BAU (USD 1.6 trillion), the largest share (33%; USD 546 billion) is allotted to energy supply infrastructure. Electricity claims the second-largest portion (28%; USD 466 billion), followed by buildings (19%; USD 312 billion) and transport (10%; USD 162 billion). An additional USD 231 billion is required in the TGT (14% more than under the BAU), and another USD 723 billion under the 2DC (44% more) due mainly to the cost of improving efficiency in end-use sectors and reducing the carbon intensity of the electricity generation sector.

Fuel costs in the BAU are more than double capital investments over the Outlook period (USD 3 190 billion compared with USD 1 653 billion) and are dominated by the buildings and transport sectors, which together account for 83%. Fuel costs in the TGT are USD 535 billion (17%) lower than in the BAU, with transport accounting for the greatest fuel-cost savings (26% or USD 358 billion lower), followed by buildings energy savings of 11% (USD 139 billion). Fuel costs in the 2DC are the lowest compared with the BAU and TGT Scenarios, at USD 1 017 billion (32%) lower than in the BAU. Supply, electricity and industry fuel costs all decrease marginally in the TGT and 2DC Scenarios owing to improved efficiency.

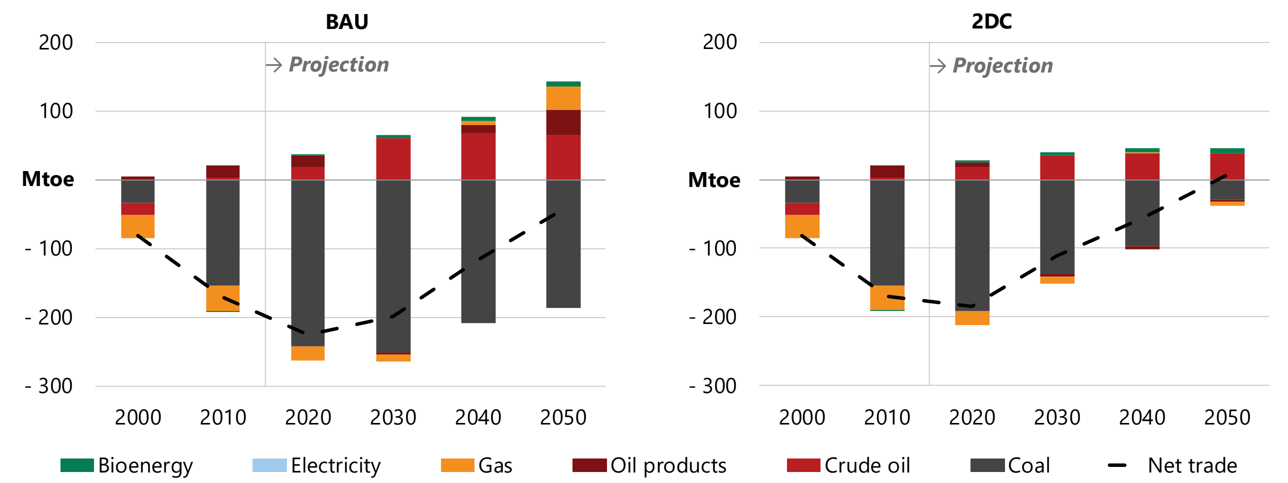
ENERGY TRADE AND SECURITY

The government of Indonesia's energy policy considers domestic energy resources more as key assets for stimulating economic growth than as commodities to be traded. Energy exports may continue when energy production exceeds domestic energy demand. In March 2019, the Indonesian government approved BP's proposal to export 84 LNG cargoes from BP Tangguh LNG Train-3 to Singapore until 2025 (Antara, 2019).

In the BAU, domestic natural gas production exceeds demand until 2040, when the trend reverses. By 2040, Indonesia therefore may need to consider importing LNG (if there are no major gas field discoveries to meet growing demand), which allows it to procure natural gas from diverse sources, including from other APEC economies. Alternatively, Indonesia has to accelerate the development of its giant gas field in East Natuna which has recoverable gas reserves between 821 and 1 614 billion cubic metres although the field contains a large volume of CO_2 (in addition to the gas reserves) (MEMR, 2016). In the 2DC, domestic gas production is sufficient to meet domestic demand as well as maintain exports, although export volumes decline 79% over the Outlook period.

Indonesia remains one of the world's largest thermal coal producers and exporters over the Outlook period. The latest MEMR decision (No.1925 K/30/MEM/2018) maintains coal production at historical levels above 460 Mt per year. Coal makes up more than 84% of total annual energy exports, despite peaking in 2030 at 251 Mtoe and then falling to 187 Mtoe by 2050 in the BAU due to rising domestic coal consumption (Figure 7.13). Coal remains the largest energy export commodity in the 2DC even though volumes are 45% to 84% lower than in the BAU between 2030 and 2050. Domestically, coal is used mainly for electricity generation and steelmaking. Coal-fired power plants consume medium- and low-calorific-value coal from Sumatra and Kalimantan. Coal mining in Kalimantan also supplies the high-calorific-value coal used in blast furnaces for steelmaking.

Figure 7.13 · Indonesia: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Oil imports continue to expand over the projection period, raising security of supply concerns as the economy becomes increasingly reliant on crude oil imports to meet domestic demand across all scenarios (Table 7.5). Crude oil imports increase by three times in the BAU, (from 8.7 Mtoe in 2016 to 66 Mtoe in 2050) and are four and half times higher than in 2016 in the 2DC (to 39 Mtoe in 2050). The trend of falling domestic crude production and rising imports does, however, presents an opportunity to promote trade with APEC member economies in which production exceeds domestic consumption, such as Canada and the United States.

Table 7.5 · Indonesia: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	89	80	84	86	72	78	88
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100	65	71	100
Crude oil self-sufficiency (%)	82	39	46	52	39	39	51
Primary energy supply diversity (HHI)	0.27	0.26	0.26	0.27	0.24	0.24	0.25
Coal reserve gap (%)	1.1	20	17	16	49	41	29
Gas reserve gap (%)	2.7	38	38	38	89	89	89
Crude oil reserve gap (%)	8.2	128	128	128	310	310	310

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

The Herfindahl-Hirschman Index (HHI) for Indonesia in 2016 was 0.27, which indicates a healthy index (Table 7.5). All scenarios show healthy HHIs over the Outlook period, despite steep declines in crude oil self-sufficiency in all scenarios. Priority will be given to the exploration of alternative fuels to optimise the fuel mix and reduce dependence on oil consumption in the transport, buildings and industry sectors. Diversifying crude oil import sources to include other APEC economies (rather than relying mainly on the Middle East) may raise Indonesia's crude oil supply security.

The Indonesian government may consider expanding its electricity transmission network for regional cooperation in the ASEAN Power Grid, which aims to interconnect the electricity grids of seven south-east Asian APEC member economies and Cambodia, Laos and Myanmar. The cross-border transmission program would improve electricity supply security by enabling the sharing of electricity generation resources, and also offer opportunities for electricity trade among south-east Asian economies.

The mandatory use of biodiesel in transport, industry and electricity has been accelerated through Presidential Regulation No. 66/2018 and MEMR regulation No. 41/2018. These programs reduce Indonesia's spending on the import on diesel oil by substituting it for biodiesel, which is produced by blending diesel oil with FAME (fatty acid methyl esters) from palm oil plantations that comply with the Indonesian Sustainable Palm Oil (ISPO) standard. Cumulative biodiesel consumption in the BAU Scenario is 445 Mtoe over the projection period, most of which is in transport (381 Mtoe or 86%) (Table 7.6). When biodiesel blending rate increases from 20% to 30% from 2020 onward, total cost saving from avoided diesel oil imports is USD 185 billion or on average USD 5.4 billion annually.

Table 7.6 · Indonesia: Biodiesel energy demand and avoided cost of diesel imports under the BAU

Sector	2016-2030		2031-2040		2041-2050	
	Demand (Mtoe)	Avoided import cost (USD billion)	Demand (Mtoe)	Avoided import cost (USD billion)	Demand (Mtoe)	Avoided import cost (USD billion)
Biodiesel demand						
Transport	110	39	123	43	148	52
Industry	17	11	17	14	23	21
Transformation						
Electricity	4.8	2.6	0.88	0.72	0.68	0.64
Total	**132**	**52**	**141**	**58**	**172**	**74**

Source: APERC analysis.

SUSTAINABLE ENERGY PATHWAY

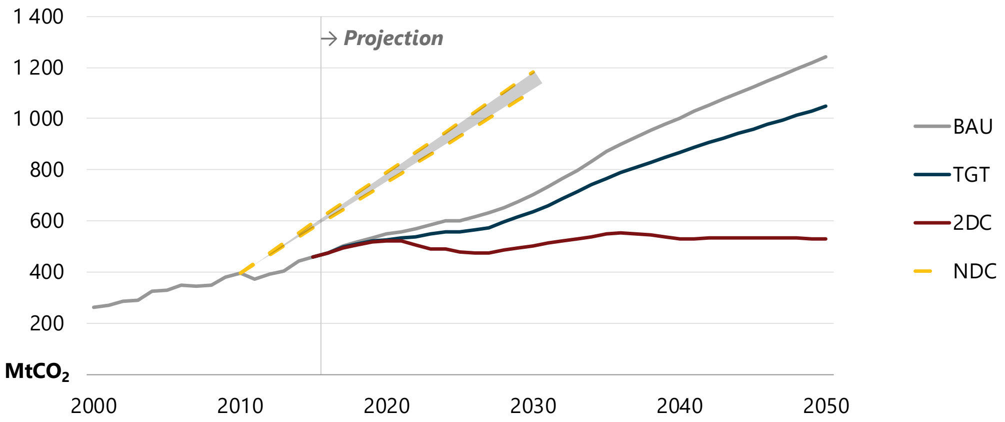
In its Intended Nationally Determined Contribution (INDC) submitted at COP21 in 2015, Indonesia committed to unconditionally reduce greenhouse gas (GHG) emissions to 26% below the 2010 level by 2020 and 29% by 2030. It also conditionally committed to a stronger GHG emissions reduction of 41% by 2020 if it receives international support such as finance, technology transfer and capacity building. In November 2016, these commitments were formalised as Indonesia's first NDC[39] (Government of Indonesia, 2016). The energy sector is

[39] NDCs reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as 'COP21 Paris Agreement'.

being held accountable for 6% of the GHG emissions reduction target[40], which is 1 355 million tonnes of CO_2 ($MtCO_2$) by 2030 in the unconditional NDC and 1 271 $MtCO_2$ in the conditional NDC.

In the BAU Scenario, CO_2 emissions rise to 1 245 $MtCO_2$ in 2050—a 155% increase from 2016 (Figure 7.14), and yet still considerably below the 2030 level stipulated in Indonesia's unconditional NDC (1 355 $MtCO_2$ by 2030). The 2DC offers a CO_2 emissions reduction pathway that can further reduce CO_2 emissions from Indonesia's energy sector. Under the 2DC, CO_2 emissions in 2050 (526 $MtCO_2$) are 7.7% higher than in 2016 (489 $MtCO_2$) and 58% less than under the BAU and 50% less than under the TGT Scenario.

Figure 7.14 · Indonesia: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

The largest CO_2 emissions reductions occur in the transport sector (61%) in the 2DC compared with the BAU, followed by buildings (40%) and industry (30%). Transport CO_2 emissions are 160 $MtCO_2$ lower in 2050 in the 2DC than under the BAU as more fuel-efficient ICEs in passenger vehicles and light- and heavy-duty trucks are deployed. The wide use of biodiesel for public transport and rail systems, as well as rapid EV deployment, significantly reduces CO_2 emissions from LDVs and 2/3-wheelers.

Buildings CO_2 emissions are 24 $MtCO_2$ (40%) lower in 2050 in the 2DC compared with the BAU. The 2DC assumes that best practices have been adopted from other APEC economies to improve the efficiency of energy utilisation in residential and service buildings. Applying higher MEPS for air conditioners also substantially reduces buildings sector energy consumption and makes Indonesian-manufactured air conditioners more competitive with imported low-efficiency ones.

Industry CO_2 emissions in 2050 under the 2DC (243 $MtCO_2$) are 30% below BAU projections. Reducing industry sector emissions in the 2DC is achieved through accelerated deployment of BATs and additional switching from fossil fuels to renewable energy sources in the 2DC. While industry-specific BATs can be installed only in new or retrofitted plants such as the six-stage pre-heater and pre-calciner in the cement industry, BATs in energy efficient machinery, such as electric motors, pumps, compressors and heat exchangers, can be applied more widely.

[40] The remainder is mostly accounted for by land use, land use change and forestry (LULUCF).

Electricity sector decarbonisation is essential to achieve the 2DC's CO_2 emissions reduction pathway. Electricity CO_2 emissions in 2050 under the 2DC (67 $MtCO_2$) are 87% below BAU projections. This is achieved through rapid deployment of renewable power generation, CCGT power plants and the introduction of nuclear power near the end of the projection period. CCS technologies are also applied to biomass power plants to create negative emissions from 2038 onwards.

OPPORTUNITIES FOR POLICY ACTION

To fulfil its NDC commitment, the Indonesian government has introduced clean/low-carbon energy transition policies that translate into medium- to long-term action plans. For example, the NEP aims for 23% renewable energy in the national energy mix by 2025 and smaller shares of coal (30%) and oil (25%). Natural gas is to account for 22% of the total primary energy mix. Indonesia may consider embracing more ambitious CO_2 reduction targets in the energy sector since the BAU projections of CO_2 emissions in 2030 (690 $MtCO_2$) are well below both conditional (1 355 $MtCO_2$) and unconditional (1 271 $MtCO_2$) NDC targets.

As coal production and exports remain strong over the projection period under the BAU, TGT and 2DC, coal-fired plants continue to contribute the largest share of electricity generation. The Indonesian government should therefore consider additional clean-coal power policies to support rapid deployment of advanced coal-based generation outside the Java-Bali grid. The government could also engage more extensively with the coal industry on commercial-scale coalbed methane (CBM) projects, as Indonesia's CBM reserves (11 415 Mtoe) are among the largest in APEC (MIGAS, 2011). Commercialisation of CBM production could be accelerated to provide domestic and export markets with an alternative fossil fuel that has a lower environmental impact than coal.

Greater policy support and further R&D are required in the biofuels industry. Indonesia's 20% biodiesel blending mandate is propelling development of this industry, but as palm oil is used for most biodiesel production, the government could harmonise transport sector biodiesel policies with those of the ISPO system. This would give Indonesia's biodiesel products access to a wider market, serving both APEC biodiesel demand and global demand for sustainable palm oil products. Indonesia could consider strengthening cooperation and trade with other APEC economies that have more advanced bioethanol industries (such as Thailand and the United States) to support its own bioethanol blending program.

A comprehensive policy, such as fuel economy regulations, should be developed to promote energy efficiency in the expanding transport sector. The rising share of oil imports in the BAU Scenario is mainly driven by oil demand in road transport, so improving the fuel economy of ICEs for passenger vehicles and light- and heavy-duty trucks is a key strategy to reduce gasoline and diesel oil demand. EVs also present medium- to long-term opportunities to improve transport efficiency and reduce oil demand. The Indonesian government could introduce policies to increase EV uptake, such as: electrifying public procurement vehicles, reducing taxes on the purchase cost of new EVs, and supporting the deployment of public and private charging stations. The automotive industry also needs a roadmap to minimise the disruption caused from transitioning to EV manufacturing. Supporting policies for domestic production of EV batteries are required, particularly relating to the mining and processing of domestic cobalt and lithium.

The Indonesian government could implement green building regulations more widely to cover all major cities, as building envelope improvements reduce energy consumption in service buildings. Energy efficient appliances are crucial in reducing energy demand in residential buildings. Adopting best practices from other APEC economies (such as Australia, Japan and the United States) would also improve the efficiency of energy utilisation in residential and service buildings, and applying higher MEPS to air conditioners would substantially reduce energy consumption and make Indonesian air conditioners more competitive with imported ones.

CCS is projected to capture a total of 874 $MtCO_2$ (18% of CO_2 emissions from the electricity sector) in the 2DC Scenario. Indonesia, with support from industry and international organisations such as the World Bank, Asian Development Bank and Global CCS Institute, has been relatively more advanced in CCS development compared with other APEC developing economies. The current demonstration project of the Merbau Gas Gathering Station may need to be expanded as a CCS-EOR system. This would improve the financial viability of installing CO_2 capture in mine-mouth coal power plants and utilising the captured CO_2 to increase oil production in the depleted oil reservoirs in South Sumatra (Atmo et al, 2019).

8. JAPAN

KEY FINDINGS

- **Japan's ongoing energy efficiency efforts coupled with modest economic growth and a declining population mean that FED decreases by 15% in the Outlook period under the BAU.** Final energy intensity improves by 42% in the period 2016-50.

- **Japan needs to consider long-term policies for energy security.** Energy efficiency, expanding renewables and nuclear energy all improve the economy's self-sufficiency rate. In the long term, however, this rate declines as existing nuclear reactors are retired under the '40-year lifetime' rule.

- **Further policy action is necessary to achieve Japan's NDC target and support the APEC energy intensity goal.** Under the BAU, energy-related CO_2 emissions reduction does not meet the NDC target.

- **The share of renewables in power generation doubles over the Outlook period under the BAU.** Solar PV under the FiT system is the main driver of renewables growth in the electricity sector.

- **Significant demand reduction, combined with decarbonising electricity supply, can help Japan contribute to global climate objectives.** Emissions in the electricity sector need to be reduced by more than 90% of the 2016 level by 2050. This could be achieved by accelerating renewable deployment, maximising the use of existing nuclear reactors and deploying CCS.

ECONOMY AND ENERGY OVERVIEW

Japan is the third-largest economy in the world and the Asia-Pacific Economic Cooperation (APEC) region with a gross domestic product (GDP) of USD 5 187 billion in 2016 (Table 8.1), up 0.94% from the previous year. The services sector contributed more than 70% of the total GDP in 2016, followed by manufacturing at about 20% (COJ, 2018). Japan's population was 128 million in 2016, slightly less than the peak in 2009 due to lower birth rates. Per capita income of USD 40 606 is about 80% higher than the APEC regional average of USD 22 536. Despite the drop in population to 109 million by 2050, GDP continues to grow at a compound annual growth rate (CAGR) of 1.1% over the Outlook period (2016-50). This growth is driven by the services subsector.

Table 8.1 • Japan: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	4 584	4 885	5 187	5 415	6 118	6 876	7 649
Population (million)	128	129	128	126	122	115	109
GDP per capita (2016 USD PPP)	35 945	38 002	40 606	42 808	50 318	59 681	70 310
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	527	509	436	441	428	397	375
TPES per capita (toe)	4.1	4.0	3.4	3.5	3.5	3.4	3.4
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	115	104	84	81	70	58	49
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	331	314	294	288	276	261	250
FED per capita (toe)	2.6	2.4	2.3	2.3	2.3	2.3	2.3
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	72	64	57	53	45	38	33
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	1 214	1 187	1 159	1 120	1 023	998	947
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

Limited domestic fossil fuel resources and high dependence on imports has made energy security a high priority for the government. Since the two oil crises in the 1970s, Japan has implemented policies aimed at strengthening energy efficiency and diversifying the energy mix. Japan has achieved the highest efficiency in APEC in terms of final energy intensity per GDP, led by continuous efforts across all end-use sectors (EGEDA, 2018). Share of oil in total primary energy supply (TPES) has decreased from 72% in 1970 to about 40% in 2016, while natural gas increased from 1.3% to 24% (METI, 2018a).

Since the Basic Act on Energy Policy was enacted in 2002, Japan has focused on the '3E' goals—ensuring energy security while adapting to the environment and pursuing economic efficiency. The Fukushima Daiichi nuclear accident in March 2011, however, created significant challenges for Japan in pursuing the '3E' policy. Although renewables have expanded thanks to the feed-in tariff (FiT) system introduced in 2012, the shutdown of nuclear reactors, which are considered to be a 'quasi-domestic' energy resource, reduced the energy self-sufficiency rate from roughly 20% in 2010 (the last year before the accident; METI, 2018a) to 8.1% in 2016. Energy related carbon dioxide (CO_2) emissions have increased by 9.2% in 2016 compared with the 1990 level, reaching

1 121 million tonnes of CO_2 ($MtCO_2$). To re-structure its energy policy, Japan revised the Strategic Energy Plan in 2018 aiming at the '3E+S' policy—the '3E' plus safety as the foremost condition. Japan now aims to reduce nuclear dependency to the extent possible by accelerating energy efficiency and renewable energy deployment.

ENERGY RESOURCES

Japan is endowed with only limited fossil fuels reserves. Domestic coal reserves are about 350 million tonnes (Mt) or 245 million tonnes of oil equivalent (Mtoe), which is much less than Japan's annual demand in fiscal year (FY) 2016 (BP, 2017; METI, 208a). [41] Natural gas reserves are around 21 billion cubic metres (bcm) or 19 Mtoe, which is around one-fifth of 2016 annual demand (BP, 2018). Methane hydrate is the most prospective unconventional fossil fuel for Japan with an estimated resource of 1.1 trillion cubic metres (Nagakubo, 2019), amounting to ten times Japan's liquefied natural gas (LNG) imports in 2016. The government and private sector cooperate to advance technologies to develop resources in an economical manner.

Japan has a wide variety of renewable energy resources, including solar, onshore/offshore wind, geothermal and hydro. Estimated potential of rooftop solar photovoltaic (PV) is 63 terawatt-hours per year (TWh per year) to 223 TWh per year, which is equivalent to between 5.9% and 21% of the total electricity generation in 2016.[42] Onshore wind potential is 693 TWh per year or 65% of the total electricity generation in 2016 (MOE, 2013; MOE, 2016). Although renewables have abundant potential, various technical, economic and institutional challenges hinder their uptake. The intermittent nature of solar PV and wind power poses grid operation issues, including frequency control and excess electricity. Solar power in the Kyushu region has been curtailed several times since October 2018 to ensure supply-demand balance. A large amount of rooftop panels connected to the distribution network also creates voltage control issues. Japan's onshore wind potential is spatially imbalanced; three-quarters of onshore wind energy potential is in Hokkaido and Tohoku, far north of the major electricity-consuming areas in Tokyo and Kansai. More than 70% of geothermal energy potential is in protected National Park Areas (MOE, 2013). While the government has relaxed some regulations to allow directional horizontal drilling in specified zones, long lead-times because of resource feasibility surveys and environmental assessments, has slowed development (MOE, 2015).

The government is currently discussing new policy measures to overcome such challenges. In April 2018, the Ministry of Economy, Trade and Industry (METI) started to review operational rules for the transmission and distribution network, including the 'Japanese Connect and Manage' rule, to expand the connection of renewables. The Organization for Cross-regional Coordination of Transmission Operators, Japan (OCCTO) manages the power grids ensuring inter-regional transmission capacity and boosting the use of renewable energy to achieve an optimal economy-wide secure and stable electricity supply.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

METI is in charge of Japan's energy policy and markets. The Basic Act on Energy Policy outlines core principles, such as energy security, environmental considerations and the market mechanism. Based on the Act, the government develops Strategic Energy Plans that provide a general direction for energy policy. The fourth plan, approved by the Cabinet in 2014, considered the energy situation after the Fukushima Daiichi nuclear accident

[41] Japan's fiscal year starts from April.
[42] The MOE (2013) estimated three sets of rooftop PV potential, varying assumptions for available rooftop space. The range indicates the minimum and maximum potential in Japan.

(METI, 2014). This plan was based on the '3E+S' policy and aimed to reduce nuclear dependency by strengthening energy efficiency and accelerating renewable energy. These core directions have been carried through into the current fifth plan, which was approved in July 2018 (METI, 2018b). The fifth plan also retains the Long-term Energy Supply and Demand Outlook (METI, 2015a), released by METI in July 2015. This outlook indicates the desired energy and electricity mix in FY 2030; total generated electricity comprises LNG (27%), coal (26%) nuclear (20% to 22%), renewables (22% to 24%) and oil (3%). The government outlook is also the basis for the nationally determined contributions (NDCs) to reduce greenhouse gas (GHG) emissions by 26% and energy-related CO_2 by 25% in the period FY 2013-30.

Since the Fukushima Daiichi nuclear accident, Japan has been implementing policies aimed at ensuring nuclear safety and promoting renewables and energy efficiency. The Nuclear Reactor Law was amended in 2012 to limit the operation of nuclear reactors to 40 years, with a possible additional lifetime extension of 20 years, known as the '40-year lifetime rule'. The Nuclear Regulation Authority (NRA), which is responsible for nuclear safety regulations, was also established in 2012. A FiT system, which boosted solar PV penetration via higher purchase prices, was also introduced in 2012. In June 2018, authorised capacity under the FiT system reached 88 gigawatts (GW), of which 71 GW is solar PV (METI, 2018c).[43] METI revised the FiT system in 2017 to promote other types of renewables with longer lead-times, such as biomass, geothermal and wind, while accelerating the cost reduction of solar via an auction system for utility-scale PV. For other renewable energy technologies, the government has begun to determine purchase prices for the next three years to improve the predictability of projects. Japan also introduced the Tax for Climate Change Mitigation in October 2012, which is levied on crude oil, petroleum products, natural gas and coal (MOE, 2012). The tax value has been JPY 289 (USD 2.6[44]) per tonne of CO_2 since April 2016. Revenue from this tax is used to implement various measures promoting energy efficiency, renewable energy and the efficient use of fossil fuels.

The nuclear accident also triggered reform of Japan's electricity and gas markets to create a more competitive and transparent system. The Electricity Business Act was amended in 2013. This amendment was to establish the OCCTO in April 2015, to fully liberalise the retail market in April 2016, and to legally unbundle the transmission and distribution sectors by 2020. To ensure a secure, stable and low-carbon electricity supply, the government will open the following markets: a non-fossil fuel market in FY 2018 for FiT electricity, a base-load market in 2019, and real-time and capacity markets in FY 2020 (METI, 2017a). Market mechanisms become the key drivers in Japan's electricity supply in the near future. Like electricity, the gas retail market has been fully liberalised since April 2017. Japan also plans to legally unbundle the gas pipeline networks by April 2022, which are owned by three of the largest city gas utilities—Tokyo Gas, Osaka Gas and Toho Gas.

To promote energy security and reduce CO_2 emissions, Japan has recently reaffirmed the potential of hydrogen, which can be produced from diverse energy sources. The government published the Basic Strategy for Hydrogen in 2017 (METI, 2017b), which targets the start-up of hydrogen-powered electricity generation in the late 2020s and the establishment of a 'CO_2-free' hydrogen supply chain by around 2040.

[43] The 'authorised capacity' includes capacity that is registered under the FiT system but not yet installed. The authorised capacity in Jun 2018 are the latest data publicly available as of January 2019.
[44] Throughout this chapter, JPY are converted to USD at 109:1, which was the exchange rate on 29th January, 2019.

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy demand and supply assumptions for Japan under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 8.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere; for example, some targets and goals are based on the Japanese FY, while this Outlook is made on a calendar year basis.

Table 8.2 • Japan: Key assumptions and policy drivers under the BAU

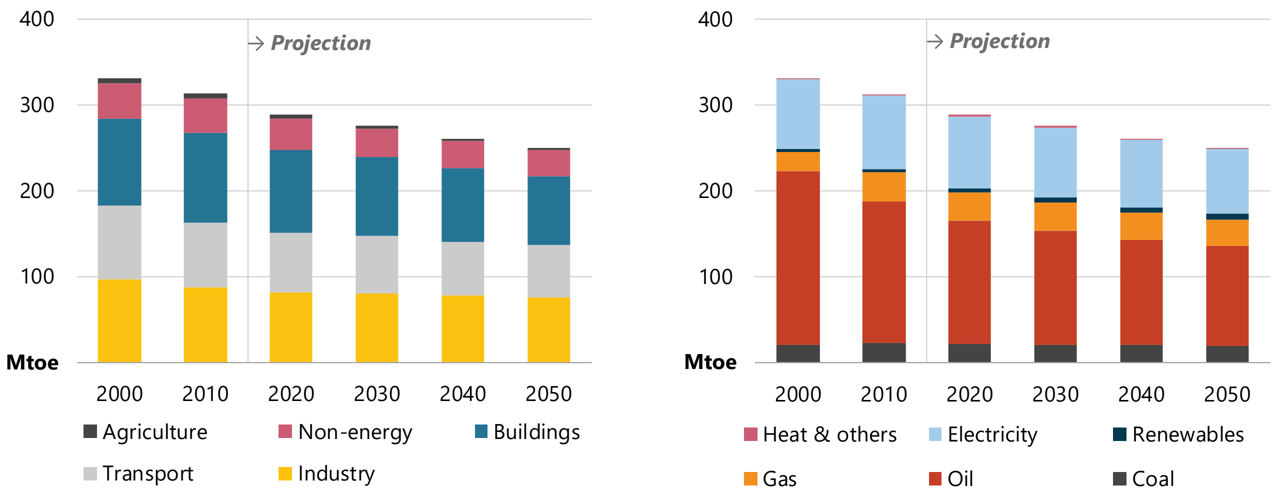
Buildings	Efficiency improvements in household and office appliances driven by the Top Runner Program. Continue to shift from oil to cleaner and more efficient fuel sources, such as electricity and natural gas.
Industry	Production of the most energy-intensive industries declines. Although reconstruction in the Tohoku region and the construction boom for the 2020 Tokyo Olympic Games creates demand for some industrial products (such as crude steel) in the short to medium term, they are partially offset by declining population and domestic markets. Energy intensive industries maintain current energy intensity.
Transport	Fuel economy improvements driven by the Top Runner Program. Expanding penetration of gasoline hybrid LDVs, replacing conventional gasoline vehicles.
Energy supply mix	Remain heavily reliant on fossil fuel imports given limited domestic resources. Methane hydrate is not included.
Power mix	Power producers' long-term plans are included (OCCTO, 2018). Renewables expansion is driven by solar PV, although other fuel types increase gradually following revisions to the FiT system. Nuclear reactor retirements in the period 2016-19 are based on reactor owners' announcements. Other existing nuclear reactors, except for those where lifetime extension has already been approved by the Nuclear Regulation Authority as of December 2018, retire after 40 years of operation. Three nuclear reactors, which are under construction as of 2018, start operation around the mid-2020s.
Renewables	FiT system continues to promote renewables with longer lead-times, including geothermal, wind and biomass power generation. Biofuel supply mandate for oil refining companies.
Energy security	Maintain current policies to decrease oil dependence and diversify energy sources.
Climate change	Japan's NDC, which aims to reduce GHG emissions by 26% and energy-related CO_2 by 25% below the FY 2013 level by FY 2030, is not achieved under the BAU given less nuclear and more coal-fired generation. The electricity sector's emission intensity target of 0.37 $kgCO_2/kWh$ in FY 2030 is not included, either (FEPC, 2015). Japan's long-term target, aiming to reduce GHG emissions by 80% by 2050, is not included (COJ, 2016). New and innovative low-carbon technologies, such as hydrogen (except for fuel cell vehicles), small modular nuclear reactors, nuclear fusion and space solar power, are not included, although the government encourages research and development.

Notes: LDVs = light-duty vehicles. FiT = feed-in tariffs. kg/kWh = kilogram per kilowatt-hours; GHG = greenhouse gas emissions; $kgCO_2/kWh$ = kilogram of carbon dioxide per kilowatt-hour. The emissions intensity target in the electricity sector is defined as emissions from power generation divided by delivered electricity to the end-users. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Since the oil crisis in the 1970s, Japan has implemented a number of policies to strengthen energy efficiency and security, starting with the Energy Conservation Law of 1979. This law was instrumental in improving energy intensity in industry in the 1980s, resulting in the final energy demand (FED) of the sector per indices of industrial production (IIP) decreasing by 46% in the period 1973-89 (METI, 2018a). By contrast, energy demand in the buildings and transport sectors increased during the same period (METI, 2015a). In response to these findings, the government launched the Top Runner Program in 1998, which enforces stricter efficiency standards for buildings and transport. This program was introduced under the framework of the Energy Conservation Law in 1979 and initially covered 11 items, including cars and air conditioners, and was later expanded to include 31 items as of 2017 (METI, 2017c). These energy efficiency efforts coupled with moderate economic growth and a peaking population, resulted in Japan's energy demand stagnating in the early 2000s. Demand then declined in the wake of the global economic recession of 2008-09 and the Great East Japan Earthquake in 2011, which slowed economic activity (Figure.8.1).

Figure 8.1 • Japan: Final energy demand by sector and fuel, 2000-50



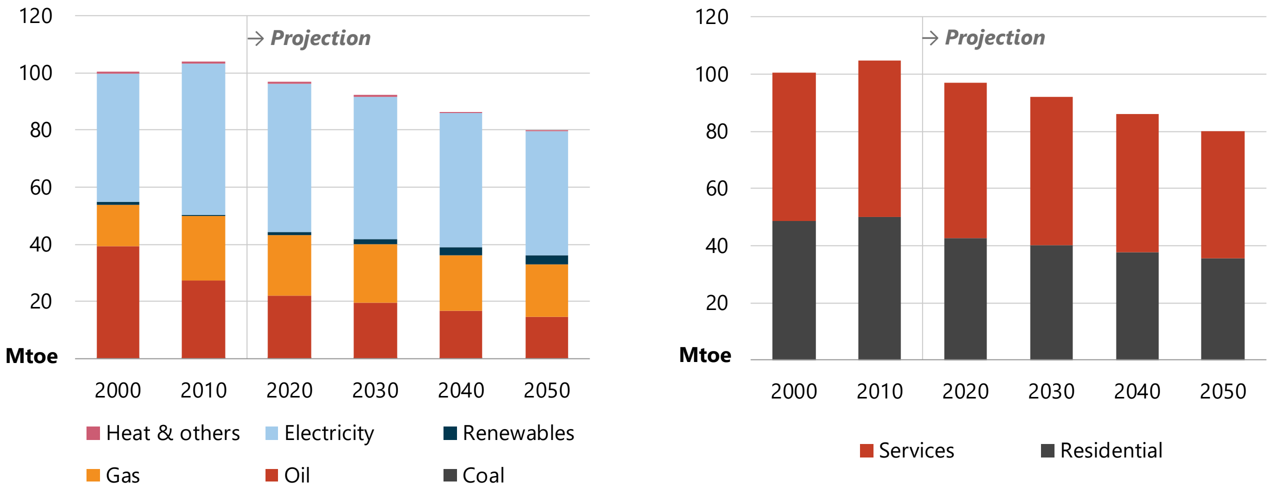
Sources: APERC analysis and IEA (2018a).

Under the BAU, energy demand decreases over the Outlook period, driven mainly by ongoing efficiency efforts and a declining population. FED decreases by 15% (-0.48% CAGR) from 294 Mtoe in 2016 to 250 Mtoe in 2050. Buildings and transport do the most to help curb energy demand with aggregate demand dropping by 17% (29 Mtoe) over the Outlook period. By contrast, decreases in industry and non-energy sectors are much less discernible as the sector already underwent intensive efficiency efforts in the 1980s. Under the BAU, final energy intensity improves by 42% in the period 2016-50.

BUILDINGS: ENERGY EFFICIENCY POLICIES DRIVE FALLING DEMAND

The buildings sector is one of the largest energy-consuming sectors in Japan, accounting for one-third of FED in 2016. Over the last two decades, the sector has switched from oil to cleaner, more efficient and safer fuels for the end user, such as electricity (Figure 8.2). Surging oil prices in the 2000s also accelerated this shift. The Top Runner Program, which was strengthened by the government to cover items contributing to energy conservation (e.g. building insulation), also helped curtail energy demand in buildings. This trend continues under the BAU driven by these policies and socioeconomic factors, such as a declining population. Electricity remains dominant, while oil continues to lose its share. FED in buildings decreases by 18%, from 98 Mtoe in 2016 to 80 Mtoe by 2050.

Figure 8.2 • Japan: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Japan's residential subsector has changed significantly as households replace oil-fuelled equipment with electrical appliances (for example, moving from kerosene heaters to hot air conditioners) over the past decade, which has led to a noticeable shift in the fuel mix. Although the number of households has increased since the 2011 earthquake, residential energy demand has dropped by 11%, from 50 Mtoe in 2010 to 44 Mtoe in 2016. Economy-wide energy conservation activities and penetration of highly efficient equipment have underpinned this change (METI, 2018a).

Over the Outlook period, residential demand continues to decline at a CAGR of -0.64%, reaching 36 Mtoe in 2050. The number of households peaks before 2020 and by 2050, average energy intensity for two major end-use activities improves compared to 2016 levels—space heating by 20% and water heating by 2.7%. These factors combine to curtail residential energy demand, particularly for electricity. The share of oil in residential demand drops gently from 27% to 26% in 2050. As of 2010, 45% (24 million) of Japan's households are located outside city gas distribution networks and rely on liquefied petroleum gas (LPG) for water heating and cooking (LPGC, 2011). The BAU does not project a large expansion in natural gas distribution infrastructure, nor a significant shift away from LPG towards all-electric households.

The services subsector includes activities related to trade, finance, real estate, public administration and commercial services. Like households, services has been substituting oil products for electricity in space heating over the past two decades. Energy efficiency has also been effectively promoted in the services subsector. Although total floor area has been increasing in the period 2000-16, energy demand grew at a much slower pace.

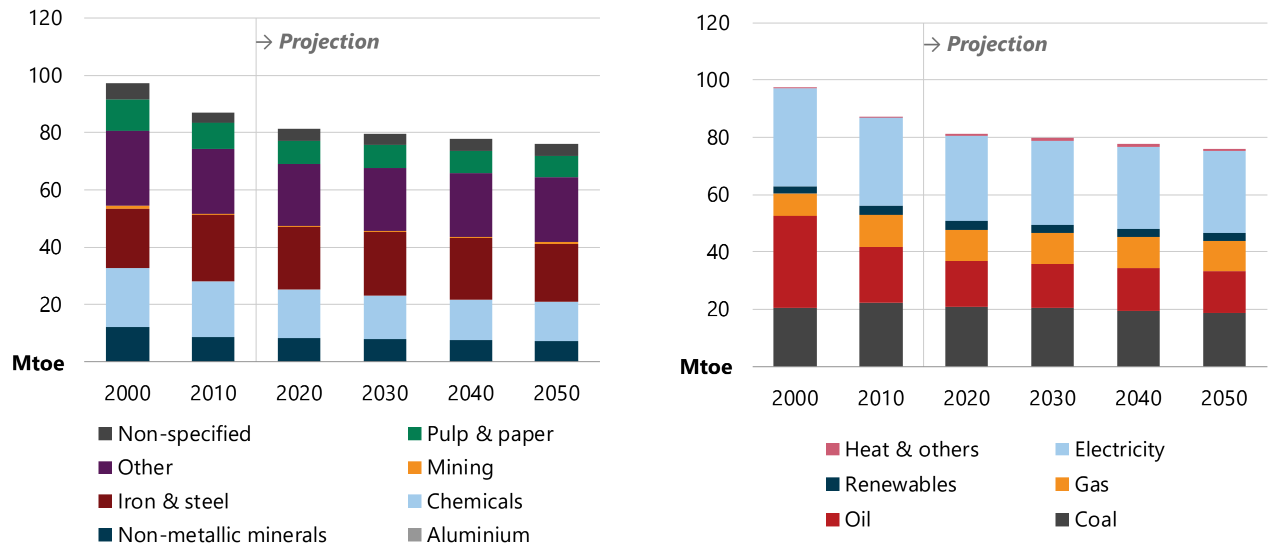
Such efforts continue under the BAU; floor area remains largely the same but energy demand in services decreases by 17% over the Outlook period 2016-50. Space heating, space cooling and lighting together largely contribute to this decline as continuing efficiency improvements are made to electrical appliances. Energy demand reduction campaigns, such as 'cool biz' and 'warm biz', which have also curtailed energy demand, are assumed to continue under the BAU. These two campaigns were introduced in 2005 by the Ministry of the Environment and are aimed at reducing Japan's electricity demand and CO_2 emissions by limiting the use of space cooling and heating. They call for workplaces to introduce a more liberal dress code and to set their air conditioners to 28°C for cool biz, usually from May to September, and 20°C for warm biz, from November to March. By 2050, oil demand shrinks by half as oil-fuelled boilers for space heating and water heating continue to be switched to gas-fuelled space heating system and/or heat pumps. As a result, demand for electricity and natural gas remain robust over the Outlook period compared with petroleum products.

INDUSTRY: ENERGY DEMAND DECLINES GENTLY

Industry is the second-largest energy-consuming sector in Japan, accounting for 28% of FED in 2016. This sector consists of energy-intensive industries such as iron & steel, non-metallic minerals, chemicals, and pulp & paper, which all produce raw materials. The sector also includes less energy-intensive industries such as machinery, transport equipment, food and tobacco. In Japan, the four energy-intensive industries hold the majority share in terms of energy demand (68% of industry FED), while the less-energy intensive contributed the majority of industrial GDP in 2016 (COJ, 2018). The sector's energy demand has decreased by 10% in the period FY 1973-2016 (since the first oil crisis) while industrial output has increased by 60% (METI, 2018a). Strong efficiency efforts to reduce oil dependence, as well as a structural shift to less energy-intensive industries have helped curb energy demand.

Energy demand in industry gradually decreases, from 82 Mtoe in 2016 to 76 Mtoe in 2050 (Figure 8.3). Although economic recovery in the Tohoku area and infrastructure needs for the Olympic Games in Tokyo in 2020 create domestic demand for some industrial products (such as steel) in the short to medium term, these impacts are partially offset by declining population and domestic market size. Crude steel production was 105 Mt in 2016; under the BAU this volume slightly increases to 108 Mt in 2030 before decreasing to 98 Mt in 2050. By contrast, chemicals decline steadily as some products, such as ethylene, come under stiff competition from overseas suppliers. Demand for pulp and paper also declines by 13% as digitalisation leads to a much less paper-intensive lifestyle.

Figure 8.3 • Japan: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

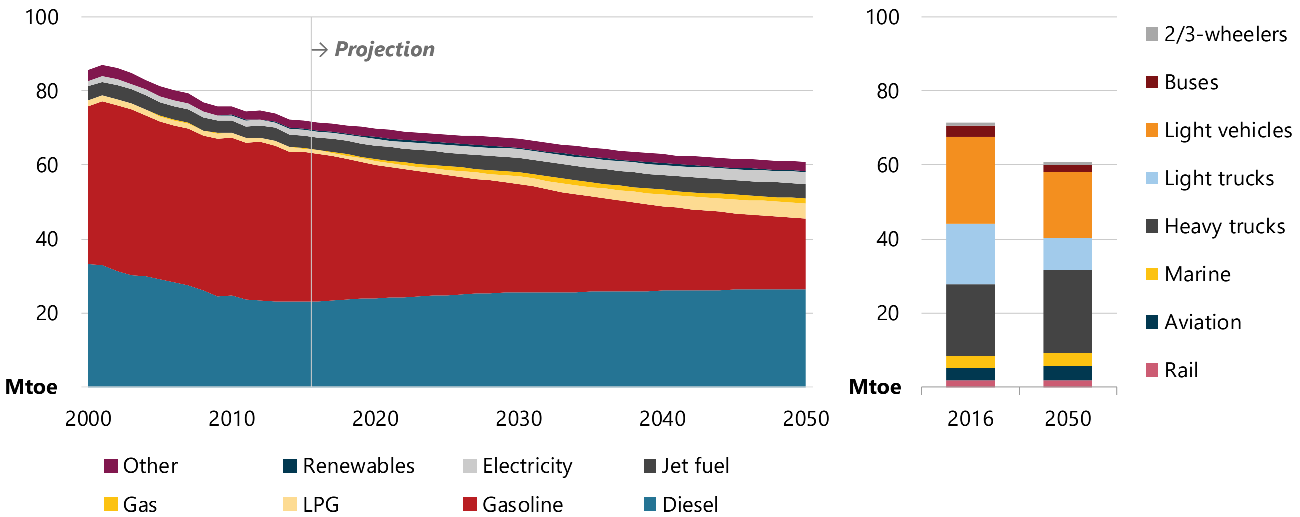
The fuel mix remains almost at the current level as the BAU does not assume major process changes in Japan. Coal remains at 26% to 25% over the Outlook period, oil is 19% to 20%, natural gas is 14% and electricity is 36% to 38%. Japan has already achieved some of the highest global energy efficiency rates in several industries, such as iron and steel, and cement (Oda, et al., 2012), which are maintained over the Outlook period.

DOMESTIC TRANSPORT: GASOLINE DEMAND DROPS WITH IMPROVED FUEL ECONOMY

Energy demand in domestic transport is driven mainly by road transport, which accounted for 88% of the sector's FED in 2016, followed by domestic aviation (4.7%). Demand peaked around 2000, due to saturated mobility demand and ongoing fuel economy improvements in road transport. The Top Runner Program covers both passenger and freight vehicles and achieved efficiency improvements of 49% (passenger) and 13% (freight) in the period FY 1995-2010 (METI, 2015b). Petroleum products, such as gasoline and diesel, dominate the fuel mix, accounting for 97% of domestic transport FED in 2016.

Domestic transport energy demand declines by 15% at a CAGR of -0.48% in the period 2016-50 (Figure 8.4), underpinned by decreasing gasoline demand. This improvement is driven by the increasing penetration of high-efficiency vehicles in passenger transport (gasoline hybrids) and declining passenger transport demand (passenger-kilometres). Under the BAU, gasoline hybrids reach 36% of the total light-duty vehicle (LDV) stock in 2050, compared with 8.2% in 2016. Diesel demand drops virtually disappears by 2050 from 0.29 Mtoe in 2016. Although fuel economy of diesel-powered heavy-duty vehicles (HDVs) improves, the impact is partially offset by increasing freight transport (tonne-kilometres) due to economic growth.

Figure 8.4 • Japan: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

The Strategic Energy Plan aims to increase the share of next generation vehicles (NGV), such as gasoline hybrids, electric, plug-in hybrid electric, 'clean diesel' and compressed natural gas-powered (CNG) vehicles, to between 50% and 70% in new total LDVs sales by 2030 (METI, 2018b). Under the BAU, the share of NGVs in new sales is 46% in 2030, of which more than half is gasoline hybrid vehicles; thus, gasoline-fuelled vehicles continue to dominate the LDV stock under the BAU. Battery electric and fuel cell LDVs also steadily grow over the longer term, reaching 17% of total stock in 2050 (14% of battery electric plus 2.8% of fuel cell vehicles).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Although Japan is the fourth-largest economy in APEC in terms of TPES, it relies on imports for nearly all of its energy supply given the limited domestic resources. To enhance energy security, the government has implemented policies to increase the economy's energy self-sufficiency rate, including nuclear power as a 'quasi-domestic' energy resource, and diversify fuel types and import origins. The nuclear accident in Fukushima and subsequent reactor shut-down significantly reduced the self-sufficiency rate posing challenges to energy security.

ENERGY INDUSTRY OWN-USE: REFINERY OVERCAPACITY IN THE BAU

To use crude oil effectively, the government has been regulating domestic refining capacity through the Act on the Promotion of the Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Materials by Energy Suppliers. The Regulation requires refining companies to raise the ratio of the heavy-oil cracking unit and residues processing unit to total distillation capacity and promote production of higher-value oil products from residues (gasoline and naphtha instead of asphalt). Oil-refining companies adhered to the Regulation mainly by reducing distillation capacity. The number of oil refineries in Japan decreased from 40 in 1996 to 22 in March 2018, with refining capacity also decreasing from 5.3 million barrels per day (263 Mtoe per year) to 3.5 million barrels per day (175 Mtoe per year; PAJ, 2017). New regulations promoting production of high-value petroleum products were enforced in October 2017. Under these regulations, refineries are required to set a target utilisation rate for their residue processing units by FY 2021.

Domestic final demand for oil declines by 22% in the BAU over the Outlook period, which could result in lower refining capacity factors and reduced profitability. Oil refining companies would need to seek opportunities to export their products or further reduce refining capacity. The government therefore may need to implement additional policies, either directly or indirectly, to resolve the issue, on top of the current regulation.

POWER: RENEWABLES GROW STEADILY

The government reformed the electricity system after the 2011 nuclear accident and the BAU Scenario incorporates recent policy directions, regulations and power producers' plans. Japan has fully liberalised power generation and retail markets and plans to legally unbundle transmission and distribution networks by 2020. Cost competitiveness is therefore the major driver of future electricity supply. Japan also aims to reduce nuclear dependence while strengthening energy efficiency and expanding renewable energy use, as stated in the Strategic Energy Plan (MEIT, 2018b). The BAU assumes the '40-year lifetime rule' for all plants, except for reactors that will be retired or whose lifetime extension was approved by the NRA (Table 8.2).

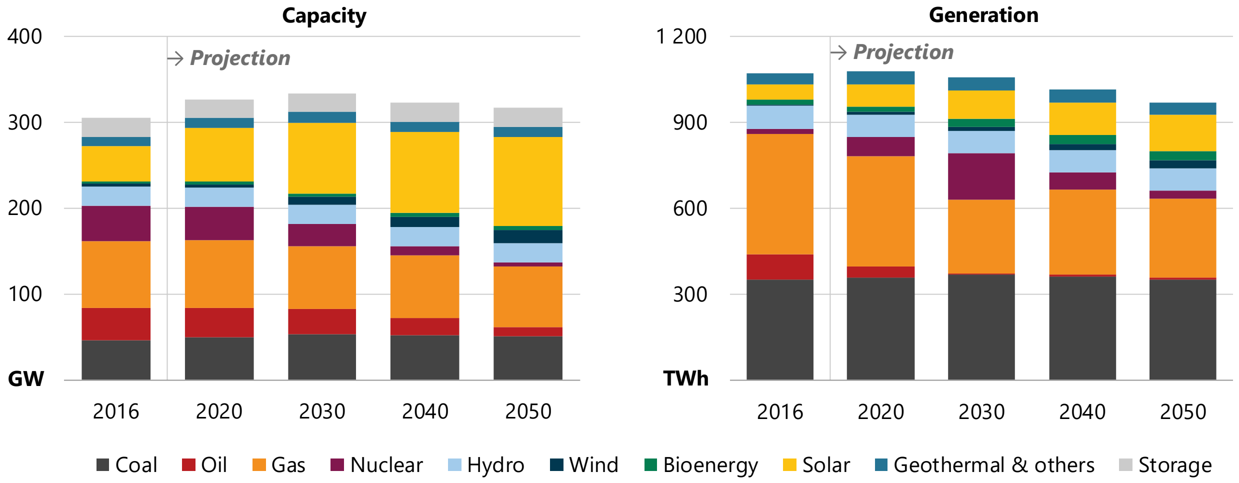
To promote renewables, Japan introduced a FiT system in 2012. As of June 2018, authorised capacity under the FiT was 88 GW (of which solar PV is 71 GW; wind 6.9 GW; biomass 8.6 GW and other renewables 1.2 GW) and 43 GW of which had been installed. The BAU assumes that almost all authorised wind power and solar PV capacity is installed by 2030; whereas some biomass projects are cancelled given fuel procurement and financing issues.[45] The Organization for Cross-regional Coordination of Transmission Operators, Japan (OCCTO) is required to submit an annual summary of the long-term plans of power producers to METI. As of 2018, coal-fired power plants feature heavily among plans for fossil-fuel power capacity; from 2017 to 2027, total coal-fired power capacity grows by 8.4 GW, whereas gas capacity decreases in the same period. The slight drop in natural gas-fired capacity is partially because of planned retirements of existing plants.

Japan is the only economy in APEC in which electricity demand decreases over the Outlook period (at a CAGR of -0.29%), from 1 072 TWh in 2016 to 970 TWh in 2050. This decline is largely due to the mature economy and improved efficiency in end-use sectors (Figure 8.5). Power generation capacity peaks in the 2020s as ageing nuclear reactors and oil-fired power plants retire. Solar PV becomes the technology with the largest capacity by 2050. Nuclear capacity drops from 42 GW to 4.1 GW over the Outlook period, while solar PV more than doubles

[45] The Biomass Power Association (BPA) of Japan, for example, projects that actual installation could be 20% of authorised capacity (BPA, 2017).

from 42 GW to 104 GW. Almost one-third of new capacity is projected to be solar PV. Flexible power plants as well as pumped hydro storage (total 22 GW in 2050), lead to higher integration of intermittent sources of renewable energy.

Figure 8.5 • Japan: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

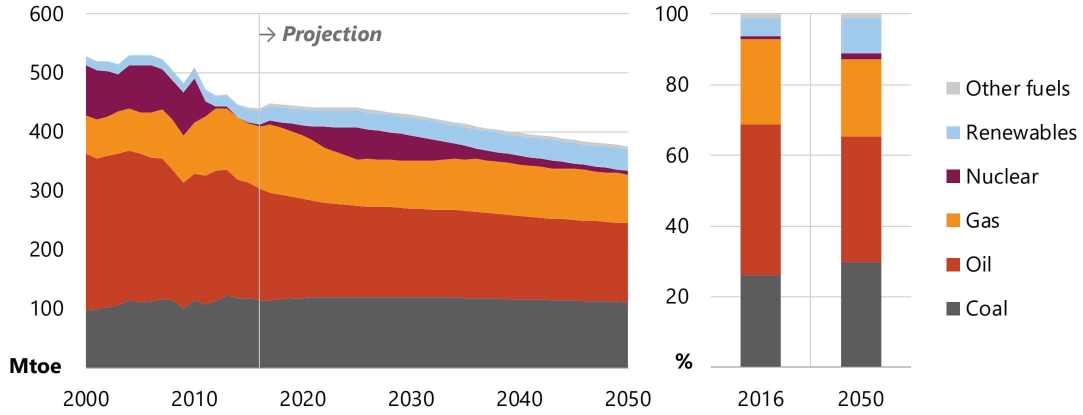
In the short to medium term, restarting nuclear power plants reduces natural gas and oil-fired power generation, which increased to cover the loss of nuclear generation after the 2011 accident. In the long term, natural gas-fired power generation resumes growth as existing nuclear reactors are retired. Renewables increase steadily in the generation mix, driven by solar PV but at a slower rate than in the capacity mix due to a relatively lower capacity factor. The power generation mix in 2030 consists of coal (35%), natural gas (25%), renewables (21%), nuclear (15%) and other fuels (4.0%). Compared with the government's outlook (see the section 'Energy Policy Context and Recent Developments'), renewables almost reach the target share; whereas nuclear is far lower because of retirements. This results in a higher share of coal-fired plants, which instead supply baseload demand. To achieve the share of nuclear outlined by the government, lifetime extensions and/or further new reactor additions would be necessary.

Several electricity business associations and utilities have voluntarily published an action plan for a low-carbon society, targeting an emissions intensity of 0.37 kilogram of carbon dioxide per kilowatt-hour demand ($kgCO_2$/kWh) by FY 2030 (FEPC, 2015). This target is in line with the government's Long-term Energy Supply-Demand Outlook (METI, 2015a). Emissions intensity under the BAU is estimated at 0.44 $kgCO_2$/kWh in 2030. Less nuclear and larger coal-fired generation under the BAU result in higher emissions intensity.

TOTAL PRIMARY ENERGY SUPPLY: LONG-TERM SECURITY CHALLENGES REMAIN

Fossil fuels have long dominated Japan's TPES, accounting for 78% in 2010—the year before the Fukushima Daiichi accident—and 92% in 2014, which was the first year without nuclear power since 1966 (Figure 8.6). Nuclear, which contributed to 15% of TPES in 2010, was replaced mainly by natural gas and coal, and by energy conservation efforts. Compared to the year 2000, Japan's TPES in 2016 dropped by 17%, from 527 Mtoe to 436 Mtoe, driven by declining oil demand in road transport and energy conservation activities after the nuclear accident.

Figure 8.6 • Japan: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

TPES in the BAU is projected to continue to decline to 380 Mtoe in 2050, reflecting the downward trend in energy demand. BAU projections highlight continuing challenges for Japan's long-term energy security. Nuclear reactor restarts in the short to medium term help the economy improve its energy self-sufficiency rate (to 18% in 2030 from 8.1% in 2016). In the longer term, however, nuclear retirements following the '40-year lifetime rule' again push down the self-sufficiency rate (13% in 2050). Although renewable energy is projected to grow steadily, the self-sufficiency rate in 2050 is below the 2010 level. Lifetime extensions of nuclear reactors and/or accelerated penetration of renewables would be necessary to maintain self-sufficiency in the long-term.

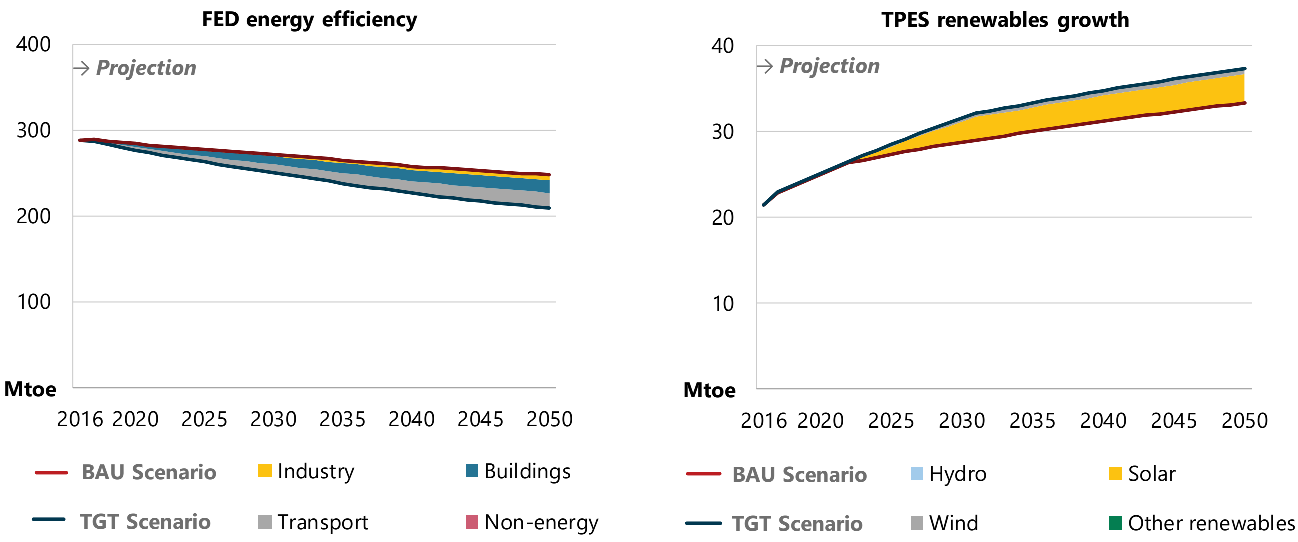
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Japan's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increased energy intensity and renewables deployment, and reduced CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that are sufficient, in unison with worldwide efforts, to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 15% lower while CO_2 emissions are 19% lower in 2050 in the TGT. Under the 2DC, the economy's FED in 2050 is 31% lower and CO_2 emissions are 61% lower.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. In 2050, FED is curtailed by 15%, from 250 Mtoe (BAU) to 211 Mtoe (TGT). The buildings and transport sectors together contribute 81% of this reduction, driven by accelerated penetration of more efficient appliances and building envelopes, fuel economy improvements, more advanced vehicle stock and greater use of public transport. In the TGT, the share of renewables in power generation more than doubles by 2050, largely due to increased solar PV deployment under a more generous FiT system.

Figure 8.7 • Japan: Energy efficiency and renewables development, TGT versus BAU, 2000-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Source: APERC analysis and IEA (2018a).

The 2DC represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. In the residential subsector, accelerated penetration of higher efficiency space heating and cooling is the main driver of lower demand under the TGT. Energy intensity per square metre for space heating declines at a CAGR of -0.88% in the period 2016-50, which is faster than in the BAU (-0.65%). In the services subsector, energy intensity improvements are driven by space cooling, lighting and water heating where accelerated replacements of ageing appliances and the installation of centralised HVAC systems helps reduce energy demand.

In transport, demand is 16 Mtoe lower than BAU at 56 Mtoe. Advanced vehicles (such as battery electric and hybrids) particularly contribute to reducing energy intensity with their share in LDV stock rising from 5.8% in 2016 to 56% by 2050 under the TGT, significantly larger than under the BAU (36% in 2050). Oil consumption drops 39% over the Outlook period as a result of these developments (compared to 17% in BAU), while electricity consumption grows at a CAGR of 3.8%.

Although modest compared with buildings and transport, industry accounts for 16% of the energy demand reduction achieved under the TGT in 2050. Improvements are made in industry by refurbishing processes, increasing recycle rates of end-of-life steel and paper products, and making a gradual shift to low-intensity processes (such as replacing blast furnaces with electric arc furnaces in the iron and steel sector).

Under the TGT, accelerated renewable deployment combined with demand reduction pushed up the renewables share to 34% of total generation in 2050, compared to 27% for the BAU projections. Installed solar PV capacity in 2050 amounts to 136 GW, which is more than triple the amount of 2016 (42GW). Wind capacity grows to 20 GW, up from 3.2 GW in 2016.

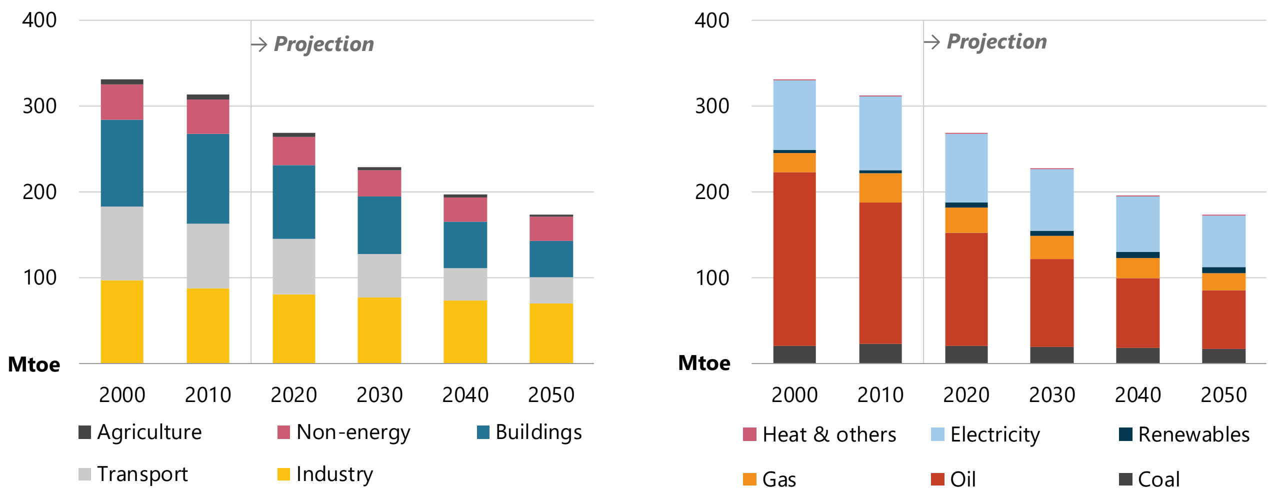
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050.To meet the aims of the 2DC, most energy sectors in Japan will have to undergo significant decarbonisation through improved efficiency, electrification and behavioural change. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the Energy Technology Perspectives publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective. Also, the 2DC is designed assuming all APEC economies fully cooperate to achieve the objective; long-term emissions reduction targets in some economies, including Japan's 80% reduction target by 2050, are not necessarily included as other economies instead contribute to reducing emissions in APEC.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Under the 2DC, FED declines by 41% from 294 Mtoe in 2016 to 173 Mtoe by 2050 (Figure 8.8). Energy efficiency trends in buildings and transport are further accelerated in the 2DC, compared with the TGT. Energy intensity for space heating in residential, for example, declines by 36% in the 2DC over the Outlook period, which is much larger than the BAU (20%) and the TGT (26%). Demand also declines in road transport due to fuel economy improvements, less vehicle stock, more mobility through the sharing economy, improved city planning and lifestyle changes. By contrast, industry plateaus; although the sector contributes to emissions reduction by using carbon capture and storage (CCS) technology for some large blast furnaces and ammonia production plants from 2030.

Figure 8.8 • Japan: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Fossil fuel demand in FED drops by half, from 204 Mtoe in 2016 to 106 Mtoe by 2050. Fuel switching from fossil fuels to electricity further accelerates across the end-use sectors, in particular, road transport. Under the 2DC, NGVs account for 85% of the LDV vehicle stock in 2050. Electric vehicles increase the most, expanding the share in stock from 0.08% in 2016 to 39% in 2050. Annual electricity demand in transport reaches 70 TWh by 2050, 10% of Japan's total electricity demand.

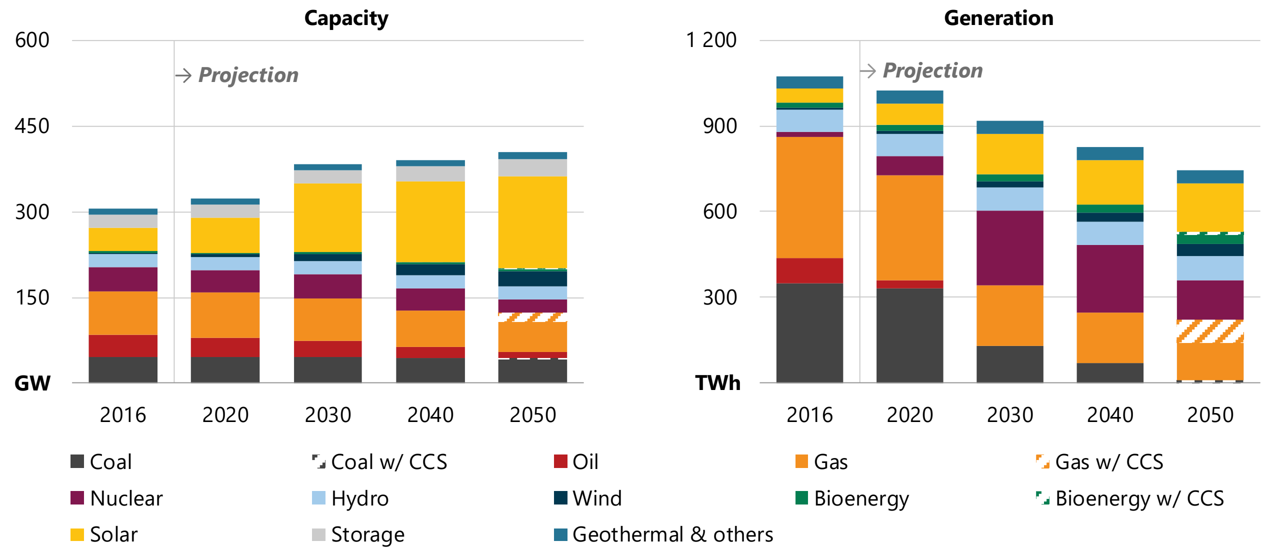
TRANSFORMATION AND SUPPLY IN THE 2DC

Decarbonisation of the electricity sector is integral to the 2DC, with emissions decreasing by more than 90% over the Outlook period. Renewables expansion, maximised use of existing nuclear reactors and CCS are all required to achieve this level of emissions reduction (Figure 8.9). Renewables in power generation triple to account for 46% of the generation mix in 2050, up from 14% in 2016. Energy storage capacity (e.g. pumped hydro and batteries) totalling 31 GW plays an important role in absorbing excess electricity from solar PV

(159 GW) and wind power (26 GW, of which 1.1 GW is offshore) in 2050. The 2DC assumes that all existing nuclear reactors, except those that have already been earmarked for retirement, continue to operate for 60 years by extending their lifespans under the '40-year lifetime rule'. The 2DC also includes new additions of three reactors that are under construction as of 2016 which supply less than a quarter of power generation in 2050. Without CCS, fossil fuels shrink under the 2DC because of carbon constraints. CCS-equipped coal-fired, natural gas-fired and biomass power plants expand in the 2040s, reaching 19 GW by 2050. Captured emissions—which reach 57 $MtCO_2$ per year in 2050—are stored in offshore aquifers.

The 2DC poses economic challenges for electricity supply. Average power generation cost, calculated by dividing total annual generation costs by generated electricity, increases by more than 50% over the Outlook period, from an estimated USD 111 per megawatt-hours (MWh) in 2016 to USD 167 per MWh in 2050.[46] The cost structure shifts to become more capital-intensive, driven by renewables expansion. The share of fuel costs in the total power generation cost drops which reduces Japan's exposure to global fuel prices. The capacity factor of combined-cycle gas power declines to about 30% in 2050, much lower than 50% in the BAU, partially because it serves as a flexible back-up generator for solar PV (rather than supplying baseload power). To maintain the profitability of back-up generators and ensure electricity supply stability, policy measures, including capacity markets set to be established in 2020, will play a vital role.

Figure 8.9 • Japan: Power capacity and electricity generation in the 2DC by fuel, 2016-50

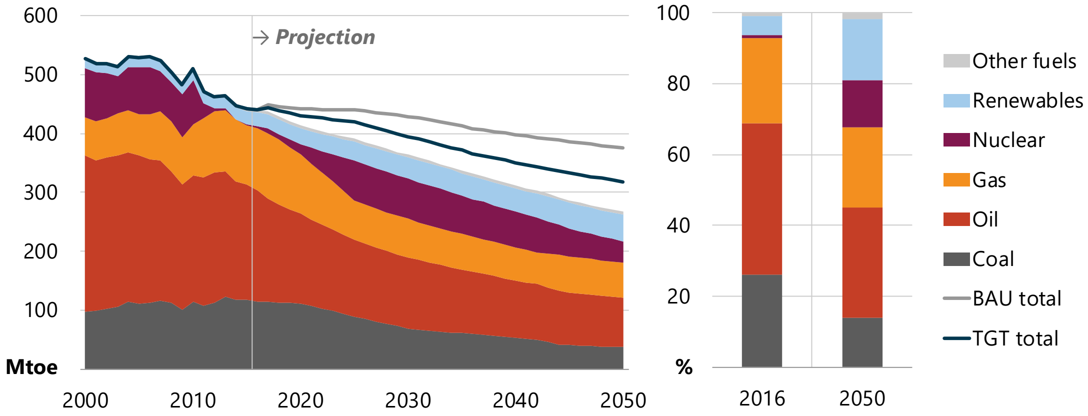


Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

TPES in the 2DC declines significantly due to reduced energy demand. It drops 39% (436 Mtoe to 268 Mtoe) by 2050 (Figure 8.10). Renewables and nuclear both expand, contributing 30% of TPES in 2050. Although the 2DC poses economic challenges, Japan's energy self-sufficiency rate improves from 8.1% in 2016 to 32% in 2050, thanks to renewables expansion, lifetime extension for existing nuclear reactors and decreased reliance on imported fossil fuels.

[46] Generation costs in this Outlook do not include transmission and distribution costs. Average generation cost provides the basis for the wholesale electricity price in both competitive and price-regulated markets.

Figure 8.10 • Japan: Total primary energy supply in the 2DC versus BAU and TGT, 2016-50



Sources: APERC analysis and IEA (2018a).

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The *APERC Outlook 7th Edition* estimates capital investments and fuel costs required for each scenario. This Outlook considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period (2016-50) and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[47]

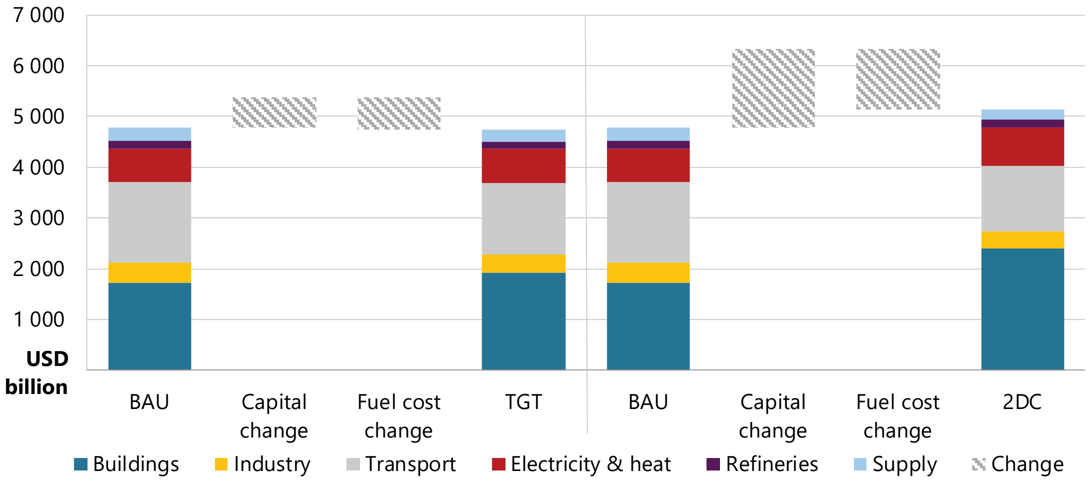
Estimated total capital and fuel costs for Japan under the BAU amount to USD 4 777 billion of which fuel costs account for 67% (USD 3 224 billion) over the Outlook period (Figure 8.11). Given the limited domestic resources, procurement of affordable fossil fuel continues to be crucial to curb Japan's total energy sector costs. Projected total cumulative capital investments are USD 1 554 billion, of which USD 802 billion is for demand side and USD 752 billion is for the transformation and supply sectors. Transport (USD 334 billion) and buildings (USD 467 billion) combine to account for almost all demand side investment requirements. In the transformation and supply sectors, 71% of investment (USD 533 billion) goes to the electricity sector, driven mainly by renewables expansion and supporting network enhancements. The remaining investments are mainly used in energy transport such as for domestic natural gas pipelines and the petroleum transportation system.

Under the alternative scenarios, accelerated energy efficiency and low-carbon technology deployment contribute to fuel cost savings, while increasing capital investments. The TGT results in a moderately lower level (0.92% less) of investment as fuel savings exceed capital costs. The deployment of net-zero or near net-zero emission buildings doubles investment in the buildings sector compared to the BAU. Although modest by comparison, investment in electricity infrastructure also increases, driven by expanding solar PV and onshore wind capacity. Compared to the BAU, capital investments in TGT amount to USD 2 151 billion (USD 597 billion larger than the BAU). This is offset by fuel savings of USD 641 billion, of which USD 591 billion comes from buildings and transport. Under the 2DC, total capital and fuel costs increase by 7.6% compared with the BAU. Incremental capital investments amount to USD 1 550 billion, which is larger than fuel cost savings

[47] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

(USD 1 189 billion). Buildings again significantly push up the capital cost (with a USD 4.2 billion addition), while fuel costs are only USD 1.1 billion lower compared to BAU.

Figure 8.11 • Japan: energy sector capital and fuel costs, 2016-50



Source: APERC analysis and IEA (2018a).

ENERGY TRADE AND SECURITY

The BAU Scenario implies long-term security challenges. Energy self-sufficiency improves in the short to medium term, from 8.1% in 2016 to 18% in 2030, thanks to demand-side energy efficiency efforts, nuclear restarts and renewables growth in the electricity sector. Retirements of nuclear reactors, however, reduce the rate to 13% in 2050. Japan, therefore, continues to remain one of the largest energy importers in APEC and the world given its limited domestic fossil fuel resources. In 2016, Japan's net imports totalled about 400 Mtoe, constituting 91% of TPES (Figure 8.12). Under the BAU, net imports decrease to 336 Mtoe by 2050. Increasing natural gas imports after 2025 make up for the retirements of existing nuclear reactors.

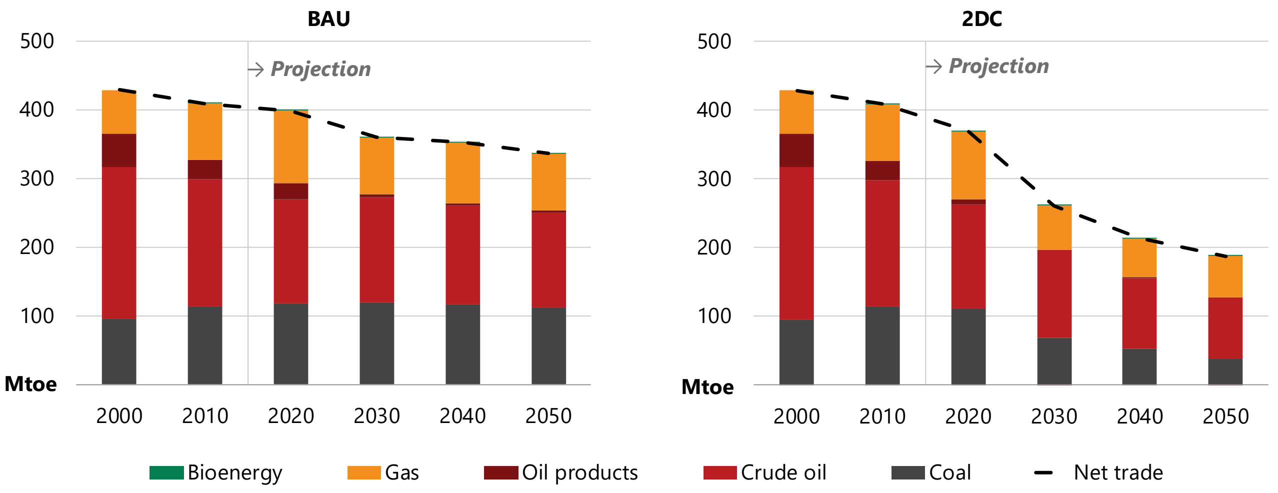
Table 8.3 • Japan: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	8.1	18	20	30	13	15	32
Coal self-sufficiency (%)	0.58	0	0	0	0	0	0
Gas self-sufficiency (%)	2.3	0.18	0.21	0.22	0	0	0
Crude oil self-sufficiency (%)	0.27	0.21	0.22	0.25	0.15	0.18	0.23
Primary energy supply diversity (HHI)	0.30	0.24	0.23	0.20	0.25	0.24	0.19
Coal reserve gap (%)	0.27	0.54	0.54	0.54	0.54	0.54	0.54
Gas reserve gap (%)	8.7	67	67	67	69	69	69
Crude oil reserve gap (%)	7.8	95	95	95	179	179	179

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges range from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

Accelerated efficiency and renewable energy under the TGT curb energy imports. Net imports in 2050 reach 277 Mtoe, 18% lower than in the BAU. Reduced demand coupled with higher renewables improves the energy self-sufficiency rate, which is 15% in 2050, almost two percentage-points higher than the BAU. Despite economic challenges, the 2DC low-carbon pathway indirectly benefits Japan's energy security by further reducing fossil fuel demand, and promoting renewables and nuclear. Net energy imports under the 2DC reach 187 Mtoe in 2050, 44% lower than in the BAU, and the estimated self-sufficiency rate reaches 32%.

Figure 8.12 • Japan: Net energy imports and exports in the BAU and 2DC, 2000-50

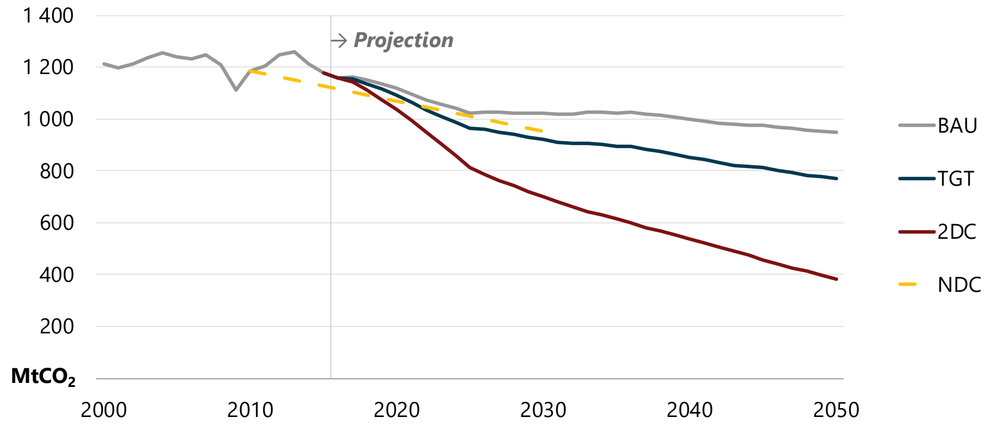


Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

At the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), Japan submitted a Nationally Determined Contribution (NDC) to reduce GHG emissions by 26% in the period FY2013-30 and energy-related CO_2 emissions by 25% (UNFCCC, 2015). Fuel combustion emissions were estimated at 1 235 million tonnes of CO_2 ($MtCO_2$) in 2013, in the base year of Japan's NDC calculations. Under the BAU, CO_2 emissions fall by 19% from the base year, which is not sufficient to reach Japan's NDC level. Emissions shrink throughout the projection period in end-use sectors, but reduction in the electricity sector slows in the medium term as existing nuclear reactors are retired. Under the TGT, emissions decrease by almost 27% in 2030 compared with 2013. Efficiency improvements and greater renewables deployment under this scenario create a pathway to achieve Japan's NDC. Policies to support energy efficiency and higher renewables are important. Enhancing efficiency standards via the Top Runner Program, for example, and revising grid operation rules (such as Japanese style 'Connect and Manage') to accelerate the connection of renewables under the FiT system help the economy to achieve the NDC level. Maintaining the share of nuclear power generation, through financial incentives to promote new development could also help curb emissions.

Figure 8.13 • Japan: CO_2 emissions pathways under the BAU, TGT and 2DC, 2010-50



Note: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The 7th Edition calculates CO2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

To contribute to global climate objectives, Japan needs to reduce CO_2 emissions significantly under the 2DC by combining energy efficiency, electrification and lifestyle changes in the end-use sectors, with strong decarbonisation measures in the electricity sector (Figure 8.13). Energy-related CO_2 emissions in the 2DC fall to about 699 $MtCO_2$ in 2030, which is 40% lower than the 2013 level, and 382 $MtCO_2$ in 2050, which is 67% lower. The electricity sector contributes the most in terms of emissions reduction by using a wide variety of technology options including renewables, nuclear and CCS. Electricity accounts for two-thirds of the cumulative emissions reduction by 2050, underlining the importance of the sector in achieving a low-carbon pathway.

OPPORTUNITIES FOR POLICY ACTION

Current policies continue to improve energy efficiency, especially in buildings and transport, and expand renewables in the electricity sector. Under the BAU, however, these improvements are not sufficient to reach the NDC target nor fully support the APEC goals. Additional measures for energy efficiency and low-carbon energy, including renewables, are necessary.

In the short term, priority should be given to improving current policies such as, for example, expanding items covered under the Top Runner Program, improving purchase price predictability under the FiT program and strengthening the carbon tax. Introducing mandatory cost-standards for renewable energy, such as the efficiency standards in the Top Runner Program, would also be beneficial in promoting renewables in a cost-effective manner.

Under the BAU, Japan's energy self-sufficiency rate improves in the short term, driven by renewables expansion and nuclear restarts. In the longer term (beyond 2030), however, it declines as existing reactors are retired under the '40-year lifetime rule'. Energy security is a priority for Japan and the government needs to design policies to maintain the self-sufficiency rate and enhance resilience. One option for maintaining the rate would be to include financial incentives to extend the lifetime of existing nuclear reactors and replace ageing ones. Enhanced energy efficiency and deployment of renewable energy, as described in the TGT, would also help the economy develop a secure and sustainable energy system. The major blackout in the Hokkaido region in September 2018 highlighted the risks of conventional centralised electricity systems. Although this Outlook assumes that system continues, designing new systems, such as distributed electricity grids that are responsive to local conditions, should be an important agenda for the government to promote grid resilience.

Global climate objectives would require a significant level of demand reduction and electricity decarbonisation in Japan. To achieve these drastic changes, the economy needs to make maximum use of existing low-carbon measures, while continuing research and development for new and innovative technologies, such as hydrogen, which can contribute to maintaining a wide variety of low-carbon options. The 2DC also includes lifestyle changes in several end-use sectors such as transport. Trans-disciplinary and integrated approaches, covering energy, urban development, healthcare and new information technologies, are important for designing the future energy system.

9. KOREA

KEY FINDINGS

- **FED rises 32% in the BAU, from 179 Mtoe to 235 Mtoe over the Outlook period,** mainly as a result of higher demand in non-energy use, which increases to 80 Mtoe, and industry, which increases to 61 Mtoe. Efficiency improvements drive FED down 9.0% in the TGT and 21% in the 2DC.

- **TPES grows marginally under the BAU, is flat under the TGT and shrinks under the 2DC.** Fossil fuels remain dominant under all scenarios but account for 62% of the fuel mix in 2050 under the 2DC compared with 87% in the BAU.

- **Renewables and natural gas become more important in the electricity sector as nuclear is phased out in stages under the BAU and TGT Scenarios.** Solar and wind resources lead the robust expansion of renewables in power generation, with solar increasing six-fold and wind growing ten-fold over the Outlook in the BAU.

- **Despite the increasing share of renewables, replacing nuclear with gas generation results in greater energy imports and reduces primary energy self-sufficiency in the BAU and TGT.** Securing stable energy supply remains a priority in all scenarios, but increasing the role of nuclear, as illustrated in the 2DC, doubles Korea’s primary energy self-sufficiency.

- **Korea is not projected to meet its NDC commitment under the BAU, TGT and 2DC Scenarios.** Enlarging the share of renewables considerably—and improving energy efficiency greatly—is needed to meet Korea’s NDC.

ECONOMY AND ENERGY OVERVIEW

Korea is a densely populated economy in north-east Asia with an urbanisation rate of 83%. Almost half the population of 51 million lives in the Seoul metropolitan area (Seoul, Incheon and Gyeonggi provinces). However, the population is projected to shrink over the Outlook period (2016-50) due to a declining birthrate. Korea consequently has a rapidly ageing population, as 38% of its citizens will be over 65 in 2050, a substantial increase from 13% in 2016, which will negatively impact economic growth (KOSIS, 2017). Fewer people and a higher median age mean reduced domestic consumption and a smaller labour pool to sustain. From 1990 to 2016, however, Korea's economy grew at an compound annual growth rate (CAGR) of 5.0%, making it one of the fastest-growing Asia-Pacific Economic Cooperation (APEC) economies.

Economic activity is driven heavily by an export-oriented manufacturing sector, with particular focus on automobiles, semiconductors, steel, digital electronics, shipbuilding, refining, petrochemicals, machinery, and parts and materials. Lacking domestic resources, however, Korea needs to secure stable energy supplies from elsewhere to support this manufacturing activity. Korea's gross domestic product (GDP) per capita is projected to double from USD 37 701 in 2016 to USD 78 487 in 2050, 1.4 times higher than the projected APEC average of USD 56 218 in 2050. Total primary energy supply (TPES) per capita is projected to increase by 18% and remain double the APEC average over the Outlook period.

Table 9.1 • Korea: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	1 041	1 605	1 915	2 170	2 806	3 393	3 960
Population (million)	47	50	51	52	53	52	50
GDP per capita (2016 USD PPP)	21 970	32 387	37 701	42 134	53 247	64 734	78 487
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	190	254	285	304	318	329	335
TPES per capita (toe)	4.0	5.1	5.6	5.9	6.0	6.3	6.6
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	183	158	149	140	113	97	85
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	127	158	179	194	213	226	235
FED per capita (toe)	2.7	3.2	3.5	3.8	4.0	4.3	4.7
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	122	98	93	89	76	67	59
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	438	567	610	611	633	655	670
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. MtCO2 = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

Korea's domestic energy resources are very limited: it has no oil except a small amount of condensate; only 315 million tonnes (Mt) of recoverable coal reserves; and 5.7 billion cubic metres of natural gas reserves (KESIS, 2017 and EIA, 2017). Because of these resource limitations, it must rely on fossil fuel imports to supply much of its energy needs. In 2016, Korea imported 87% of its primary energy supply, making it the world's fifth-largest importer of oil, second-largest importer of liquefied natural gas (LNG) and fourth-largest importer of coal (IEA, 2018b; 2018c; 2018d).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Korea's 2nd National Energy Master Plan was announced in January 2014 to provide a mid- to long-term framework for coordinating energy policy throughout the economy. The plan identifies several problem areas affecting Korea's energy system: inefficient resource distribution, which causes disproportionate electricity use; energy supply policies that do not address safety concerns; and unbalanced goal-setting that focuses on quantitative growth only (MOTIE, 2014a). It also introduces solutions, such as instituting a demand management system to reduce electricity demand by 15% by 2035; building a distributed generation system to supply more than 15% of power from distributed generation by 2035; balancing quantitative growth with environmental and safety concerns; enhancing energy security and energy supply stability; establishing a stable supply system for each energy source; and shaping energy policy to reflect public opinion.

In July 2014, the government revealed its intention to help new energy-related businesses reduce carbon dioxide (CO_2) emissions and increase energy efficiency. The Ministry of Trade, Industry and Energy established the Energy Efficiency and Climate Change Bureau, and several plans to develop energy-related technology and regulatory reforms to support policy implementation (Government of Korea, 2014 and 2015).

In October 2017, Korea released an Energy Transition Roadmap to reduce nuclear generation in the electricity fuel mix and augment renewable generation (Government of Korea, 2017). The new roadmap nullifies plans to construct new nuclear reactors and does not allow lifespan extensions of existing ones; it also proposes the increased deployment of natural gas and renewable energy sources. The roadmap aims to have 20% of electricity generated from renewable sources by 2030, a sizeable jump from the previous target of 13% in the 4th New and Renewable Energy Basic Plan of 2014 (MOTIE, 2014b).

The 8th Electricity Demand and Supply Plan for 2017-2031, released in December 2017 following the roadmap, provides detailed plans to reduce nuclear-based generation. According to the plan, nuclear capacity peaks in 2022 at 28 gigawatts (GW) and decreases thereafter to 20 GW by 2030. It will take more than 60 years to shut down all the reactors since the most recent one (Shingori #6) is currently under construction and is designed to operate for 60 years.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Korea under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 9.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere. The 8th Electricity Demand and Supply Plan, which aims for new and renewable energy to make up 20% of the power generation mix by 2030, seems overly ambitious given the current share and recent developments. The Outlook includes this target in the APEC Target (TGT) Scenario and the 2-Degrees Celsius (2DC) Scenario, but bases BAU assumptions on current developments only (MOTIE, 2017).

Table 9.2 · Korea: Key assumptions and policy drivers under the BAU

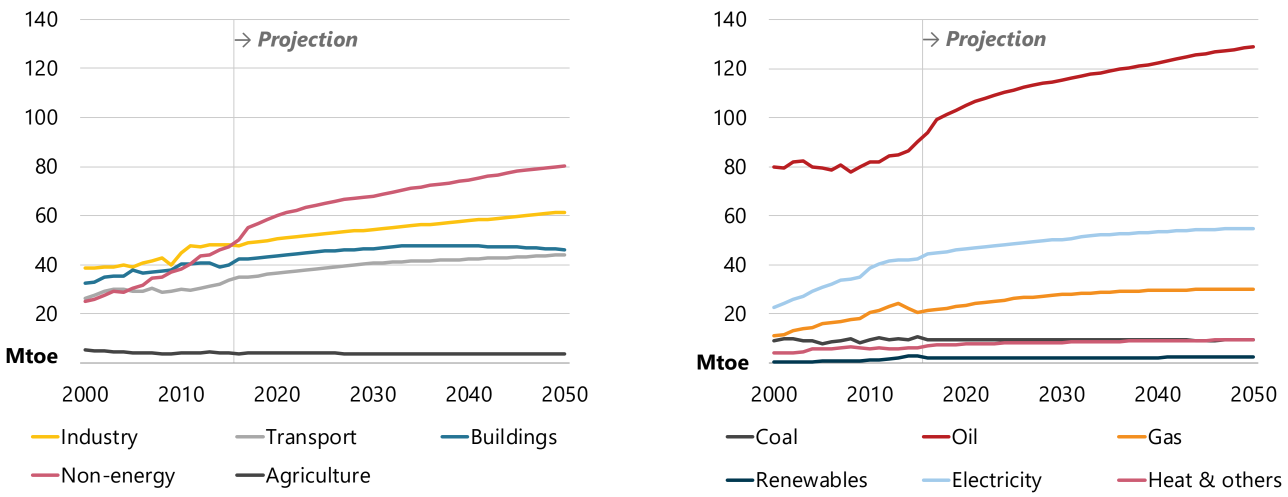
Buildings	Energy management systems introduced in new buildings and energy-intensive buildings and factories. The proliferation of energy efficient appliances that use information and communications technologies, and the introduction of an energy efficiency market allowing people to trade reductions by installing efficient equipment.
Transport	Mandated biodiesel blend rate of 2.5% in 2015, rising to 3% after 2018.
Energy supply mix	Higher renewables and LNG shares, and lower nuclear and coal.
Power mix	No lifetime extensions for existing nuclear reactors. Cancellation of new reactor construction plans.
Renewables	The current pace of renewables development is sustained.
Energy security	Higher renewables share in TPES.
Climate change	Development of an emissions trading system and emissions target management system.

Note: LNG = liquefied natural gas. TPES = total primary energy supply. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Korean energy demand has grown steadily since 2000 (at 2.2% CAGR), to reach 179 million tonnes of oil equivalent (Mtoe) in 2016. Since the global financial crisis of 2008, the expansion of the manufacturing industry has been the primary driver of energy demand, particularly electricity. Final energy demand (FED) is projected to grow from 179 Mtoe in 2016 to 235 Mtoe in 2050, but the rate of increase slows down around 2042 as the population continues to shrink and the economic structure changes. Most of the growth is driven by the industry sector, which grows at 0.74% CAGR through the Outlook, and non-energy use (Figure 9.1). Energy use in both buildings and transport grows steadily until the early 2030s. As the population becomes smaller and efficiency improves thereafter, energy use in buildings begins to decline and the rate of transport growth decreases. Overall buildings consumption expands by 9.0%, and that of transport rises 26%.

Figure 9.1 · Korea: Final energy demand by sector and fuel, 2000-50



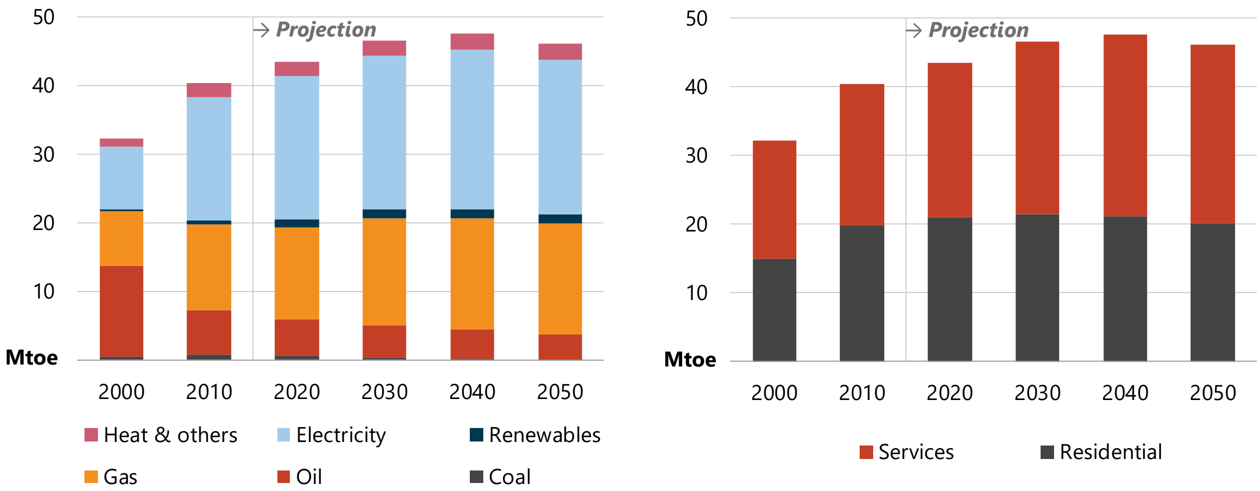
Sources: APERC analysis and IEA (2018a).

The government introduced a demand management scheme in 2014 which has stymied energy demand growth in a number of FED sectors. Measures included in the scheme are the stronger oversight of energy-intensive industrial facilities, the gradual strengthening of energy conservation design standards for new buildings, and the expansion of the scope of fuel efficiency standards to include not only passenger cars but small commercial vehicles as well.

BUILDINGS: ELECTRICITY INCREASES SHARE AS DEMAND PEAKS IN 2037

Energy demand in the buildings sector is projected to grow to 48 Mtoe in 2037, from 42 Mtoe in 2016, before decreasing slightly to 46 Mtoe in 2050 as population shrinks in the second half of the Outlook period. Services subsector demand increases by 20% through the Outlook (rising to 26 Mtoe in 2050 from 22 Mtoe in 2016) while the residential subsector shrinks marginally (0.56 Mtoe) (Figure 9.2).

Figure 9.2 · Korea: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Residential energy demand is projected to peak at 22 Mtoe in 2035—shortly after Korea's population peaks in 2034—and then fall back to the 2020 level until 2050. However, continually increasing household numbers (22 million in 2045, from 19 million in 2016), and thus residential floor area, slightly delays the residential energy demand decline (KOSIS, 2017). High urbanisation results in wide accessibility to gas distribution networks, partly propelling gas consumption up 26% over the Outlook period, and policy incentives result in an even stronger expansion of renewables usage (34%). In contrast, consumption falls for oil (-40%) and coal (-77%) by 2050.

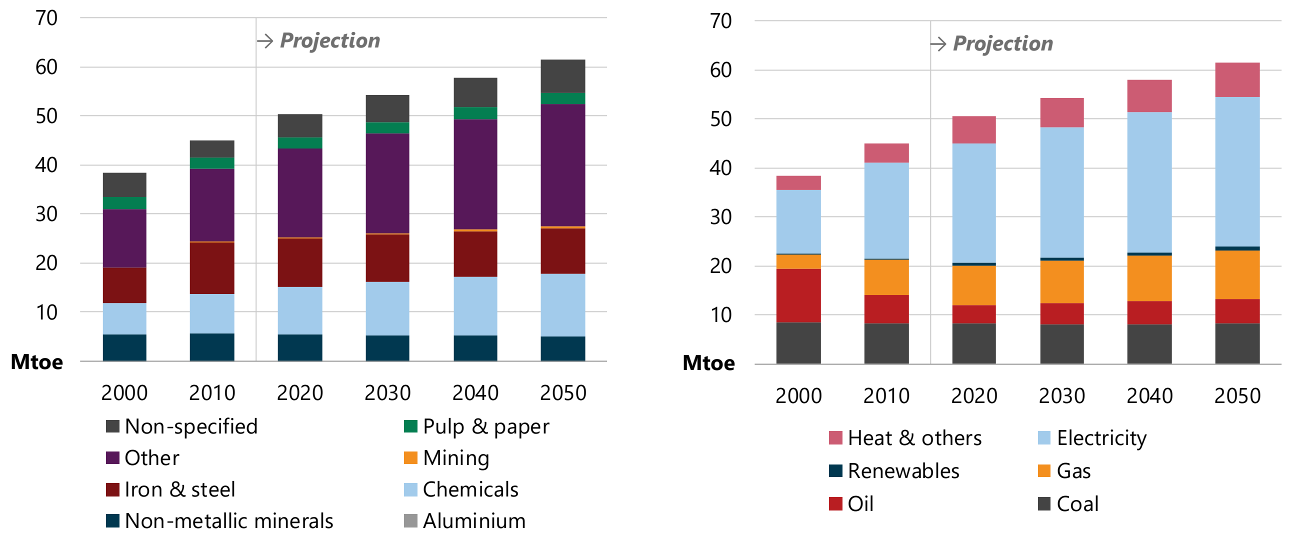
Energy demand in the services subsector increases by 20%, from 22 Mtoe in 2016 to 26 Mtoe in 2050, as the service industry expands and replaces some manufacturing industries. After peaking in 2039, FED declines as energy efficiency improvements began to outweigh modest growth in service floor area. Similar to the residential subsector, renewables use increases 33% and that of gas rises 53%, while oil demand decrease by more than 30%. Electricity use in commercial buildings grows 18% over the projection period and is projected to peak in 2037.

The government continues to reinforce policy measures to reduce building energy use. Firstly, it is implementing the gradual application of stricter energy conservation designs to meet zero-energy standards for all new buildings by 2025. Both new and existing buildings are now included in the expanded scope of the energy efficiency rating system, and major appliances now have energy efficiency labelling. Additionally, the government has initiated an energy service company (ESCO) project (wherein an ESCO invests in energy-saving facilities) and set up a market for energy-efficient technologies.

INDUSTRY: STEADY GROWTH MAINLY IN OTHER SUBSECTORS

Industry was Korea's largest energy demand sector for several decades before being overtaken in 2016 by non-energy use.[48] Industry energy demand increases at a CAGR of 0.74% throughout the Outlook period, rising from 48 Mtoe to 61 Mtoe (Figure 9.3). The share of industry consumption in total FED decreases slightly from 27% in 2016 to 26% in 2050 under the BAU.

Figure 9.3 · Korea: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Most of the increase in industry energy demand comes from two subsectors. The other subsector (which includes semiconductor, electronics, car and shipbuilding industries) increases from 17 Mtoe in 2016 to 25 Mtoe in 2050 (46%). The chemical and petrochemical subsector grows even more strongly (61%) but from a lower base— from 8.0 Mtoe in 2016 to 13 Mtoe in 2050. The increases from these subsectors more than offset lower energy demand in the iron and steel (decreases by 9.9%, from 10.3 Mtoe in 2016 to 9.3 Mtoe in 2050) and non-metallic minerals subsectors (9.7% decrease), which are declining in line with reduced construction activity.

Electricity is the largest end-use fuel in industry and is used mostly in the chemical and petrochemical and other subsectors. It grows by 34% over the Outlook period to account for half of the sectoral increase over the Outlook period. The share of coal use by industry drops slightly, from 17% in 2016 to 13% in 2050, as consumption falls in the declining iron and steel and non-metallic subsectors.

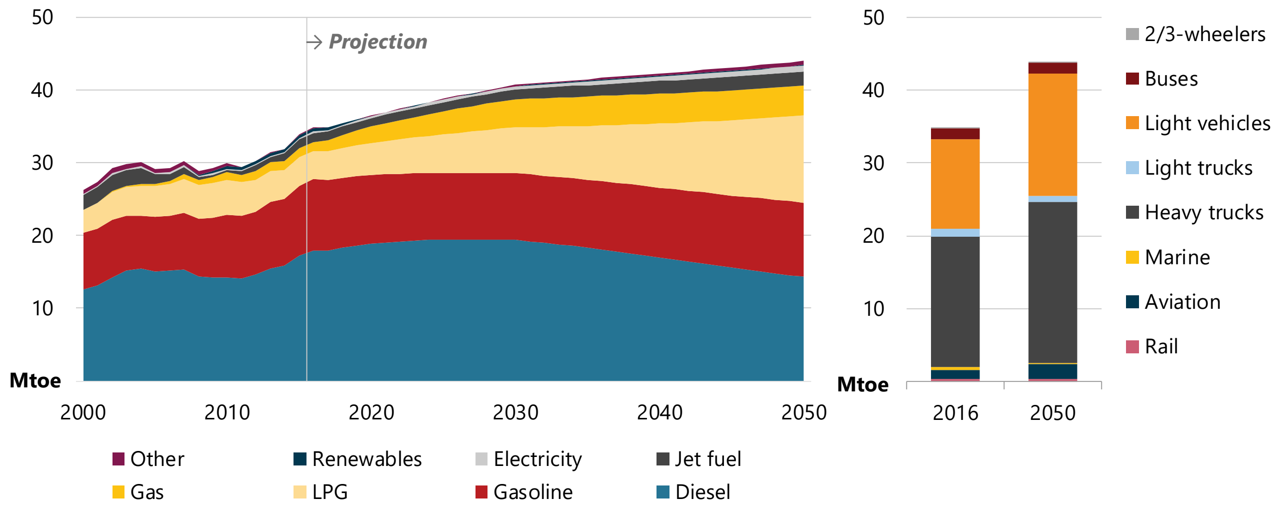
Policy measures to reduce industry energy demand include demand management for energy-intensive businesses, energy management systems in factories, and additional support and incentives for small and medium-sized companies. In the chemical and petrochemical subsector, measures involve investing in better heat-recovery equipment, improving processes to minimise standby power and installing waste vapour reuse facilities.

[48] Non-energy use refers to energy products used as raw materials that are not consumed as fuel or transformed. These are generally oil products used in the chemical and petrochemical subsector (to make plastics or lubricants, for example).

TRANSPORT: INCREASING SHARE OF LIQUEFIED PETROLEUM GAS

Domestic transport energy use is projected to grow from 35 Mtoe in 2016 to 44 Mtoe in 2050 (0.68% CAGR). Growth is primarily driven by increasing demand from light-duty vehicles (LDVs) and heavy-duty trucks in the road transport subsector, which accounted for 86% of domestic transport energy demand in 2016 (increasing to 88% in 2050). Road energy use rises 26% from 33 Mtoe in 2016 to 41 Mtoe in 2050, whereas rail and air show modest increases over the Outlook (0.33 Mtoe to 0.41 Mtoe for rail, and 1.2 Mtoe to 2.0 Mtoe for air), as incomes rise and more people travel (Figure 9.4).

Figure 9.4 · Korea: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

The LDV stock expands by 1.3% annually under the BAU and by 2050 there are 27 million vehicles compared with 17 million in 2016. While gasoline and diesel are still the dominant transport fuels at the end of the Outlook period, greater fuel efficiency and stronger regulations on exhaust emissions helps limit growth and reduces their combined fuel share from 77% in 2016 to 56% in 2050. As replacement fuels for gasoline and diesel, natural gas and liquefied petroleum gas (LPG) increase sharply, with natural gas rising from 3% in 2016 to 9.3% in 2050 and LPG from 11% to 27%. The deregulation of LPG vehicle restrictions and strengthening support policies for compressed natural gas vehicles contribute to growing demand for those fuels.

Various policy measures to reduce transport sector energy consumption are under consideration: broadening the scope of fuel efficiency standards for passenger cars to include small commercial vehicles; setting energy conservation targets for freight; offering incentives for the uptake of hybrid cars; and building charging stations for electric vehicles. Developing business models such as car-sharing and long-term lease services for eco-friendly cars as well as introducing a system for subsidising sunrise/sunset industries and tax credits based on vehicle age and type are also under consideration and would help to curb energy demand growth if implemented.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Energy use in Korea's transformation sectors has grown rapidly since 2000, driven by a steady expansion of refinery and electricity generation capacity. Over the Outlook period, refinery capacity is stagnant, while electricity grows to 2030 before flattening over the remainder of the projection. These dynamics are reflected in TPES and energy imports, which grow steadily in the 2020s before slowing down through to 2050.

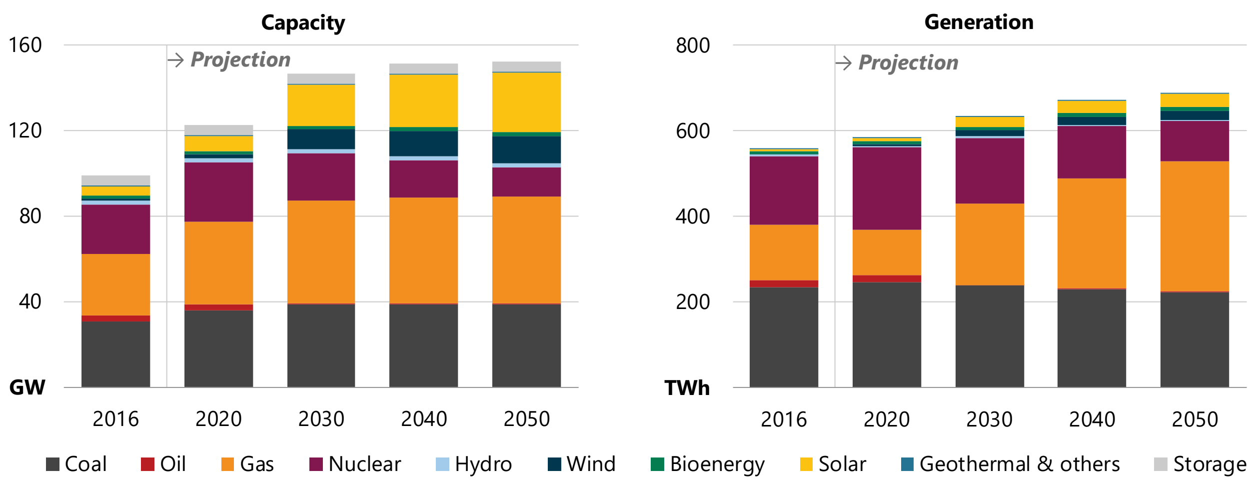
ENERGY INDUSTRY OWN-USE: MODEST DECREASE IN LIQUID FUEL PRODUCTION

Korea's refinery capacity tripled in the 1990s to reach 147 Mtoe in 2016 and it is projected to stay at the current level throughout the BAU. Total oil product production of 132 Mtoe is constant throughout the Outlook period. However, product demand differs considerably by fuel type, with consumption of diesel (from 47 Mtoe in 2016 to 44 Mtoe in 2050), gasoline (18 Mtoe to 17 Mtoe) and LPG (2.6 Mtoe to 2.2 Mtoe) all decreasing over the Outlook. Korean refineries will, therefore, need to re-optimise in order to meet this changing demand dynamic or find export markets for excess diesel and gasoline production. Domestic demand for LPG will be high enough to absorb production and require imports to grow strongly.

POWER SECTOR: GAS AND RENEWABLES REPLACE COAL AND NUCLEAR

Korea's electricity demand increased sharply in the 1990s and 2000s, leading to electricity supply restrictions in selected areas in 2011. Securing a stable supply of electricity to support economic growth is, therefore, one of Korea's top energy policy priorities. Total electricity generation increases by 23% over the Outlook period, to 690 terawatt-hours (TWh) in 2050 (Figure 9.5). Input fuel shares in the generation mix change considerably, however, as gas and renewables expand to replace coal and nuclear, which drop from 42% in 2016 to 32% in 2050 (coal) and 29% to 14% (nuclear), as directed by the new energy roadmap (Box 9.1). To make up for these decreases, gas expands to account for 44% of generation in 2050 (from 23% in 2016), while renewables to 9.3% (from 2.8%).

Figure 9.5 · Korea: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

Overall generation capacity increases by 53%, from 99 GW in 2016 to 152 GW in 2050. Capacity expands more than generation because the renewable energy sources that replace nuclear are available only intermittently. Nuclear capacity, which has a very high utilisation rate, drops by almost half, from 23 GW in 2016 to 13 GW in 2050, while renewable capacity increases fivefold, from 8.8 GW in 2015 to 45 GW in 2050. Over 90% of renewable capacity is solar (28 GW) and onshore wind (13 GW) in 2050, as the availability of hydro, geothermal and bioenergy resources is limited in Korea.

Natural gas capacity expands moderately over the Outlook to reach 50 GW in 2050 and account for 33% of total capacity (compared with 29% in 2016), while coal capacity shrinks slightly (from 31% to 26%). Policy changes to reduce nuclear-based generation more quickly than prescribed in the 2nd National Energy Master Plan result in considerably higher generation from renewables and gas. Since nuclear and coal resources are relatively inexpensive, replacing them with gas and renewables may raise electricity prices significantly. Balancing electricity supply stability with the affordability needed to support economic growth, along with the logistical transition from nuclear and coal to gas and renewables will be a challenge for Korea's power sector.

Box 9.1 · Korea: Energy transition roadmap

In October 2017, the Korean government released its Energy Transition Roadmap to reduce nuclear generation and replace it with renewables. The plan announced that construction of new reactors not yet initiated would be annulled, and lifespan extensions for existing ones no longer granted. The Shin-gori #5 and #6 reactors, which are currently under construction, are slated to go ahead as scheduled after a three-month public debate. The number of reactors will diminish in stages, from 24 in 2017 to 28 in 2022, 18 in 2031 and 14 in 2038.

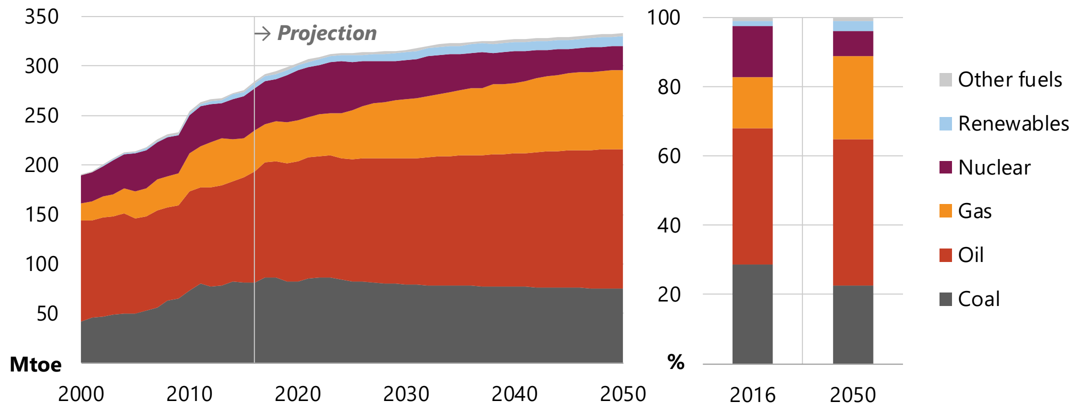
The government's follow-up 8th Electricity Demand and Supply Basic Plan released in December 2017 announced greater shares of natural gas and renewable energy sources in the generation mix. It aims to triple the renewables share from 6.2% in 2017 to 20% by 2030, and targets a natural gas share of 19% in 2030, up from 17% in 2017. The share of nuclear-based generation is expected to drop to 24% in 2030, down from 30% in 2017, while the share of coal-fired generation is also expected to drop, from 45% in 2017 to 36% in 2030.

TOTAL PRIMARY ENERGY SUPPLY: CONTINUED RELIANCE ON IMPORTED FOSSIL FUELS

TPES is projected to increase from 285 Mtoe in 2016 to 337 Mtoe in 2050 (18% increase) to meet demand growth in the industry and non-energy sectors (Figure 9.6). Similarly, oil supplies grow 24% to maintain a 41% share in TPES over the Outlook period. Gas supplies almost double from 41 Mtoe in 2016 to 80 Mtoe in 2050, whereas the share of coal in TPES drops slightly to 22% (75 Mtoe) in 2050, from 29% (82 Mtoe) in 2016, in response to climate change and environmental concerns.

The share of nuclear energy drops by more than half, from 15% (42 Mtoe) in 2016 to 7.3% (25 Mtoe) in 2050, as the Energy Transition Roadmap prohibits lifespan extensions of reactors as well as new builds. The reductions in coal (-7.9%) and nuclear (-42%) are compensated for by increases in gas (93%) and renewables (106%). Although greater use of renewable sources, especially solar and wind, reduces energy import dependency, lower nuclear supply results in greater imports overall. More than 80% of TPES, therefore, continues to be supplied by imports, which will underpin continuing efforts to promote energy security.

Figure 9.6 · Korea: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

ENERGY TRADE: GAS IMPORTS ALMOST DOUBLE

Korea is one of the world's largest energy importers. Total primary energy production of fossil fuels was only 1.6 Mtoe in 2016, comprising 0.77 Mtoe of coal, 0.69 Mtoe of condensate and 0.14 Mtoe of gas, while TPES of fossil fuels was 234 Mtoe. Korean refineries, however, exported 64 Mtoe of oil products in 2016 after processing 149 Mtoe of imported crude oil.

Net energy imports are projected to increase by 31% to meet growing energy demand, from 247 Mtoe in 2016 to 323 Mtoe in 2050. In 2016, almost 100% of Korea's crude oil was imported, with most imports being sourced from the Middle East (86% in 2016 [KESIS, 2019]). Crude oil imports are projected to decrease slightly to 138 Mtoe over the Outlook period (from 149 Mtoe in 2016), as refinery utilisation decreases slightly with lower domestic demand. Oil product exports decrease by 5.9%, from 64 Mtoe in 2016 to 60 Mtoe in 2050, while imports rapidly increase 125%, from 41 Mtoe to 91 Mtoe.

Coal imports fall 8.8% from 81 Mtoe in 2016 to 74 Mtoe in 2050. Unlike for crude oil, Korea imports coal from a range of sources, mostly Australia, Canada, the People's Republic of China, Indonesia, Russia and the United States. Elevated environmental concerns have caused the government to change its policy direction to favour natural gas and renewables over coal for electricity generation.

Gas imports double to 80 Mtoe over the Outlook period to replace coal and nuclear resources for electricity generation. As nuclear reactors are projected to retire regularly through the 2020s, gas imports expand at a rapid 3.0% CAGR between 2016 and 2030 but slow to 1.5% CAGR between 2030 and 2050. Because Korea lacks pipeline connections, it imports natural gas in the form of LNG only, mostly from Qatar, Oman, Indonesia and Malaysia.

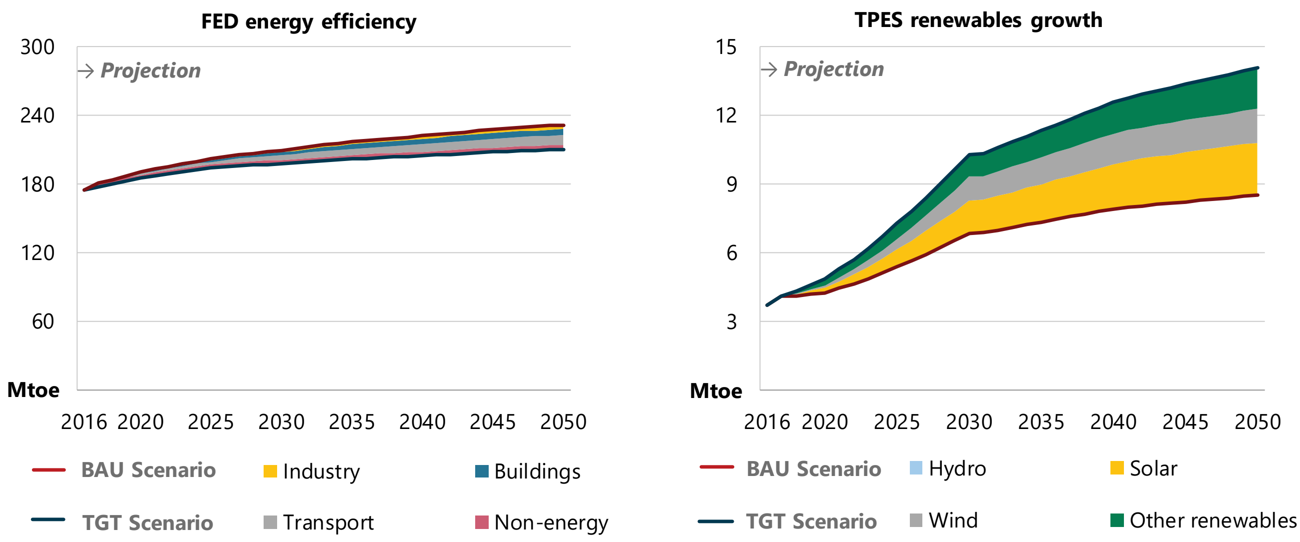
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Korea's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The TGT Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2DC Scenario is the most ambitious of the three scenarios in terms of increased energy intensity and renewables deployment, and reduced CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 9.0% lower while CO_2 emissions are 13% lower under the TGT. Under the 2DC, Korea's FED is 21% lower and CO_2 emissions are 63% lower. The share of renewables in TPES is 75% higher in the TGT and 257% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. Achieving the TGT assumptions requires numerous sector-level policy changes, such as more stringent fuel efficiency regulations in the transport sector, stricter building and appliance standards, and stronger government support for renewables. FED is projected to increase by 20% to 214 Mtoe in 2050 under the TGT, as opposed to 235 Mtoe in the BAU Scenario (Figure 9.7).

Figure 9.7 · Korea: Energy efficiency and renewables development, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows energy demand reduction by sector. TPES renewables growth shows additional renewables by fuel type compared with the BAU, but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Domestic transport sector energy demand grows marginally from 34.9 Mtoe in 2016 to 35.3 Mtoe in 2050, which is 8.7 Mtoe less than under the BAU. Demand in road transport is almost unchanged throughout the Outlook as increasing efficiency offsets strong growth in vehicle stock numbers. Rail grows more strongly in the TGT than the BAU due to behavioural assumptions, such as increased mode shifting in work commutes, but air grows less strongly in the TGT due to lower passenger-kilometres travelled.

Buildings sector energy demand under the TGT is projected to decrease by 2.9%, from 42.3 Mtoe in 2016 to 41.1 Mtoe in 2050, which is 5.0 Mtoe less than under the BAU Scenario. The slight decrease in demand results mainly from less oil used for space and water heating in residential buildings, and for electricity and space heating in service buildings.

Although industry sector energy demand increases 21% under the TGT, from 48 Mtoe in 2016 to 58 Mtoe in 2050, it is still 3.6 Mtoe less than under the BAU. Demand does fall in the iron and steel subsector, however, as a result of improved recycling rates, and in cement production due to higher clinker-to-cement ratios. Non-energy use, which mostly occurs in the petrochemical industry, rises 53% from 50 Mtoe in 2016 to 76 Mtoe in

2050 and is 3.9 Mtoe lower than in the BAU. Energy demand in the other industry subsector increases from 17 Mtoe in 2016 to 23 Mtoe in 2050, which is 1.7 Mtoe less than the BAU.

Renewables in FED is projected to increase from 2.2 Mtoe in 2016 to 3.3 Mtoe in 2050 in the TGT, due to increased use by the buildings (1.7 Mtoe) and industry (1.3 Mtoe, mostly in non-metallic minerals, chemical and petrochemical subsectors) sectors. However, renewable sources expand the most in the electricity sector as input fuels for electricity generation, where their use expands by more than five times—from 2.3 Mtoe in 2016 to 12 Mtoe in 2050 (4.9% CAGR).

Power capacity doubles from 99 GW in 2016 to 187 GW in 2050 under the TGT. Renewables capacity increases almost nine times, reaching 79 GW in 2050 from 8.8 GW in 2016—35 GW higher than under the BAU, which accounts for most of the difference in electricity capacity between the two scenarios. Solar (50 GW) and wind (24 GW) make up more than 90% of renewables capacity in 2050.

TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

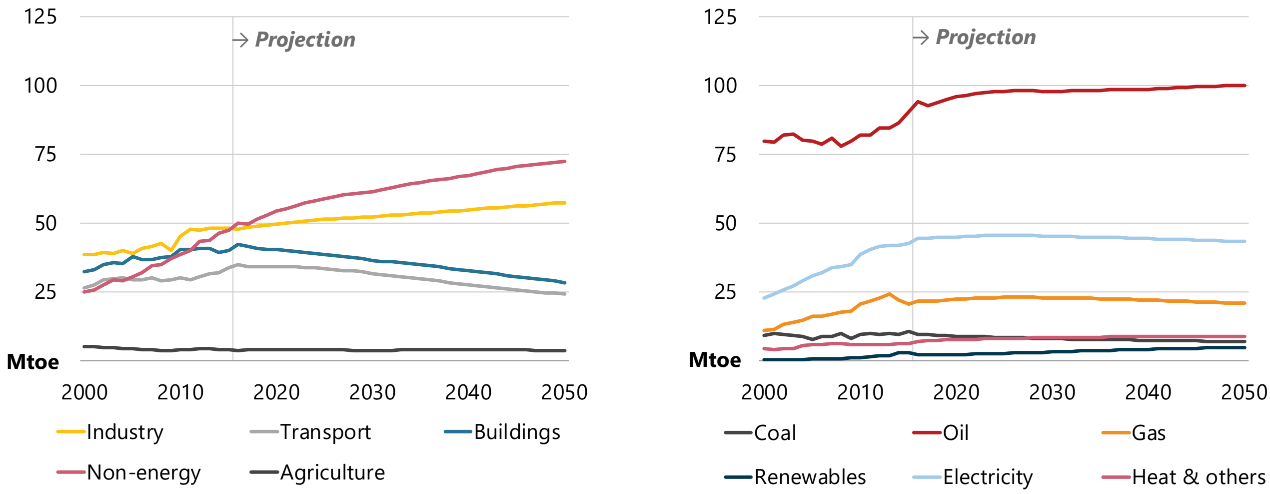
The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Korea will have to undergo some degree of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Because Korea's FED sectors are highly dependent on fossil fuels, decarbonisation under the 2DC requires significant energy efficiency improvements and lifestyle changes since significant increases in renewable deployment is not feasible. As the economy relies heavily on a fossil fuel-driven manufacturing sector, significant progress is required to reduce energy demand in the buildings and transport sectors, because opportunities for reductions in industry and non-energy use are limited.

FED increases 4.1% from 179 Mtoe in 2016 to 186 Mtoe in 2050 under the 2DC, which is significantly less than in the BAU (235 Mtoe) and TGT Scenarios (214 Mtoe). Leading the declines over the projection period are transport (to 24 Mtoe) and buildings (to 28 Mtoe), while non-energy use and industry both grow (to 72 Mtoe and 57 Mtoe). (Figure 9.8).

Figure 9.8 · Korea: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Buildings sector energy demand under the 2DC decreases 33%, from 42 Mtoe in 2016 to 28 Mtoe in 2050—falling 18 Mtoe more than in the BAU and 13 Mtoe more than in the TGT. Residential building consumption falls 27%, mainly owing to efficiency improvements, which reduce oil, gas and electricity use in space and water heating. Services buildings energy demand is almost halved from 22 Mtoe in 2016 to 13 Mtoe in 2050, with reduced electricity use in space heating and cooling owing to improved efficiency as well as lifestyle changes that reduce total floor area. The use of renewables increases more than double, from 0.85 Mtoe in 2016 to 2.0 Mtoe in 2050, mostly for water heating and other end-uses in service buildings.

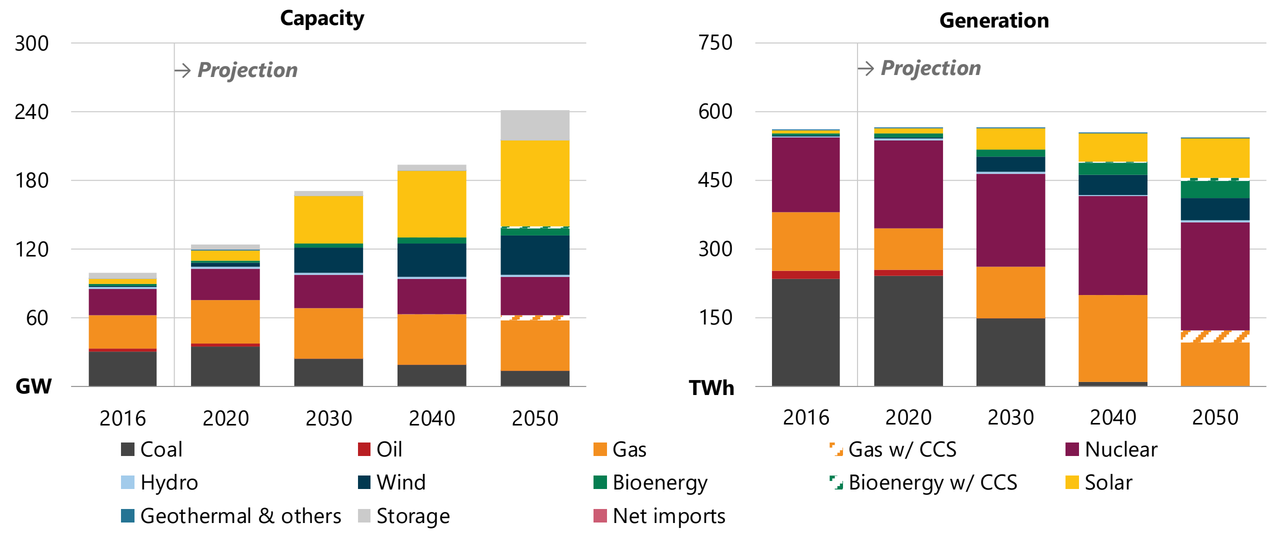
Domestic transport energy demand is projected to drop 31%, from 35 Mtoe in 2016 to 24 Mtoe in 2050, as oil use in road transport falls. Although the LDV stock increases 30%, the number of conventional gasoline and diesel vehicles shrinks, especially in the LDV category (in which the stock is halved), while advanced vehicles expand to 59% of the total vehicle stock. Higher fuel efficiency and a greater number of advanced electric and hydrogen vehicles, therefore, underpin declining energy demand.

FED in industry increases slightly from 48 Mtoe in 2016 to 57 Mtoe in 2050 under the 2DC but this is still 4.1 Mtoe below projected BAU industry demand in 2050 and 0.48 Mtoe less than under the TGT. 2DC demand is lower primarily because of reduced coal use in the non-metallic minerals and iron and steel subsectors, which are assumed to increase efficiency even more strongly than in the TGT due to best available technology (BAT) adoption. Overall coal use in industry falls 26%, from 8.3 Mtoe in 2016 to 6.2 Mtoe in 2050, some of which is substituted with modern renewables (such as biomass pellets and biogas), which triple, from 0.61 Mtoe to 1.9 Mtoe.

TRANSFORMATION AND SUPPLY IN THE 2DC

Electricity generation remains flat around 560 TWh under the 2DC but power capacity more than doubles to accommodate the significant expansion of intermittent renewable sources (solar and wind) (Figure 9.9). Coal generation is phased out by the end of the Outlook period, though some supercritical and ultra-supercritical plants remain as backup capacity. Oil is also phased out, while the share of gas in electricity generation slightly fluctuates around 22% (compared to retaining a share of 44% in the BAU, and 33% in the TGT).

Figure 9.9 · Korea: Power capacity and electricity generation in the 2DC by fuel, 2016-50

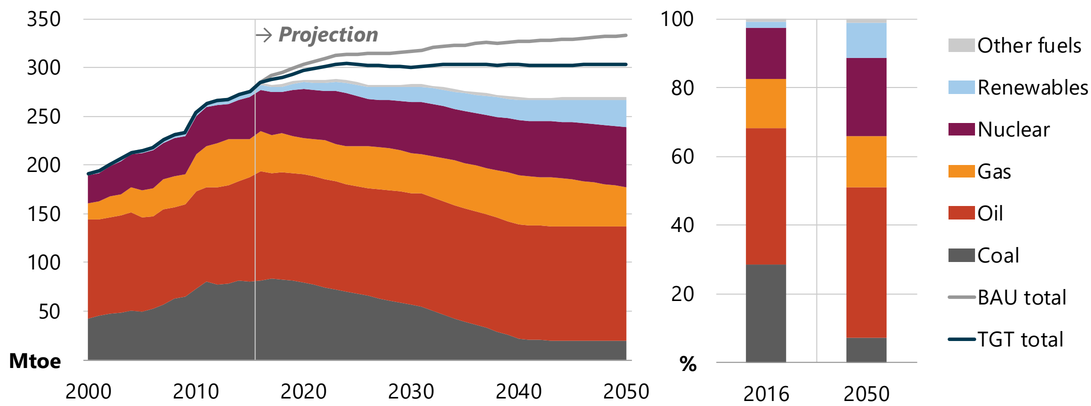


Notes: CCS = carbon capture and storage
Sources: APERC analysis and IEA (2018a).

The share of total electricity generated from nuclear resources increases to 44% in 2050, up from 29% in 2016, and the share of nuclear-based power capacity decreases half from 23% in 2016 to 14% in 2050. At a CAGR of 1.1%, nuclear electricity generation increases from 162 TWh to 236 TWh in the 2DC. Given the diminishing nuclear shares under the BAU and TGT Scenarios, the 2DC assumptions clearly conflict with the government's current policy preferences but are necessary to achieve the 2DC emissions pathway. Renewables are also essential to achieving this pathway, so their share in electricity generation rises dramatically, from 2.8% in 2016 to 34% in 2050, in line with their share in electricity capacity (49% in 2050 from 8.9% in 2016). Solar is the pre-eminent renewable energy source, at 16% of power generation in 2050, followed by wind at 9% and bioenergy with CCS at 8%.

In the 2DC, TPES drops 3.9% over the Outlook period to 274 Mtoe in 2050 (Figure 9.10). This is 63 Mtoe less than in the BAU Scenario and 34 Mtoe below the TGT. The share of coal in TPES is quartered (7.0%), and the share of oil slightly rises 43% by the end of the projection period. The portion of nuclear resources in TPES increases 23% (in complete contrast with the BAU and TGT Scenarios), from 42 Mtoe in 2016 to 62 Mtoe in 2050. Renewables expand considerably to 28 Mtoe in 2050 (from 4.7 Mtoe in 2016), mostly owing to increased use of solar, wind and solid bioenergy resources in electricity generation.

Figure 9.10 · Korea: Total primary energy supply in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[49]

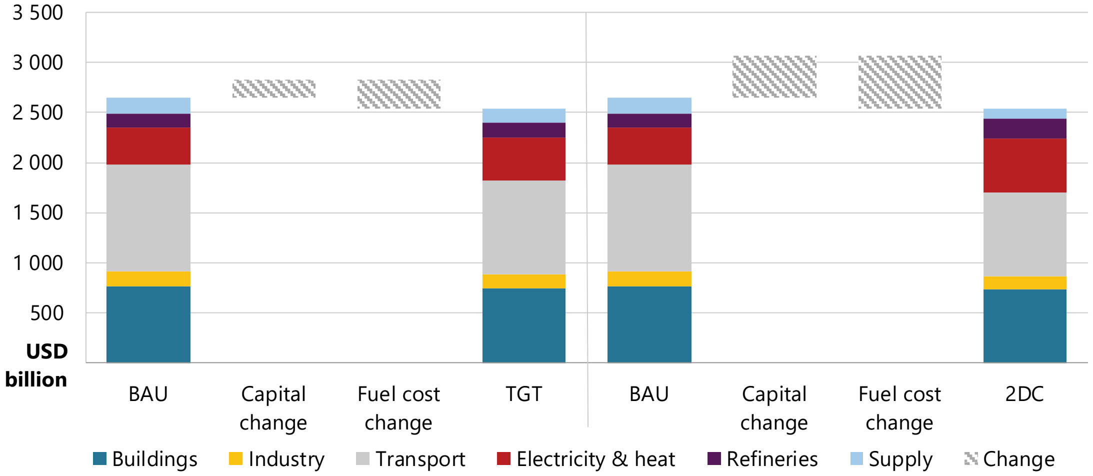
Korea's total capital investment and fuel costs over the Outlook period are USD 2 651 billion. Capital investments amount to USD 912 billion, of which the electricity and heat sector accounts for 36%. Transport accounts for 24% of total capital investment and is the largest demand-side sector, followed by buildings (22%) and industry (0.04%). Fuel cost investments amount to USD 1 740 billion: 48% for transport, 32% for buildings and 8.9% for industry.

Total investments of USD 2 540 billion under the TGT are USD 111 billion less than in the BAU. Capital investments amount to USD 1 089 billion, which is USD 177 billion higher than the BAU. Fuel cost investments total USD 1 452 billion, which is USD 288 billion below the BAU. The difference results mainly from deploying zero-emissions buildings and raising transport fuel efficiency in the TGT, which both increases capital investment and reduces fuel costs.

[49] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Total investments under the 2DC are USD 2 543 billion, which is USD 108 billion below the BAU. The capital investments amount to USD 1 324 billion and fuel costs are USD 1 219 billion. While the amount of capital investment is highest in the 2DC, its fuel costs are the lowest of the three scenarios. Significant costs from the additional deployment of renewables are partially offset by keeping nuclear reactors running for longer than in other scenarios, while demand sector fuel savings are lower than other scenarios due to behavioural change assumptions.

Figure 9.11 · Korea: Energy sector capital and fuel costs, 2016-50



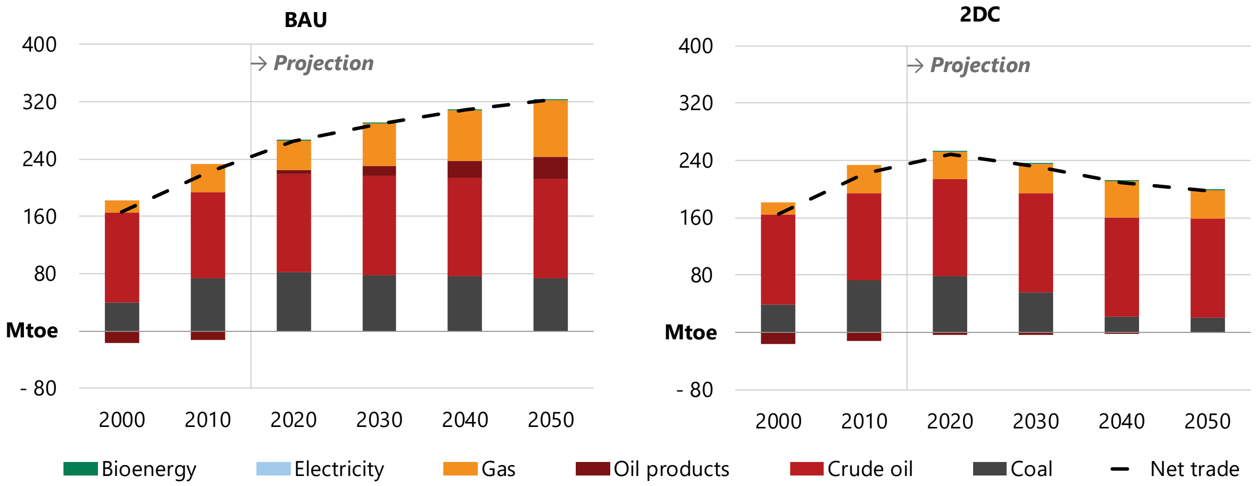
Sources: APERC analysis and IEA (2018a).

ENERGY TRADE AND SECURITY

As it is essential for Korea to secure the energy supplies it needs to support its manufacturing-based economic growth, and as its domestic resources are limited, energy imports are considerable. Almost 100% of the crude oil Korea uses is imported, mostly from the Middle East, so finding alternative suppliers (i.e. within APEC) to reduce its dependency on Middle Eastern oil would greatly improve the economy's energy security. Unlike its crude oil imports, Korea's coal comes from diverse sources, mostly Australia, Canada, China, Indonesia, Russia and the United States. It also imports LNG from Qatar, Oman, Indonesia and Malaysia.

Net import of energy in Korea in 2016 is 247 Mtoe, the majority of which was crude oil (60%), followed by coal (33%) and gas (16%). Under the BAU, energy imports grow to 323 Mtoe in 2050. Crude oil still occupies the largest share at 43%, but gas increases to 25% and coal falls to 23% (Figure 9.12). Under the 2DC, imports peak around 2020 at 252 Mtoe and then decrease to 198 Mtoe in 2050, with the share of crude oil rising from 60% in 2016 to 70% in 2050. As in the BAU, the share of gas is second-largest (20%), and coal imports fall sharply to third place (10%).

Figure 9.12 · Korea: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Korea's primary energy supply self-sufficiency rate is one of the lowest in APEC, and under the BAU it decreases greatly to 11% in 2050 (from 19% in 2016) because of lower nuclear energy use and moderate growth in renewable generation (Table 9.3). Under the 2DC, however, energy self-sufficiency increases to 33% in 2050, owing to higher renewables-based power generation from solar and wind, and greater nuclear generation.

Table 9.3 · Korea: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	19	16	18	25	11	14	33
Coal self-sufficiency (%)	0.94	1.0	1.0	1.4	1.0	1.1	4.1
Gas self-sufficiency (%)	0.33	0.0	0.0	0.0	0.0	0.0	0.0
Crude oil self-sufficiency (%)	0.46	0.0	0.0	0.0	0.0	0.0	0.0
Primary energy supply diversity (HHI)	0.27	0.27	0.26	0.25	0.28	0.26	0.25
Coal reserve gap (%)	0.89	13	13	13	30	31	31
Gas reserve gap (%)	16	73	73	73	75	75	75
Crude oil reserve gap (%)	48	111	111	111	123	123	123

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

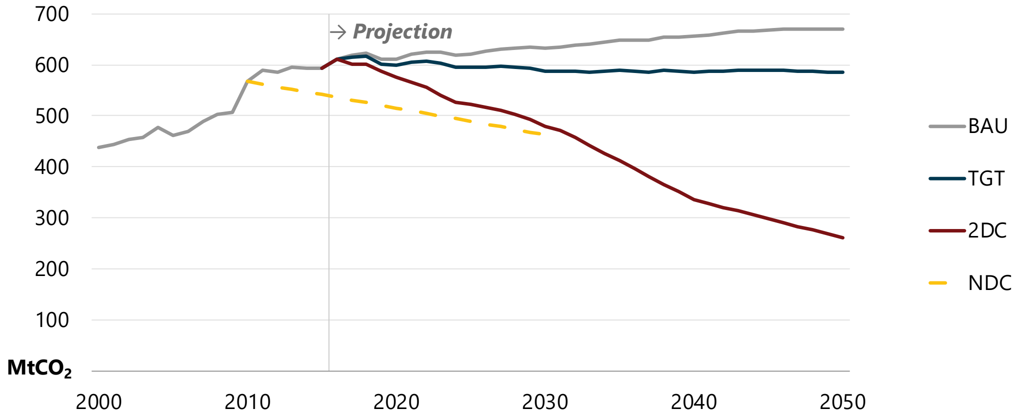
SUSTAINABLE ENERGY PATHWAY

At the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, hereafter referred to as the 'COP21 Paris Agreement', Korea announced its Intended Nationally Determined Contribution (INDC)[50] to reduce greenhouse gas emissions across all economic sectors by 37% below the business-as-usual level of 850 million tonnes of carbon dioxide ($MtCO_2$) per year by 2030. In March 2016, this INDC was ratified as Korea's first Nationally Determined Contribution (NDC) (UNFCC, 2015).

[50] Intended Nationally Determined Contributions (INDCs) reflect policy action to support the agreement reached during the COP21 Paris Agreement.

Under the BAU Scenario, CO_2 emissions increase gradually from 606 $MtCO_2$ in 2016 to 659 $MtCO_2$ in 2050, in contrast with a modest decrease to 573 $MtCO_2$ in 2050 in the TGT (Figure 9.13). In the 2DC, however, emissions fall sharply throughout the projection period to 241 $MtCO_2$ in 2050. Declines in the TGT are driven by increasing energy efficiency and the increased role of renewable power in Korea's electricity mix. These declines are limited, however, by Korea's policy to decrease nuclear use. Attaining the 2DC targets requires additional policy measures. In particular, strong efforts should be made to reduce coal-fired power generation as much as possible while maintaining security of supply.

Figure 9.13 · Korea: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

The effects of recent energy policy developments on CO_2 emissions, energy stability and security are uncertain. Expanding renewable sources for electricity generation would reduce CO_2 emissions and increase energy security, but the intermittency of renewables-based generation could jeopardise electricity supply stability. In addition, energy prices could rise to cover the cost of deploying significant new generation capacity.

Similarly, using natural gas instead of coal to generate electricity would reduce CO_2 emissions but raise the economy's import dependency and energy prices. Although gradually reducing the use of nuclear resources would quell public fears over nuclear safety, it would make it difficult to reach CO_2 emissions reduction and energy security goals.

Improving energy efficiency is essential to reduce energy consumption and CO_2 emissions. Applying stricter fuel standards for road vehicles may be necessary, as well as higher efficiency standards for residential and service buildings. Rapid implementation and expansion of net-zero-energy buildings, as well as continued improvements in energy efficiency labelling and standards for appliances, would also curtail demand and avoid some possible electricity dilemmas.

As illustrated by the BAU and TGT Scenarios, Korea's current policy to use less nuclear and more renewable energy to generate power will require additional measures to maintain energy stability and work towards the NDC. Renewable energy is vulnerable to weather variability, so having storage and backup is necessary to ensure a steady electricity supply. Furthermore, if natural gas generation is used to compensate for declining nuclear generation, both coal and gas plants may need to be fitted with CCS systems to control CO_2 emissions. In the pursuit of these policies, maintaining a reasonable electricity price will be a considerable challenge.

Projections indicate that Korea needs to maintain a certain portion of nuclear-based electricity generation to meet the 2DC goal, which contradicts current policy. Therefore, additional policies to reduce CO_2 emissions, such as increasing spending on low-carbon research and development (particularly CCS), expanding smart factories to use energy more efficiently, and increasing the use of EVs will have to be adopted to help reduce emissions from the generation fleet.

10. MALAYSIA

KEY FINDINGS

- **Strong economic growth propels Malaysia into high-income economy status in the early 2020s.** GDP increases at a CAGR of 4.0% during 2016-50 while population growth is more modest (0.86% CAGR).

- **Malaysia's FED increases from 52 Mtoe to 89 Mtoe over the Outlook period.** The transport sector continues to be the greatest energy user in all scenarios. Compared with the BAU, energy demand is 11 Mtoe lower under the TGT by 2050 and 25 Mtoe lower under the 2DC.

- **Malaysia's generation capacity reaches 55 GW in 2050, with fossil fuels accounting for 64% (35 GW) of total capacity.** Total generation capacity is 1.5 GW higher under the 2DC than in the BAU, but fossil fuels account for only 48% (27 GW).

- **Energy intensity improves by 55% in the BAU and 67% in the 2DC.** Ongoing energy efficiency and conservation programs help reduce Malaysia's energy intensity in the future.

- **As it transitions to being a net energy importer, Malaysia must ensure the security of its energy supply.** It becomes a net energy importer by 2026 in the BAU as the result of higher coal imports, and by 2046 it is also a net natural gas importer as imports to Peninsular Malaysia outweigh exports from Sarawak.

- **Malaysia's unconditional energy sector NDC is achievable in all three scenarios.** However, total energy-related emissions in the BAU reach 330 MtCO_2 in 2050—50% higher than the 2016 level of 220 MtCO_2, illustrating the importance of long-term policies to deliver sustained emissions reductions.

ECONOMY AND ENERGY OVERVIEW

Located in south-east Asia, Malaysia has a total territory of about 330 535 square kilometres (km^2), roughly the same size as Viet Nam and the Philippines but slightly smaller than Japan. The economy is separated by the South China Sea into the two main geographical areas of Peninsular Malaysia (West Malaysia) and East Malaysia (Sabah and Sarawak on the island of Borneo). Kuala Lumpur is the capital, but the seat of the federal government is in Putrajaya. The population was 31 million in 2016 and has been increasing at a compound annual growth rate (CAGR) of 1.9% since 2000.

Malaysia's gross domestic product (GDP) reached USD 854 billion in 2016, a 35% increase from 2015. GDP per capita also increased by 2.7%, from USD 26 677 in 2015 to USD 27 289 in 2016 (Table 10.1). The largest contributions to GDP in 2016 were from services (54%), manufacturing (23%), agriculture (8.1%), mining and quarrying (8.8%) and construction (4.5%) (MEA, 2017).

Table 10.1· Malaysia: Macroeconomic drivers and projections, 2000-2050

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	403	633	854	1 039	1 592	2 332	3 232
Population (million)	23	28	31	33	37	40	42
GDP per capita (2016 USD PPP)	17 402	22 521	27 389	31 625	43 249	58 787	77 463
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	36	68	83	89	103	115	131
TPES per capita (toe)	1.6	2.4	2.7	2.7	2.8	2.9	3.1
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	90	108	97	86	65	49	41
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	18	39	52	55	66	77	89
FED per capita (toe)	0.78	1.4	1.7	1.7	1.8	1.9	2.1
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	45	61	61	53	42	33	28
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	91	182	213	219	270	295	324
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	97	99	99	99	99	99	99

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

Malaysia has traditionally been an energy exporter, mainly of crude oil and natural gas (through pipelines and as liquefied natural gas [LNG]). Total energy exports were 57 million tonnes of oil equivalent (Mtoe) in 2016, a 4.8% increase from 2015. Most of the recent growth in energy exports has been in oil products, which expanded from 10 Mtoe in 2015 to 12 Mtoe in 2016 (EGEDA, 2018). At the same time, total energy imports increased by 8.0% owing to strong crude oil import expansion from 8.4 Mtoe in 2015 to 11 Mtoe in 2016.

To meet rising gas demand, a second LNG import terminal with a capacity of 3.5 million tonnes per annum (Mtpa) started operating in 2017. The government has also introduced regulations to promote third-party access, aiming to liberalise the Malaysian gas market and create competition for gas sellers and buyers. However, gas imports decreased by 18% from 2015 to 2016 (1.6 Mtoe to 1.4 Mtoe) (Energy Commission, 2017).

Under the Economic Transformation Program (ETP) launched in 2010, the government set a target to elevate Malaysia to a developed and high-income economy by 2020. The World Bank defines high-income economies as those whose gross national income (GNI) per capita stands at USD 12 236 or more in 2016. According to the World Bank, in 2017 Malaysia's average GNI per capita was USD 9 660. World Bank projections suggest that Malaysia could cross the high-income economy threshold at some point during 2020-24 (WB, 2017). A recent mid-term of the 11th Malaysian Plan 2016-2020 anticipates 2024 as the crossing point (MEA, 2018).

ENERGY RESOURCES

Malaysia's energy resources are adequate to support significant exports of oil and natural gas but are moderate compared with some larger Asia-Pacific Economic Cooperation (APEC) economies. Nearly two-thirds of Malaysia's energy reserves are in East Malaysia and the rest are in Peninsular Malaysia. The economy's oil reserves (including condensate) in 2016 were 3.6 billion barrels (bbl), with 35% found in Peninsular Malaysia (the Malay Basin) (Table 10.2) (Energy Commission, 2017). Natural gas reserves were approximately 2.7 trillion cubic metres (tcm) or 97 trillion cubic feet (tcf) in 2016, with more than half found in the Sarawak Basin. Coal resources, which are largely undeveloped, are estimated at 1.9 billion tonnes, located mostly in Sarawak and Sabah (Energy Commission, 2017).

Table 10.2 · Malaysia: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Oil (billion bbl) [a]	3.6	14	0.21	27	8.0
Natural gas (tcm) [a]	2.7	35	1.4	15	6.0

Notes: a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions.
Source: BP (2018).

The economy also has vast potential to use biomass as an energy resource owing to its palm oil plantations and industries. As of 2016, Malaysia accounted for 29% of global palm oil production and 34% of palm oil exports (Palm Oil Analytics, 2017) (MPOC, 2017). Production creates abundant agricultural residue, particularly of empty fruit bunches.[51] Although solar irradiance in Malaysia is not as high as elsewhere in APEC (such as Australia, Mexico, the west of China and the United States), resources are abundant (as is common around the equator) (WBG, 2018).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

The National Renewable Energy Policy and Action Plan (NREPAP) and the 11th Malaysia Plan provide the longstanding framework for the sustainable development of the energy sector. More recently, the National Energy Efficiency Action Plan (NEEAP) and the Green Technology Master Plan (GTMP) were also introduced, becoming key energy policy instruments to catalyse sustainable economic growth in Malaysia.

The 11th Malaysia Plan (for 2016-20) aims to expand renewable energy capacity from 243 megawatts (MW) in 2014 to 2.1 gigawatts (GW) by 2020 by implementing a feed-in tariff (FiT), along with both the Net Energy Metering (NEM) and Large-Scale Solar (LSS) programs. As of December 2018, 602 MW of renewables had been

[51] In the process of palm oil production, a large amount of residue such as empty fruit bunches (EFBs) of palm is generated. The EFB is a type of woody biomass with a calorific value of 4 400 kilocalories per kilogramme of dry matter (kcal/kg-dry) and a very low chlorine content, making it very promising for use as a biofuel (Asia Biomass, 2009).

installed under the FiT: 379 MW of solar photovoltaics (PV), 172 MW of biomass and biogas and 50 MW of small hydro (SEDA, 2018).

The 11th Plan also focuses on sustainable energy use and energy efficiency initiatives through the introduction of the NEAAP 2016-25, which provides policy guidance to implement energy efficiency measures for electricity use in the industry and buildings sectors (residential and services). Both sectors aim to reduce electricity demand by 52 233 gigawatt-hours (GWh) over 10 years (equivalent to 8% of total electricity demand or 38 million tonnes of carbon dioxide [$MtCO_2$] compared to business-as-usual levels) (MESTECC, 2017). Energy efficiency in buildings and industry is currently regulated through the Efficient Management of Electrical Energy Regulation (EMEER) 2008. Installations that consume or generate electricity for their own consumption equal to at least 3 000 GWh for six consecutive months are mandated to appoint a registered electrical energy manager, report on consumption every six months and implement measures to reduce electricity demand along the way.

In April 2017, an Energy Performance Contracting (EPC) Fund was established to act as a catalyst for the nascent energy efficiency service industry. The fund aims to enhance the credibility and financial ratings of energy service companies (ESCOs) to perform energy efficiency and conservation projects, and also to increase confidence in financial institutions that provide funding for ESCOs by creating successful model projects. Malaysia Debt Ventures Berhad (MDV), a subsidiary of the Malaysian government, is leading the financing initiative for energy efficiency projects by providing a fund of around USD 51 million, with further credit guarantees of about USD 3.0 million contributed by other government organisations.

In July 2017, in collaboration with United Nations Development Program (UNDP), Malaysia completed a demand-side management (DSM) preliminary study to analyse electrical and thermal energy demand trends as well as energy use in the transport sector. Following the DSM study, Malaysia began drafting a comprehensive new Energy Efficiency and Conservation Act (Electrical and Thermal) and related sub-regulations to achieve government targets, to be released in 2019.

The GTMP, derived from the National Green Technology Policy (NGTP), was developed to foster a 'green culture' in Malaysia and was launched in October 2017 (Box 10.1). The GTMP serves as a guide to develop green technology as well as programs and projects for the 11th and 12th Malaysia Plans.

Box 10.1 · Malaysia: Green Technology Master Plan 2017-30

The GTMP focuses on six key sectors (energy, manufacturing, transport, buildings, waste and water) and attempts to harmonise sector policies with shared goals in natural resource development. The GTMP goals established for each sector are to be achieved gradually and fine-tuned in the policies and actions developed in every five-year National Development Plan period. To achieve the aspirational goals, the government has set out the strategic thrust as well as the key areas to be targeted.

Table 10.3 · Malaysia: Green Technology Master Plan strategic thrust

Strategic thrust	Key areas
Promotion and awareness	Tailored communication strategy. Industry and business promotion via International Greentech and Eco Products Exhibition (IGEM) and other platforms. Collaboration with primary and secondary educational institutions.
Market enablers	Government Green Procurement. Green incentives. Innovative financing. Green cities. International collaborations.
Human capital development	Capability building in the public sector. Capability building in the private sector. Collaboration with higher education institutions.
Research, development and commercialisation (RD&C)	RD&C funding. Public-private partnerships.
Institutional framework	Governance (policy leadership). Policy planning. Policy implementation.

Source: MESTECC (2017).

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy demand and supply assumptions for Malaysia under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 10.4). Definitions used in this Outlook may differ from government targets and goals published prior to 2018 (such as renewables targets and industry classifications).

Table 10.4 · Malaysia: Key assumptions and policy drivers under the BAU

Buildings	Adoption of green building design encouraged. DSM program maintained. 11th Malaysia Plan targets achieved. MEPS and labelling programs expanded, and efficient management of electrical energy regulations implemented. GTMP implemented.
Industry	SIT abolished and EToU for electricity introduced.
Transport	Deployment of hybrid cars and EVs encouraged. Efficient engine vehicle deployment pursued, as in National Automotive Policy. New rail projects such as Klang Valley Mass Rapid Transit and High-Speed Rail introduced.
Energy supply mix	National Depletion Policy on oil and natural gas applied. ORRR maintained at greater than 1 over the Outlook period. Oil, natural gas and renewables self-sufficiency optimised.
Power mix	Use of renewables and coal expanded. Hydropower projects in East Malaysia completed on schedule.
Renewables	National Renewable Energy Policy renewables targets achieved, as well as 20% renewables by 2025.
Energy security	HHI for fuel mix maintained at less than 0.5.
Climate change	Malaysia's NDC pledge to reduce GHG emissions intensity of GDP by 35% (unconditionally) to 45% (conditionally) by 2030 (relative to the 2005 level) is not achieved in the BAU.

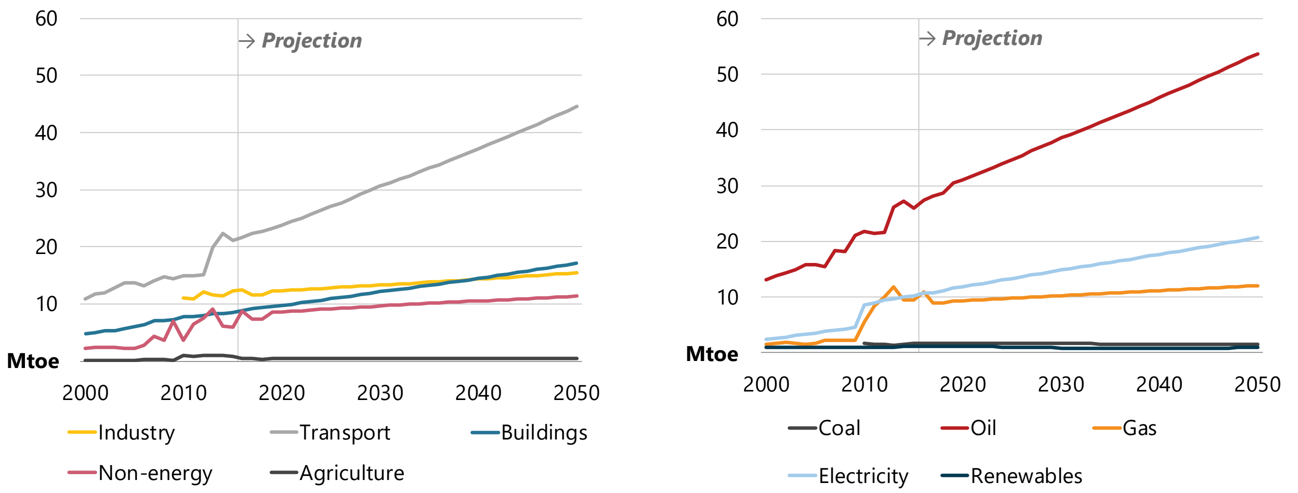
Notes: DSM = demand-side management. MEPS = minimum energy performance standard. GTMP = Green Technology Master Plan. SIT = Special Industrial Tariff. EToU = Enhanced Time of Use. EV = electric vehicle. Outlook period = 2016-50. HHI = Herfindahl-Hirschman Index. ORRR = Overall Resource Replenishment Ratio (measures discovered reserves versus production; a ratio of 1.0 and above is considered 'healthy'). NDC = Nationally Determined Contribution. GHG = greenhouse gas. This table summarises some of the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Malaysia has maintained one of the strongest economic growth records in Asia, in part because of the availability and reliability of its energy supply. Most government policies have focused on supply issues with less attention on demand, although since 2016 this has been changing with the 11th Malaysia Plan emphasising DSM.

In the BAU, final energy demand (FED) rises from 52 Mtoe in 2016 to 89 Mtoe in 2050 at a CAGR of 1.6%, which is well above the APEC average of 0.57% (Figure 10.1). Disaggregated data on industrial energy demand prior to 2010 were not available, and data for 2010 through 2016 were obtained from statistics published in the National Energy Balance (NEB) by the Malaysian government (EC, 2017).

Figure 10.1· Malaysia: Final energy demand by sector and fuel, 2000-50



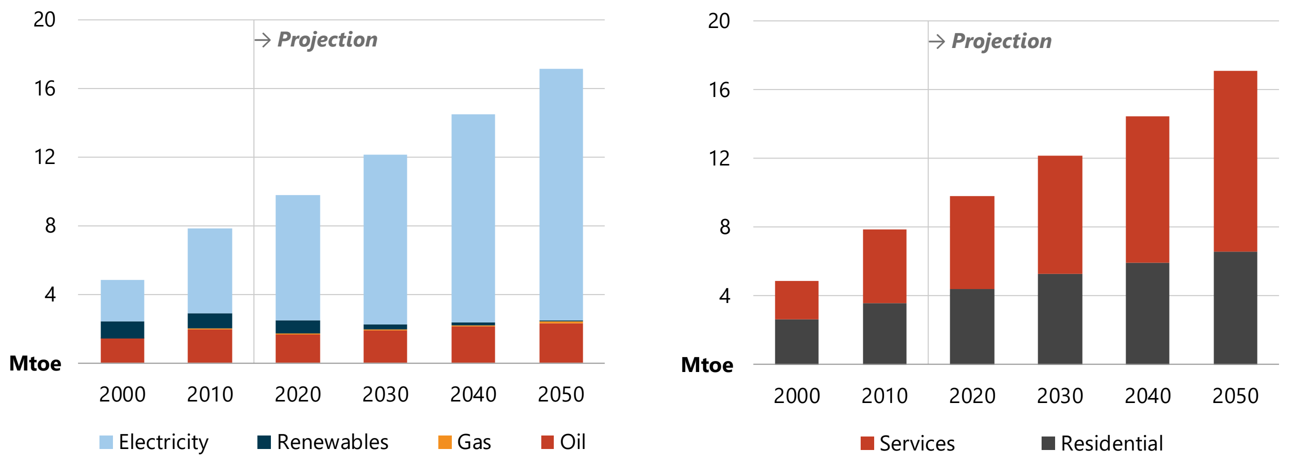
Sources: APERC analysis; industrial data for 2010-16 from (EC, 2017); remaining data from IEA (2018a).

Domestic transport demand accounted for 41% of FED in 2016, followed by industry (24%), buildings (17%), non-energy use (17%) and agriculture (0.79%). Energy demand in the buildings sector doubles from 8.9 Mtoe in 2016 to 17 Mtoe in 2050 and its share increases from 17% to 19%. The share for domestic transport increases to 50% in 2050 as its absolute value increases from 22 Mtoe in 2016 to 45 Mtoe in 2050, whereas the industry share of FED decreases from 24% in 2016 to 17% in 2050. Expansion in buildings and transport is driven by strong economic growth during the Outlook period (2016-50) (4.0% CAGR) and modest population growth (0.89% CAGR).

BUILDINGS: ENERGY DEMAND ALMOST DOUBLES WITHIN 30 YEARS

Energy demand in the buildings sector (services and residential combined) increases at a CAGR of 1.9% in 2016-50. Commercial activity accounts for the highest share (62%) of FED in this sector by 2050, while electricity (with a share of 73% in 2016 and 86% in 2050) continues to dominate energy demand throughout the period. Oil (13%) and natural gas (0.63%) make up the rest of the shares in 2050 (Figure 10.2).

Figure 10.2 · Malaysia: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Residential FED increases from 4.1 Mtoe in 2016 to 6.5 Mtoe in 2050 in line with continued electricity demand growth, which rises from 2.7 Mtoe in 2016 to 5.6 Mtoe in 2050 (2.2% CAGR). Since Malaysia is a tropical economy with average daily temperatures of between 21 degrees Celsius (°C) and 32°C, energy demand for space cooling in residential buildings nearly doubles during 2016-50, from 1.0 Mtoe in 2016 to 1.7 Mtoe in 2050. The number of households also doubles from 7.6 million in 2015 to 13 million in 2050, and the average floor area per household increases by 30% over the period. With this increase in households and floor area (as well as rising GDP per capita), the average energy intensity for space cooling increases from 28 kilowatt-hours per square metre (kWh per m^2) in 2016 to 35 kWh per m^2 in 2050.

Oil, including liquefied petroleum gas (LPG), which is used mainly for cooking, shows a modest increase from 0.60 Mtoe in 2016 to 0.89 Mtoe in 2050 (1.2% CAGR). However, the shift of some households to other fuel types such as electricity (which increases from 0.10 Mtoe in 2016 to 0.43 Mtoe in 2050) is already becoming a trend. Nevertheless, LPG remains the fuel of choice for most households because of the national LPG subsidy (for household use only, not commercial), equivalent to 38% of the LPG price (MDTCA, 2016).

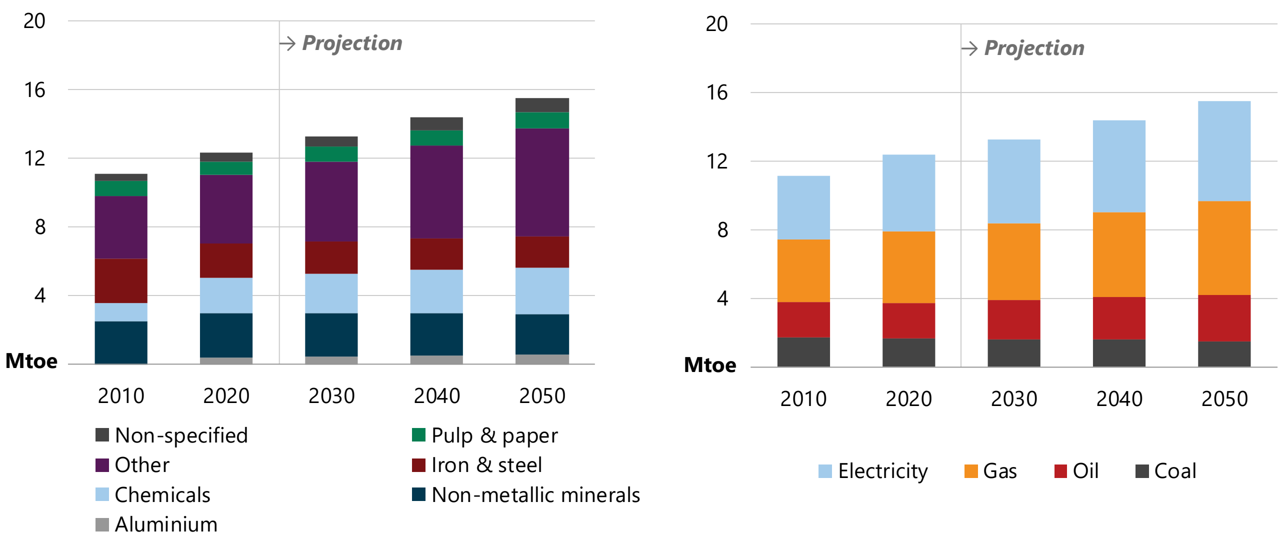
In the services subsector, floor space increases at a CAGR of 2.8% (in tandem with economic growth), from 215 million square metres (m^2) in 2016 to 557 million m^2 in 2050. Services FED doubles, from 4.8 Mtoe in 2016 to 11 Mtoe in 2050. Space cooling makes up one-third of buildings FED in 2050 while lighting decreases from 10% in 2016 to 6.7% in 2050 as more efficient bulbs are deployed. Most of the electricity is used in space cooling and in other end-use sectors (such as computers, appliances, refrigeration and lifts).

INDUSTRY: SIGNIFICANT PETROCHEMICAL INVESTMENTS DRIVE NON-ENERGY DEMAND

In pursuing the ambition to become a high-income economy by 2020, the government has launched many important investment initiatives, among them the Pengerang Integrated Petroleum Complex (PIPC). The PIPC was developed as part of the ETP to establish a dynamic downstream oil and natural gas industry. The project will house oil refineries, naphtha crackers, petrochemical plants and an LNG regasification terminal.

With this development, chemical subsector energy demand nearly doubles from 1.5 Mtoe in 2016 to 2.7 Mtoe in 2050, as does the output of petrochemical products, from 4.2 million tonnes (Mt) to 7.0 Mt (Figure 10.3). Despite a slight decrease, the 'other' subsector—which includes food and beverages, textiles and other industries—continues to be the greatest energy user, accounting for 40% of FED in 2050, an increase from 31% in 2016.

Figure 10.3 · Malaysia: Industry final energy demand by subsector and fuel, 2010-50



Sources: APERC analysis and EC (2017b).

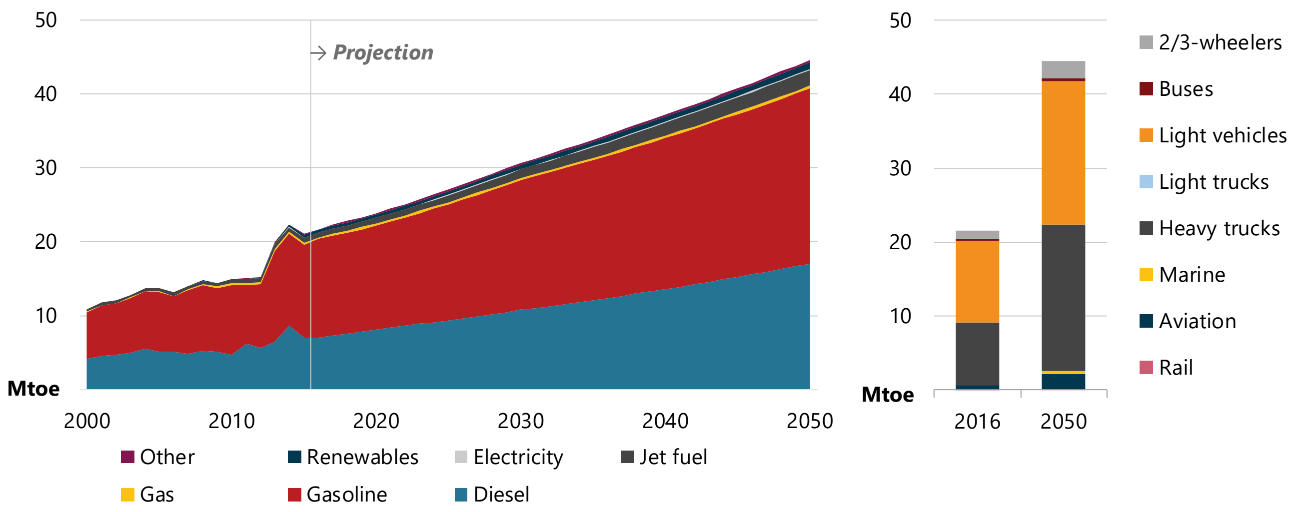
Overall FED for industry expands at a CAGR of 0.62% during 2016-50—much less than the south-east Asia CAGR of 2.3%, but higher than the total APEC CAGR of 0.29%. Electricity and oil shares in industry FED both increase over the Outlook: electricity from 34% to 38% and oil from 16% to 18%. Conversely, the shares of coal and natural gas both shrink (coal from 13% to 10% and natural gas from 37% to 35%), as most of the sectoral growth is in the chemical and petrochemical and 'other' subsectors.

TRANSPORT: ELECTRIC VEHICLE ADOPTION REMAINS LOW DESPITE HIGH GROWTH RATE

Road transport doubles from 21 Mtoe to 42 Mtoe over the Outlook and remains dominant in Malaysia's domestic transport energy demand. This growth is underpinned by a more than doubling of stocks of all vehicle types during the period. Road transport loses some of its share, decreasing from 86% in 2016 to 83% in 2050, to air transport, which increases from 0.60 Mtoe in 2016 to 2.1 Mtoe in 2050 as passenger-kilometres (pkm) travelled increase three-fold (Figure 10.4).

Energy intensity for transporting freight, measured in megajoules (MJ) per tonne-kilometre (tkm), improves from 2.2 MJ per tkm in 2016 to 1.8 MJ per tkm in 2050 with efficiency improvements in the road and air subsectors. Domestic passenger energy intensity falls by an even greater amount, from 1.7 MJ per pkm in 2016 to 1.3 MJ per pkm in 2050 from efficiency improvements in road transport.

Figure 10.4 · Malaysia: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Gasoline and diesel remain the primary fuels in the transport sector over the Outlook, with gasoline increasing from 11.9 Mtoe to 21.1 Mtoe and diesel from 7.4 Mtoe to 17.9 Mtoe. The use of renewables, particularly biodiesel, also expands, from 0.39 Mtoe to 0.86 Mtoe. Electricity demand for transport has the highest CAGR (4.5%), which can be attributed to strong growth in both the electric and hybrid car vehicle stock (albeit starting from a very low base) and growth the use of electrified railway lines.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Malaysia's energy sector has expanded rapidly in recent decades, with total primary energy supply (TPES) more than doubling from 36 Mtoe in 2000 to 83 Mtoe in 2016. Electricity generation, TPES, primary energy production and trade have all historically been dominated by fossil fuels, reflecting Malaysia's considerable crude oil and natural gas resources. The share of renewables increases over the Outlook period, particularly in electricity generation, owing to a succession of government programs.

REFINERIES: NEW INVESTMENT SUPPORTS SELF-SUFFICIENCY

Malaysia currently has five refineries, all in Peninsular Malaysia, with a total capacity[52] of 566 000 bbl per day (28 Mtoe per year) (Energy Commission, 2017). Although this capacity is enough to meet local demand, Malaysia imports a significant quantity of petroleum products from other economies, mostly neighbouring Singapore (UN Comtrade, 2018). It imported 15 Mtoe of petroleum products in 2016 and exported 12 Mtoe, making it a net importer of petroleum products by 3.1 Mtoe, a trend that began in 2010 (Energy Commission, 2017).

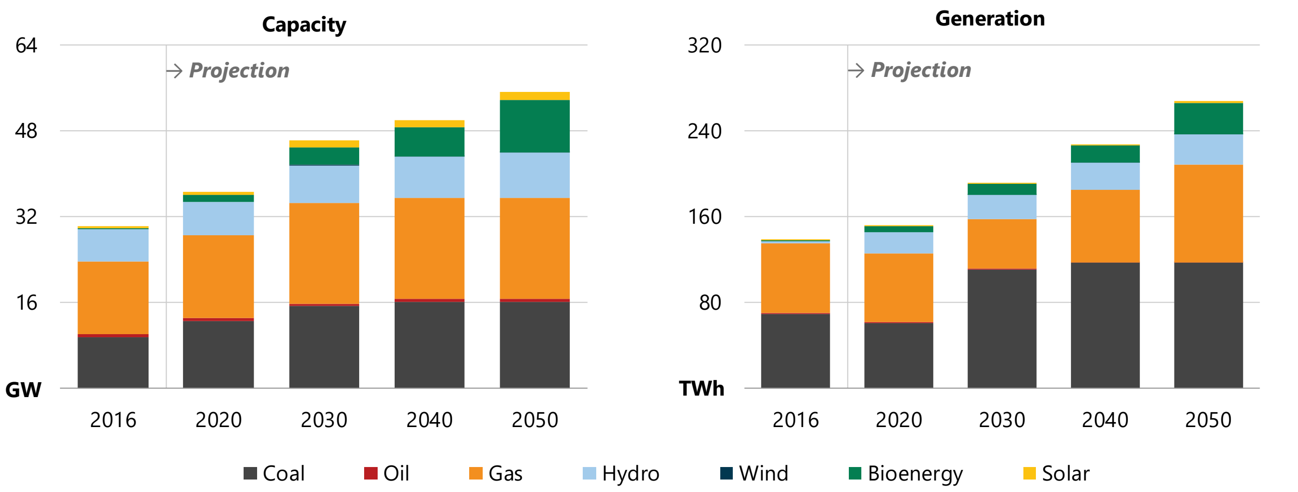
To meet the shortfall, state-owned PETRONAS has invested in a new refinery complex—Refinery and Petrochemical Integrated Development (RAPID)—with a capacity of 300 000 bbl per day (15 Mtoe per year), making it the largest downstream investment in Malaysia (USD 27 billion) (Flour, 2019). The facility, which is poised for start-up in 2019 (PETRONAS, 2017), is expected to increase petroleum product output by 41% to 38 Mtoe in 2020, compared with 27 Mtoe in 2016. As gasoline and diesel demand increase, especially after 2035, the production of petroleum products is assumed to continue expanding to meet local demand.

POWER SECTOR: FOSSIL FUELS TO DOMINATE DESPITE RENEWABLES GROWTH

There are three major electricity grids in Malaysia: the national grid in Peninsular Malaysia and the Sabah grid (on Borneo) are both regulated by the federal government, and the Sarawak grid (also on Borneo) is under the jurisdiction of the state government. The national grid is connected to Thailand's grid to the north (with a power transfer capacity of 380 MW) and to Singapore's main grid to the south (with a power transfer capacity of 450 MW) (Yu Wen Huang, 2019). The Sarawak grid is connected to the Kalimantan grid in Indonesia.

Malaysia's generation capacity reaches 55 GW by 2050, which is 1.8 times higher than the 30 GW in 2016 (Figure 10.5). Natural gas and coal plants continue to be the majority of installed capacity: 5.3 GW and 6.6 GW of natural gas and coal capacity, respectively, is added by 2050. Total generation capacity from fossil fuels is 35 GW (64%) in 2050, which is lower than the 78% registered in 2016.

Figure 10.5 · Malaysia: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

[52] Including condensate splitters.

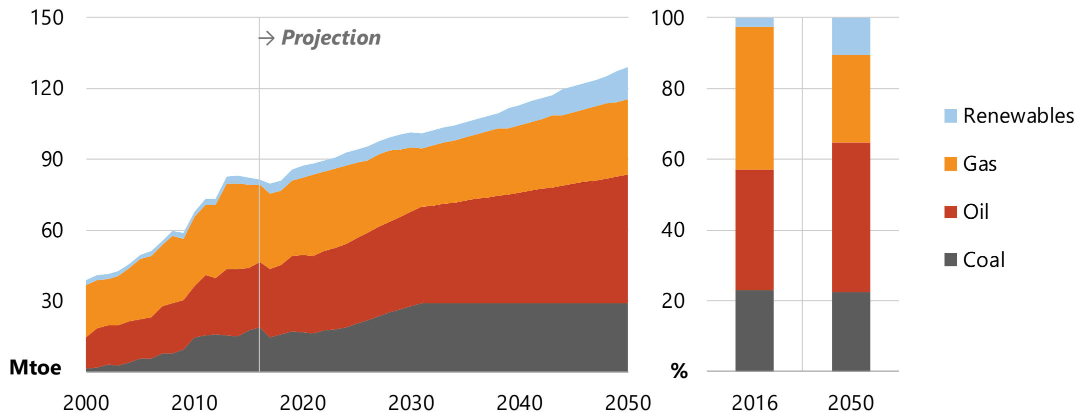
Renewable capacity expands by over 13 GW, from 6.7 GW in 2016 to 20 GW in 2050, achieving the policy target set under the NREPAP 2010. Solar power generation increases at a CAGR of 3.9%, spurred by several mechanisms such as the FiT and the introduction of NEM in 2016, which enables renewable energy generators to sell excess electricity back to the grid system after prioritising internal demand. Biomass also expands rapidly under this scheme, at a CAGR of nearly 12%, and accounts for the majority of renewable capacity additions (9.6 GW) over the Outlook period. More rapid growth occurs during 2016-30, when solar power expands at a CAGR of 9.5%, but it slows rapidly to a CAGR of 0.1% during 2030-50.

The three separate grid systems serving the economy generated a total of 138 terawatt-hours (TWh) of electricity. The share of electricity generated from fossil fuels falls 20% from 2016 to 78% in 2050 as renewable generation increases substantially from 1.8% to 22% over the same period. A mismatch between load centres and resource locations is a major challenge for Malaysia. While Peninsular Malaysia accounts for more than 85% of electricity demand, over two-thirds (69%) of fossil fuel production and most hydro plants (60% of installed capacity) are located in Sabah and Sarawak (Energy Commission, 2017; Borneo Post, 2018).

TOTAL PRIMARY ENERGY SUPPLY: FOSSIL FUELS DOMINATE

TPES grows by 60% between 2016 and 2050 led by strong growth in oil (Figure 10.6). Together, fossil fuels comprise 90% of TPES in 2050. While large, the share of fossil fuels declines from 99% in 2016. In 2050, oil is the largest share of primary fuel (43%), followed by gas (24%), and coal (22%). Coal supply continues to expand at a CAGR of 1.3% (from 19 Mtoe in 2016 to 29 Mtoe in 2050), plateauing from 2031 onwards.

Figure 10.6 · Malaysia: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis; industrial data for 2010-16 from EC (2017); remaining data from IEA (2018a).

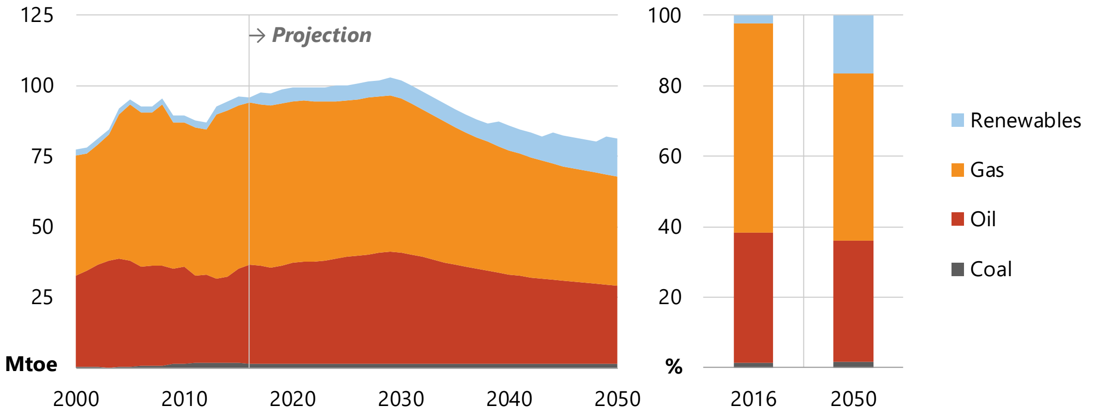
Natural gas supply decreases at a CAGR of 0.071% (from 33 Mtoe to 32 Mtoe). Malaysia started to import LNG in 2013 to meet demand in Peninsula Malaysia. This has driven prices towards global benchmarks, which tend to be higher than for domestically produced natural gas. Malaysia becomes a net natural gas importer by 2046 as demand outstrips production, which is set to decrease from 57 Mtoe in 2016 to 39 Mtoe in 2050.

Malaysia's strong renewables growth (5.6% CAGR) is higher than the APEC CAGR of 1.7% and the APEC south-east Asia regional CAGR of 1.8% due to government policies targeting a higher deployment of renewables, such those under the NREPAP 2010 (i.e. to achieve 12 GW capacity, excluding hydropower capacity above 30 MW) (SEDA, 2011).

PRODUCTION AND TRADE: OIL AND GAS DECLINE WITHOUT ADDITIONAL DISCOVERIES

Primary energy production peaks in 2029 at 103 Mtoe, then begins to decline through 2050 to 81 Mtoe (Figure 10.7). New deep-water wells and enhanced oil recovery help sustain mature fields, causing oil production to expand from 35 Mtoe in 2016 to 40 Mtoe in 2029. After 2029, however, production from mature fields such as Bekok and Dulang begins to decline. Natural gas production declines after 2027, but at a rapid pace, falling to 39 Mtoe.

Figure 10.7 · Malaysia: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Total fossil fuel production decreases by 28% over the Outlook, from 94 Mtoe in 2016 to 68 Mtoe in 2050 while demand rises by 68%. Within this context, Malaysia shifts from being a net energy exporter to net energy importer in 2026 in response to rising domestic energy demand. However, renewables is the only fuel to increase production between 2016 and 2050. Renewable production jumps from 2.1 Mtoe (2.2%) in 2016 to 13.4 Mtoe (17%) in 2050. Government policies supporting bioenergy make it the largest source of renewables (11 Mtoe) in 2050.

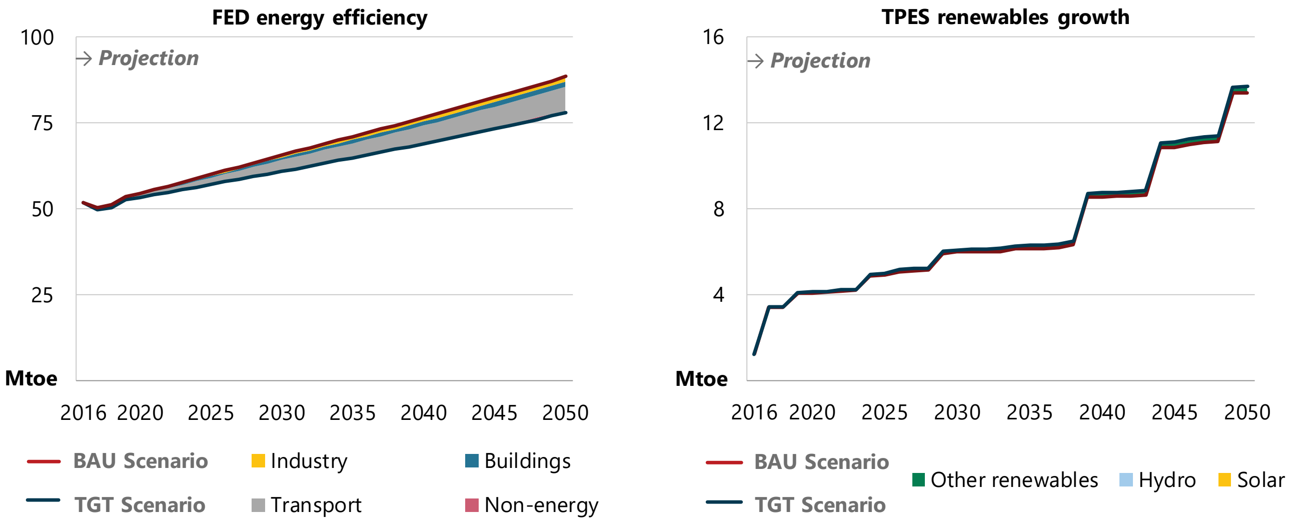
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Malaysia's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 12% lower and CO_2 emissions are 14% lower under the TGT by 2050. Under the 2DC, Malaysia's FED is 28% lower and CO_2 emissions are 55% lower. The share of renewables in TPES is 2% higher in the TGT and 6% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. FED in Malaysia grows strongly throughout the Outlook period, underpinned by robust economic growth (4.0% CAGR in all scenarios). In the TGT there is greater decoupling of energy demand and economic activity that results in FED reaching 78 Mtoe in 2050, compared with 89 Mtoe in the BAU (Figure 10.8). To help meet the APEC target, Malaysia has increased efforts to reduce energy intensity, for example, by introducing the GTMP and the NEEAP.

Figure 10.8 · Malaysia: Energy efficiency and renewables growth, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU, excluding biomass in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Under the TGT, Malaysia could reduce demand by up to 11 Mtoe in 2050, equivalent to 12% of FED in the BAU. Two-thirds of this energy demand reduction is in the transport sector, followed by buildings (15%), industry (14%) and non-energy (8%). Demand reductions amount to a cumulative 189 Mtoe over the Outlook period, which is 3.6 times the FED in 2016.

Deployment of more advanced vehicles (hybrids, plug-in hybrids, battery electric and fuel cell electric) is essential in the TGT to reduce energy demand in transport. There are nearly twice as many advanced light-duty vehicles (LDVs) by 2050 under the TGT (844 000) as in the BAU (477 000). Average energy intensity for domestic freight improves from 1.8 MJ per tkm for road transport in 2050 in the BAU to 1.6 MJ per tkm under the TGT. The buildings and industry sectors each consume 1.5 Mtoe less energy in 2050 compared with the BAU, owing to higher efficiency from stronger building and electric appliance regulations in the buildings sector, and to wider deployment of best available technologies in industry.

Renewable energy supplies in the TGT in 2050 are only marginally higher (0.39 Mtoe) than in the BAU. The strong renewables penetration projection in the BAU, especially in the power sector, results in renewable energy expanding more than 500% by 2050 in all three scenarios. The greater deployment of renewables in the TGT is achieved mainly by substituting bioenergy for coal in the industry sector.

TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

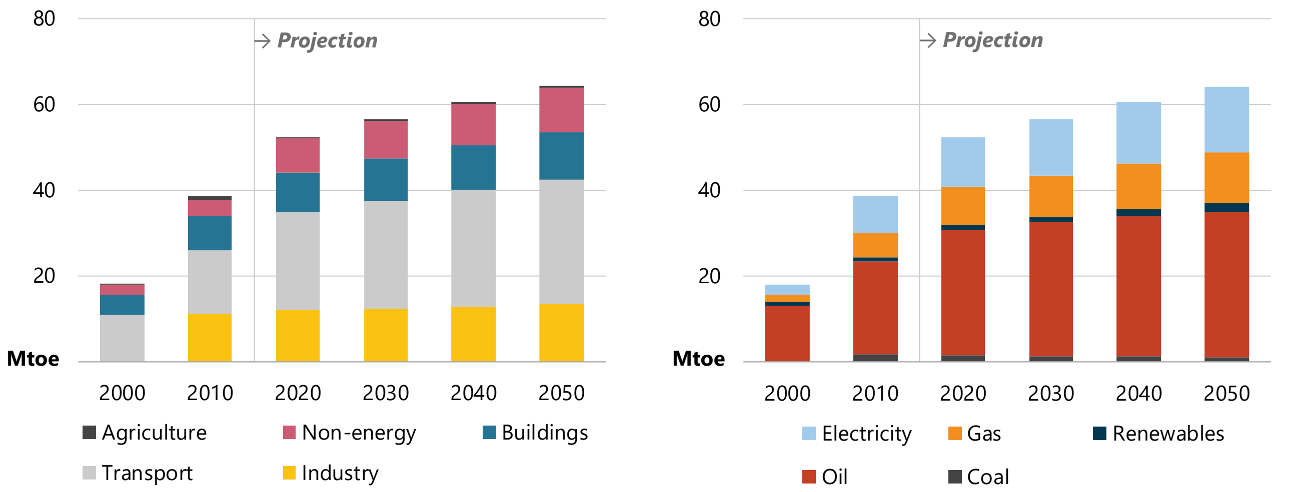
The 2DC represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050.

To meet the aims of this scenario, the energy sectors in Malaysia will have to undergo various levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA) (IEA, 2017). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

With a CAGR of 0.63% over the Outlook period, FED is 28% lower in the 2DC than in the BAU in 2050. Buildings (36%) energy demand contributes the most to this reduction, followed by transport (35%) and industry (14%). Electricity and renewables, particularly modern biomass and biofuel, are more important in the 2DC, mainly displacing oil (Figure 10.9).

Figure 10.9 · Malaysia: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis; industrial data for 2010-16 from EC (2017b); remaining data from IEA (2018a).

Buildings energy demand reaches 11 Mtoe in 2050, compared with 17 Mtoe in the BAU. Building envelope and appliance efficiency standards are assumed to be even more rigorous than in the BAU, resulting in significantly lower energy demand, particularly from space cooling. The energy demand reduction is determined by total floor area in the services subsector, which in the BAU and TGT reaches 557 million m^2 in 2050. In the 2DC, however, total floor area is 445 million m^2 as a result of behavioural changes (such as increased teleworking), although the same economic growth projections are applied.

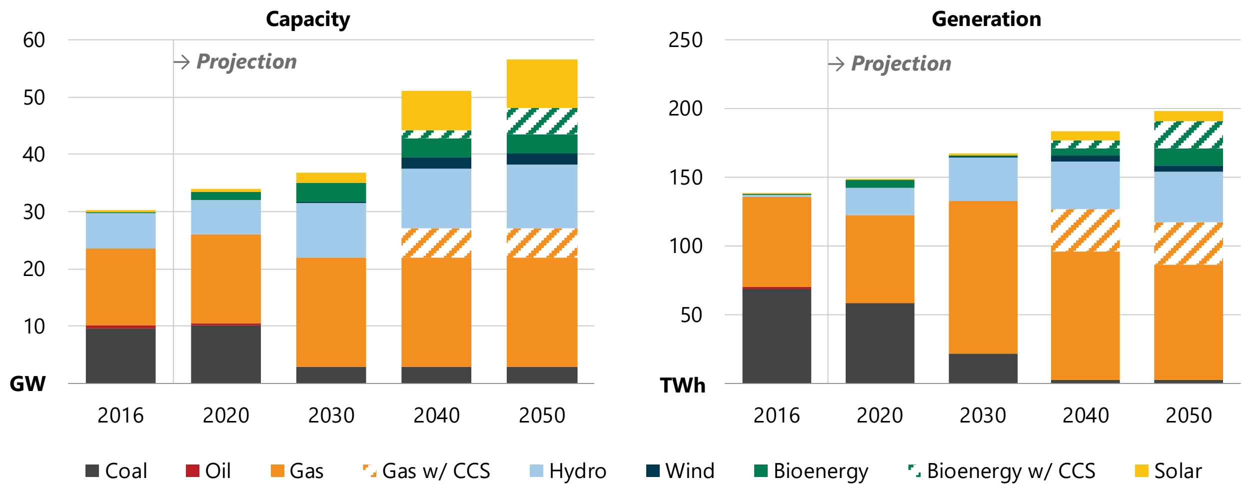
Domestic transport FED continues to increase in the 2DC, but to only 29 Mtoe in 2050—15 Mtoe lower than in the BAU. Although gasoline and diesel continue to dominate the market under the 2DC in 2050 (with a combined share of 79%), the absolute volume (23 Mtoe) is 59% of the BAU projection (39 Mtoe). Electricity has a larger share in the 2DC (2.5% in 2050) than in the BAU (0.34%), as more advanced vehicles are assumed to be deployed. To achieve the 2DC target, Malaysia would need at least 400 000 battery-operated electric vehicles on the road by 2030 and 680 000 by 2050.

Industry demand also drops under the 2DC, though not as much as in transport and buildings. Industry FED in the 2DC in 2050 is 2.1 Mtoe lower than in the BAU, owing to improved scrap recycle rates in iron and steel and clinker-to-cement ratios in non-metallic minerals. These two industries also introduce some carbon capture and storage (CCS) technology during the Outlook period and substitute some coal and natural gas demand with biomass and biogas where feasible.

TRANSFORMATION AND SUPPLY IN THE 2DC

Substantial shifts occur in the power sector, as it is Malaysia's most cost-effective energy sector to decarbonise (Figure 10.10). Fossil fuels account for only 48% of generation capacity in the 2DC, compared with 64% in the BAU and 62% in the TGT. While the total installed capacity in 2050 increases only slightly relative to BAU (by 1.5 GW), generation shifts away from coal-fired plants. Coal capacity declines from 10.2 GW to 3.0 GW between 2020 and 2030, replaced initially by gas, hydro and bioenergy. Unlike under the BAU and TGT scenarios, CCS for gas-fired and bioenergy plants is deployed nearly equally for a total of 9.6 GW. CCS for gas-fired capacity is introduced in 2035 but has limited long-term potential due to a mismatch between geological storage capacity and electricity demand (in Peninsular Malaysia). This mismatch partially explains the addition of six times the amount of solar PV as the installed base in the BAU Scenario.

Figure 10.10· Malaysia: Power capacity and electricity generation in the 2DC by fuel, 2016-50

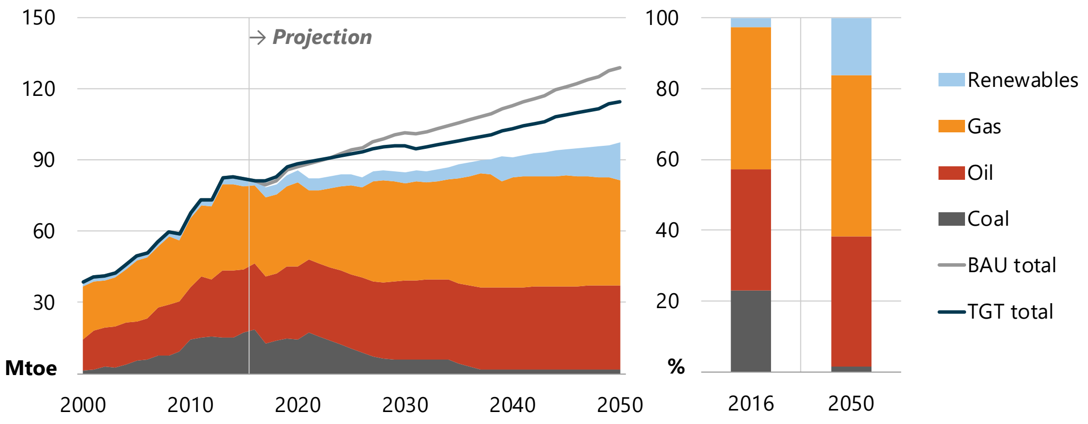


Notes: CCS = carbon capture and storage. The inclusion of nuclear power is based on the modelling results and does not reflect Malaysian government policy.
Sources: APERC analysis and IEA (2018a).

The bulk of electricity generation comes from natural gas plants (58%), followed by renewables (41%) and coal (1.3%). This shift is in stark contrast with the BAU scenario, in which 44% of all electricity is generated from coal while gas (34%) and renewables (22%) supply the remainder. Decarbonisation accelerates quickly after 2020 owing to the shift away from coal capacity. However, decarbonisation of the refinery and upstream sectors is challenging because of the limited scope for less carbon-intensive processes and fuels. Substituting fossil fuel use in the coal mining and oil and gas subsectors is generally neither practical nor financially viable. As such, no renewables are projected to be deployed in these sectors or in refining even in the 2DC.

Under the 2DC, the absolute volume and composition of TPES reflects the demand reductions and shift away from coal in the power sector (Figure 10.11). At 100 Mtoe in 2050, TPES in the 2DC is significantly lower than in both the BAU (131 Mtoe) and the TGT (117 Mtoe). The share of renewables increases by more than six times from 2016, reaching 16% in 2050. The substitution of gas and renewables for coal is clear from 2020 onwards, and the oil share grows by only 0.75% between 2016 and 2050 as vehicle efficiency standards and wider EV deployment temper growth in oil consumption.

Figure 10.11· Malaysia: Total primary energy supply in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Malaysia's primary energy production is dominated by gas and oil, which together account for 79% of total production (66 Mtoe). Renewables make up another 19%, with the remainder from coal (1.4%). The domestic production profile is very similar to those of the BAU and TGT scenarios, but net imports reflect the changes in demand and transformation. Lower coal demand reduces net coal imports from 28 Mtoe in the BAU to only 0.13 Mtoe in the 2DC. Reflecting the expansion of gas plants in the power sector, net gas imports remain strong at 3.0 Mtoe (declining from 3.9 Mtoe in the BAU). However, net oil imports increase by 0.49 Mtoe more than in the BAU (to 12 Mtoe), driven by transport demand.

SCENARIO IMPLICATIONS

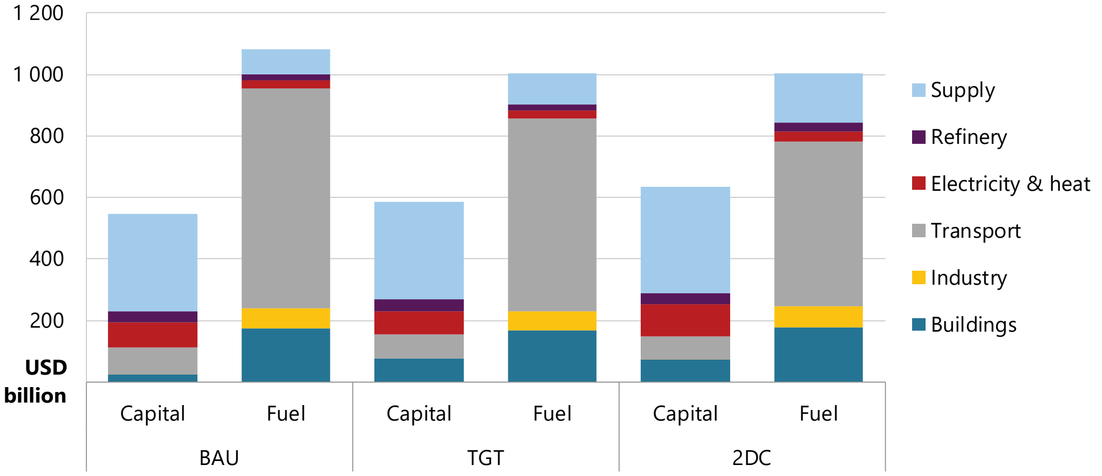
ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[53]

Under the BAU, total energy investments reach USD 1 627 billion over the Outlook period (Figure 10.12). The largest share of spending (49%) is in the transport sector (USD 804 billion cumulatively), of which fuel costs are USD 715 billion. The second largest share of spending (19%) is allotted to upstream activities – USD 315 billion over the Outlook period – including fossil fuel exploration and production. An additional USD 38 billion is invested in refineries, and investment in electricity amounts to USD 82 billion (5.0% of the total).

[53] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 10.12· Malaysia: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

Total investment in the TGT decreases by 2.4% (USD 40 billion) compared with the BAU. Buildings receive the highest incremental investment over the BAU (USD 52 billion) as a wider deployment of energy-efficient technologies contributes to a reduction in FED by 12% compared with the BAU in 2050. Total fuel costs decrease by USD 78 billion (7.2%) relative to BAU on increased biomass consumption. Under the 2DC, overall investment is only 0.55% (USD 8.9 billion) higher than in the BAU. Capital expenditures increase by USD 87 billion, reflecting substantial investments in buildings, power and supply (particularly in new LNG terminals). Fuel expenditures decrease by USD 78 billion (relative to BAU) leaving a net cost of USD 8.9 billion meaning the fuel savings in 2DC are not quite enough to offset the capital expenditures.

ENERGY TRADE AND SECURITY

The National Depletion Policy, introduced in 1980, aimed to safeguard the development of natural oil reserves as crude oil production increased rapidly. This policy caps oil production at around 650 000 bbl per day (32 Mtoe per year). Under the 11th Malaysia Plan, the government introduced a fuel diversity index that uses the Hirschmann-Herfindahl Index (HHI) as guidance, whereby an HHI value exceeding 0.50 reflects overdependence on certain fuel resources (MEA, 2015). Priority is given to exploring alternative fuels to optimise the fuel mix and reduce dependence on fossil fuels for electricity generation. The HHI for 2016 was 0.32, which indicates a healthy index (Table 10.5). The BAU and TGT scenarios show improvement by 2050, but the index in the 2DC increases to 0.36.

Table 10.5 · Malaysia: Energy security indicators under the BAU, TGT and 2DC

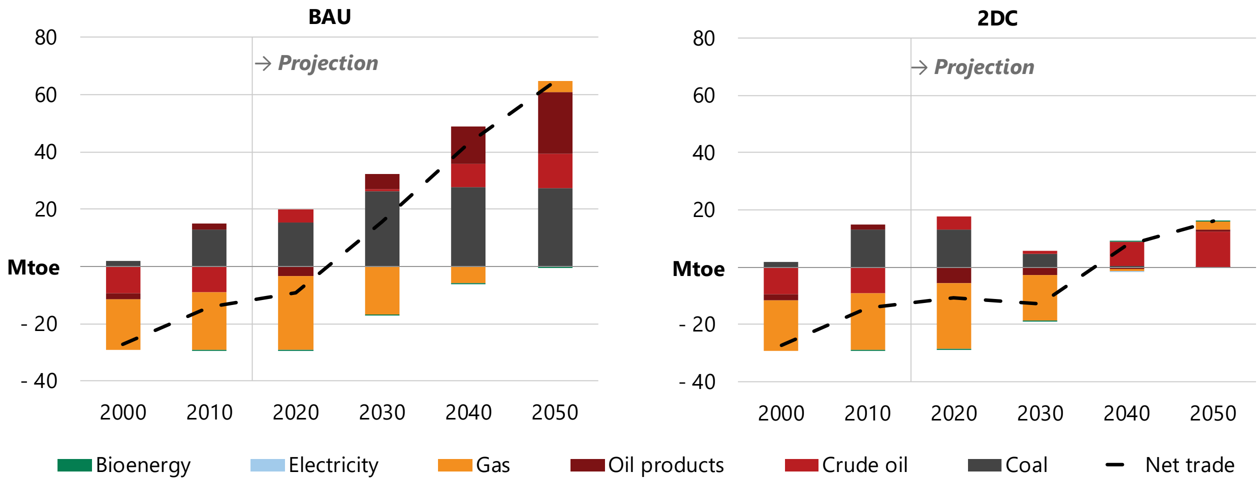
	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	80	73	77	99	56	64	84
Coal self-sufficiency (%)	7.6	5.1	6.0	23	4.9	6.1	92
Gas self-sufficiency (%)	100	100	100	100	100	100	87
Crude oil self-sufficiency (%)	100	98	98	97	73	73	72
Primary energy supply diversity (HHI)	0.32	0.31	0.31	0.39	0.30	0.29	0.36
Coal reserve gap (%)	0.12	1.6	1.6	1.6	3.7	3.7	3.7
Gas reserve gap (%)	2.3	33	33	33	68	68	68
Crude oil reserve gap (%)	4.4	72	72	72	158	158	158

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

Malaysia's coal imports reached 29 Mt in 2016, ranking it the eighth-largest coal importer in the world (IEA, 2017b). This reflects rapid expansion of coal generation capacity, especially during 2000-16 when coal demand in the power sector swelled from 1.5 Mtoe to 17 Mtoe. Though Malaysia has 1.9 billion tonnes of proven coal reserves, most deposits are of poor quality and are in protected areas such as national parks in Sabah and Sarawak (Energy Commission, 2017). With limited options to extract enough domestic coal to meet demand in 2016, Malaysia resorted to imports, mainly from Indonesia (64%), Australia (20%) and Russia (10%) (UN Comtrade, 2018).

Although Malaysia is a significant crude oil importer, it can be considered self-sufficient in meeting its oil demand as half of its crude oil production was exported in 2016 (Energy Commission, 2017). The high-quality oil (Tapis blend) with low sulphur content and density (i.e. crude that is very sweet and light) fetch a high price on the global market. As one of the very few net oil exporters left in south-east Asia (along with Brunei Darussalam) and one of the largest LNG exporters in the world in 2016, Malaysia has relied on energy exports to develop its economy (IGU, 2017). North-east Asia has traditionally been the main export destination for Malaysian LNG. New markets are currently being explored to expand the customer base. In 2017, PETRONAS signed a 15-year LNG export contract with Thailand (OGJ, 2017). PETRONAS also signed an agreement with United States-based Cheniere Energy to receive 1.1 Mt of LNG per year for 20 years (Houston Chronicle, 2018).

Figure 10.13 · Malaysia: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Under the BAU, Malaysia becomes a net energy importer in 2026 when net coal and oil imports outweigh net gas exports (Figure 10.13). Coal imports continue expanding throughout the period to reach 27 Mtoe in 2050 while growing domestic demand for gas causes Malaysia to become a net natural gas importer in 2046. Under the 2DC, it becomes a net gas importer in 2041 due to higher domestic demand, but overall energy imports are much lower by 2050 (16 Mtoe, compared with 65 Mtoe in the BAU) because oil demand is significantly lower and coal demand is negligible.

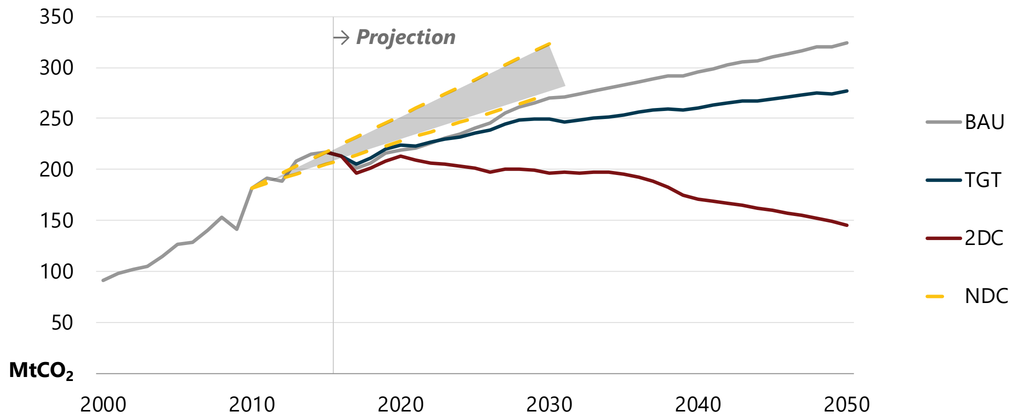
SUSTAINABLE ENERGY PATHWAY

The Nationally Determined Contributions (NDCs) reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement'. Malaysia's NDC pledges to reduce the greenhouse gas (GHG) emissions intensity of its GDP by 45% from the 2005 level by 2030. Of this reduction, 35% is pledged unconditionally and a further 10% is conditional on receiving climate financing, technology transfer and capacity building from developed countries. The target is not limited to energy-related emissions only (UNFCCC, 2015).

Although the NDC target covers all economic activities, APERC compared the energy-related CO_2 emissions reduction by applying the target proportionately to energy-related emissions. Both the unconditional and conditional targets are achieved in all three scenarios by 2030, although only barely in the BAU, in which energy-related emissions reach 330 $MtCO_2$ in 2050—50% higher than the 2016 level of 220 $MtCO_2$ (Figure 10.14). Transport-related CO_2 emissions grow the most quickly (CAGR of 2.1%), at a slightly lower growth rate than FED (2.2%), reflecting the improvement in passenger and freight energy intensities. Electricity sector CO_2 emissions continue to increase at a CAGR of 1.1%, which is lower than the 1.2% CAGR of total energy-related emissions. While expanding renewables- and biomass-based power generation capacity supplies electricity that is less carbon-intensive, emissions do not peak by 2050 because coal-fired generation continues to be used.

Energy-related emissions increase to 282 $MtCO_2$ in 2050 in the TGT Scenario but drop to 150 $MtCO_2$ (55% of the BAU level) in the 2DC. In the TGT, CO_2 emissions increase at a CAGR of 0.73% owing to the combined effects of lower demand and energy intensity gains in the electricity sector. Total energy-related CO_2 emissions are substantially lower in the 2DC, shrinking at a CAGR of 1.1%, with most progress in the power and transport sectors. Fuel switching away from coal and large-scale deployment of renewables and CCS result in power sector emissions declining 88% below the 2016 level in 2050. In the transport sector, CO_2 emissions grow at roughly a third of the rate of the BAU—at a CAGR of 0.69% in comparison with 2.1%.

Figure 10.14 · Malaysia: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, where applicable. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018)

OPPORTUNITIES FOR POLICY ACTION

All three scenarios provide insights into different ways to balance Malaysia's rising energy demand with government and APEC targets for increased energy efficiency and renewables penetration, reduced emissions and greater energy security. The substantial CO_2 emissions reductions demonstrated in the 2DC attest to the value of a policy package that improves both the energy and carbon intensities of technologies and fuels by considering the energy system as a whole. By expanding renewable energy appreciably, Malaysia could help double the share of renewable energy in the APEC energy mix overall while also raising its own energy security. However, the cost of renewable fuels like biomass must be considered when weighing the benefits of CO_2 emissions reductions. The Malaysian government can help balance these goals through initiatives like competitive bids, as it has recently with its Large Scale Solar competitive bidding tender (EC, 2018). Renewable technology deployment should also be accompanied by efforts to reduce energy intensity at the sectoral level.

To this end, clear sectoral goals for energy efficiency would support the government's 2DC ambitions. Implementation timelines could be based on cost prioritisation (i.e. zero-cost projects first, and more expensive ones next). Likewise, initiatives requiring less investment, such as removing inefficient electrical appliances from the market, could be enacted ahead of more costly ones. For example, banning the sale of incandescent light bulbs in 2014 has improved lighting energy efficiency significantly, and extending this ban to similarly outdated and inefficient electrical appliances could build on this policy momentum.

Introducing uniform building by-laws in 2014 to incorporate the MS 1525—a Malaysian standard for energy efficiency and renewable energy use in non-residential buildings—was the first step to further promote energy efficiency (Green Building Index, 2017), but the standards should be updated regularly by benchmarking against international best practices. The mandatory use of thermal insulation for roofs in new air-conditioned buildings to save energy is also worth considering.

Balancing energy exports and imports is an opportunity for policy makers to take a long-term view of energy planning and policy design. Although higher volumes of some domestic energy resources are being exported while reserves decline, Malaysia is concurrently shifting from being a net oil exporter to a net importer. Policy makers must therefore balance the flow of energy imports and exports while ensuring reliable and sustainable energy services for future generations. Because energy efficiency programs and targets can help mitigate domestic energy demand growth, policy makers should set clear and ambitious goals for energy efficiency improvements by sector and develop strategies to measure and verify progress.

Data availability is foundational to policy analysis and design. As noted in Figures 10.1 and 10.6, disaggregated data on industrial energy demand prior to 2010 were not available; data for 2010 through 2016 were obtained from statistics published by the Malaysian government but were not available from the IEA. Collecting and disseminating relevant datasets is a step that can be taken immediately to support future analysis and policy design.

Finally, reforming domestic energy subsidies can help make the energy system more efficient and productive. Subsidy reform is, however, a complex multi-year process that must be carefully designed to reduce unintended consequences while delivering welfare improvements to citizens and the government. For this reason, exploring the costs and benefits of changing the energy subsidy regime should be a priority for the Malaysian government.

11. MEXICO

KEY FINDINGS

- **Mexico's energy sector transformation continued following the 2013 reform.** Renewables, oil and gas have considerable potential, but the transition from state-owned monopolies to a free-market system has presented challenges. Substantial progress has been made in deploying renewables and strengthening regulatory bodies.

- **FED grows 42% from 2016 to 2050 in the BAU Scenario** as all demand sectors grow steadily, with transport remaining the largest. Under the 2DC Scenario, FED remains stable over the Outlook period, highlighting opportunities for energy efficiency and low-carbon technologies.

- **TPES increases 44% from 2016 to 2050, with growth in all fuel shares in the BAU, except coal.** Natural gas grows the most, surpassing oil in the fuel mix after 2040. Wind and solar grow more than fivefold. Fossil fuels, however, still account for 86% of TPES by 2050 under the BAU (from 90% in 2016).

- **Electricity generation expands 75% and installed capacity 122% over the Outlook period in the BAU.** Capacity expansion is led by a 50 GW expansion in gas-fired plants and 43 GW of new renewables, mainly wind power. Power generation becomes more diverse as non-fossil fuel-based generation expands, from 19% in 2016 to 28% in 2050.

- **Energy-related CO_2 emissions rise 31% in the BAU,** exceeding Mexico's conditional NDC but meeting the unconditional NDC. Both the conditional and unconditional NDCs are met in the TGT and the 2DC.

ECONOMY AND ENERGY OVERVIEW

Mexico is a federal republic bordered by the United States to the north, Belize and Guatemala to the south, and the Atlantic and Pacific Oceans to the east and west. Although it is geographically and economically incorporated within North America, Mexico is also considered part of Latin America for cultural and historic reasons. Mexico has a high level of biodiversity, with abundant fossil and renewable energy resources spread across its 1.9 million square kilometres (INEGI, 2018). Climatic conditions are also diverse, ranging from very dry with high temperatures in the north to very humid with high temperatures in the south, mild temperatures in the centre and warm coasts. Mexico's population of 128 million makes it the 11th-most-populated economy in the world (UN, 2017) and the 6th-most-populated in the Asia-Pacific Economic Cooperation (APEC) region. Mexico City, the capital, is the world's fourth-largest urban centre with more than 22 million people (UN, 2018).

Table 11.1 · Mexico: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	1 702	1 967	2 342	2 589	3 462	4 913	6 817
Population (million)	102	117	128	134	148	158	164
GDP per capita (2016 USD PPP)	16 733	16 769	18 359	19 338	23 468	31 155	41 497
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	153	177	189	192	215	243	272
TPES per capita (toe)	1.5	1.5	1.5	1.4	1.5	1.5	1.7
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	90	90	81	74	62	49	40
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	95	117	122	123	138	155	173
FED per capita (toe)	0.94	1.0	1.0	0.92	0.94	1.0	1.1
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	56	60	52	48	40	32	25
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	364	439	467	465	493	549	613
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	98	99	99	99	99	99	99

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018); UN DESA (2018) and World Bank (2018a and 2018b).

Economic reforms and free-trade agreements introduced since the 1990s have resulted in macroeconomic stability, increased flows of foreign direct investment and the development of a robust manufacturing industry, making Mexico the 15th-largest economy in the world and the 5th-largest in APEC, economically comparable with Spain and Australia (WB, 2018). Most Mexican exports (83%) are manufactured products (WB, 2018). However, the economy expanded at a compound annual growth rate (CAGR) of only 2.0% between 2000 and 2016, and real gross domestic product (GDP) in 2016 was USD 2 342 billion (Table 11.1). Per-capita GDP growth was similarly modest (0.58% CAGR) over the same time period. Income inequality remains a challenge, as reflected in Mexico's Gini coefficient rating of 48 in 2014 (WB, 2018), and 44% of the population was living in poverty in 2016 (CONEVAL, 2017). Mexico's population and economy are projected to continue expanding, driving up energy demand. GDP grows at a CAGR of 3.2%, almost tripling over the Outlook period (2016-50).

Population growth is more moderate (0.75% CAGR), reaching 164 million by 2050— around 37 million higher than today.

Energy, particularly oil, is a significant component of the Mexican economy. However, in 2017, crude oil accounted for only 6.0% of Mexico's total export value, compared with 15% in 2005 (Banxico, 2018). Whereas crude oil provided 39% of total government revenue in 2005, it contributed 24% in 2016 because domestic production fell, highlighting the risk of relying too exclusively on oil revenues and having low tax revenue rates (Banxico, 2018). Consequently, Mexico has the lowest rate of tax revenue as a share of GDP among Organisation for Economic Co-operation and Development (OECD) members (OECD, 2019a).

ENERGY RESOURCES

Mexico has abundant fossil and renewable energy resources. In 2017, it registered reserves of 7.2 billion barrels of crude oil (21th largest in the world and 5th in APEC), around 200 billion cubic metres (bcm) of natural gas and 1.2 billion tonnes of coal (Table 11.2). Owing to its geography and climate, potential for renewable energy development is estimated at 397 gigawatts (GW) of predominantly wind and solar resources, still largely untapped (SENER, 2017a).

Table 11.2 · Mexico: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	1 211	116	0.12	26	9.0
Oil (billion bbl) [a]	7.2	8.9	0.43	21	5.0
Natural gas (tcm) [a]	0.20	4.8	0.10	41	12
Uranium (tU) [b]	1 800	0.00	0.05	33	9.0

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. tU = tonnes of uranium. a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kgU.
Sources: For coal, oil and natural gas, BP (2018). For uranium, NEA (2018).

Mexico was the 11th-largest oil producer globally in 2017, producing 1.9 million barrels (Mbbl) per day (113 million tonnes of oil equivalent [Mtoe]) of mostly heavy crude oil (CNH, 2018a). Production has been falling, however, and replacing the output from Mexico's once-largest oil asset, the Cantarell supergiant field, is a challenge: it produced 2.1 Mbbl per day at its peak in 2004 (121 Mtoe)—more than 60% of the economy's total crude oil production in that year (SIE, 2018). Owing mainly to Cantarell's depletion, overall oil production also peaked in 2004 and has been declining since (SIE, 2018).

More than three-quarters of natural gas production is associated with crude oil production (SENER, 2018a). The availability of affordable US natural gas has hampered efforts to boost domestic natural gas exploration and development, including of unconventional resources such as shale gas, and resulted in higher imports. In addition to its natural gas reserves, the economy has the sixth-largest prospective shale gas reserves in the world (EIA, 2013).

Renewable energy potential is conservatively estimated at 397 GW, almost 20-times Mexico's total power generation capacity (SENER, 2017a). About 60% of this potential is in solar power, which is at least 5.5 kilowatt-hours per square metre—double that of Germany, but Germany's installed solar capacity was 10-times higher than Mexico's in 2016 (IEA, 2016b) Wind potential is estimated at 158 GW (compared with capacity of 4.1 GW in 2016), hydro power potential at 12 GW and geothermal potential around 0.25 GW (SENER, 2017a).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Since the landmark energy reform of 2013, Mexico's energy sector has changed dramatically with the introduction of new institutional arrangements and restructuring. Before the reform, two state-owned companies monopolised most of the oil, natural gas and power industries: *Petróleos Mexicanos* (Pemex) in oil and natural gas and *Comisión Federal de Electricidad* (CFE) in power. A transition to competitive markets for oil products, natural gas and electricity is currently under way, as Pemex and CFE now compete with other companies in different areas of the value chain.

In the oil sector, international and domestic companies other than Pemex are already conducting oil and gas exploration and extraction. Since July 2015, the National Hydrocarbons Commission (CNH) has awarded 110 contracts to more than 70 companies from 20 countries to explore and extract hydrocarbon resources. Net revenue from these contracts has amounted to more than USD 1.1 billion, while committed private investments amounted to USD 3.9 billion from 2015 to mid-2018 (CNH, 2019a). Pemex however, has reported annual losses since 2012, mainly owing to resource depletion, low oil prices, and a lack of significant new field discoveries (Pemex, 2018). By 2018, over 40 companies were undertaking oil product transportation, distribution and retail activities, although most midstream infrastructure and fuels are still supplied by Pemex (SENER, 2018f).

The creation of a gas market, currently under way, is another important transformation. As the Energy Regulatory Commission (CRE) now prohibits natural gas companies from simultaneously engaging in both marketing and transporting of natural gas, Pemex transferred its natural gas pipelines—more than 10 000 kilometres (km), which make up around 90% of Mexico's natural gas pipeline network—to the new independent system operator, CENAGAS, in 2015 (Pemex, 2012) (Pemex, 2015). Since 2011, investment of around USD 12 billion has seen a 75% increase of the gas pipeline network (more than 8 500 km of new pipelines) and the addition of eight interconnections with the United States (SENER, 2018x). Pemex was also mandated to transfer 70% of its marketable natural gas volume to other companies, allowing clients to choose another provider or stay with Pemex. However, despite the strong growth in natural gas distribution networks since 2013, most residential consumers still have no access to this fuel.

Electricity sector reform has captured less attention, but changes have been equally profound. CFE was vertically unbundled and divided into 13 subsidiary and affiliate companies to cover all activities within the sector, including six power generation subsidiaries (SENER, 2017b). In January 2016, the Mexican Wholesale Electricity Market began operating, with companies other than CFE making up 83% of the 48 participants (SENER, 2017b). Since March 2016, three auctions for long-term contracts have been held to purchase energy, capacity and clean energy certificates. As a result, more than 7.5 GW of clean-generation capacity will be added by around 35 companies at a cost of USD 9.0 billion: wind and solar photovoltaic (PV) power account for more than 90% of the new capacity. Owing to a high level of participation and competition, prices obtained in both auctions were among the best in the world (USD 21 per megawatt-hour in the last auction, held in November 2017), and in some cases were more competitive than prices for fossil fuel-fired plants (SENER, 2018x).

In late-2018, Mexico's new President, Andres Manual Lopez Obrador, was sworn in, bringing about significant changes in Mexico's energy policy. In its first hundred days in office, the new government has prioritised energy self-sufficiency and state-owned companies while decreasing emphasis on renewable energy capacity additions, transitioning to more efficient and low-carbon technologies and efforts to increase private sector investment. For example, the government has announced that Pemex will be provided with an additional USD 3.6 billion to develop 20 new fields with the goal of increasing Mexico's crude oil production by 37% by 2024 (Pemex, 2019). However, CNH has recently cancelled two oil and gas production bidding processes—the method by which new companies enter the upstream sector—so that the Ministry of Energy can evaluate the results and progress of current hydrocarbon exploration and extraction contracts (CNH, 2019b). The government has also announced the construction of a 340 Mbbl (50 Mtoe) capacity refinery with a minimum government investment of USD 6.0 billion to reduce gasoline imports (SENER, 2018e). In the downstream sector, an ambitious plan to tackle gasoline and diesel theft, mainly from pipelines, has also begun (SENER, 2019b).

Despite the encouraging results of Mexico's 2017 long-term energy auction—which saw prices for renewable energy below USD 20 per MWh—the government recently cancelled the fourth energy auction for renewable energy. No new renewable energy auctions have been announced in their place as CFE instead delays its capacity retirement program for existing fossil-fuelled plants (RENMX, 2019). CFE also recently cancelled a tender for a USD 2.1 billion direct-current (DC) transmission line that would connect Mexico's main wind power generation region with demand centres (REN21, 2018) (BNAmericas, 2019).

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Mexico under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 11.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 11.3 · Mexico: Key assumptions and policy drivers under the BAU

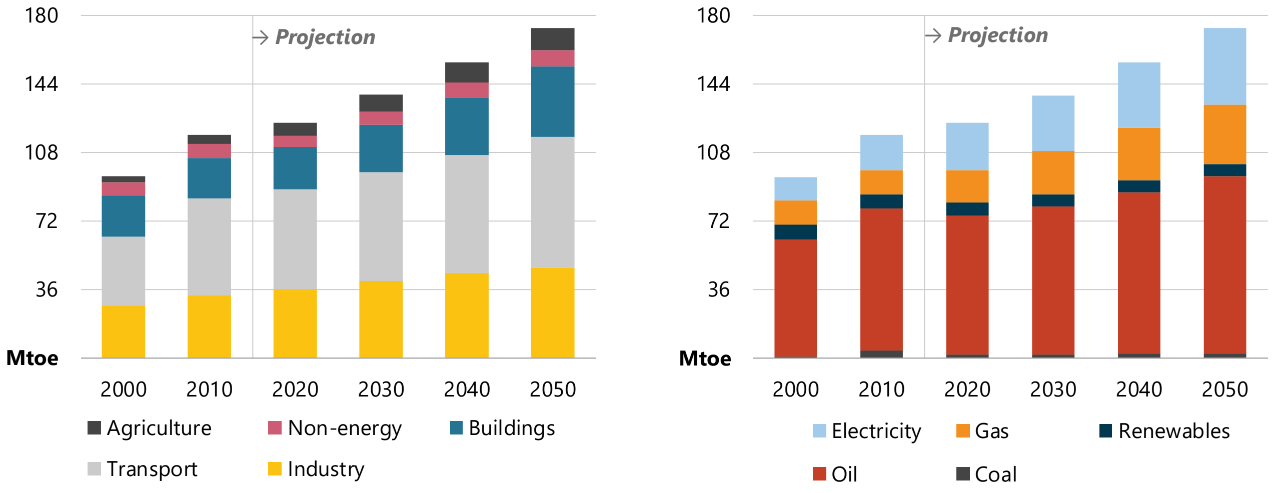
Buildings	Mandatory appliance minimum energy performance standards (MEPS) maintained at current levels. New labelling programs put in place by the Federal energy efficiency agency, CONUEE.
Industry	Implementation of energy management systems and other cost-effective technological improvements for large energy users.
Transport	Slow deployment of hybrid and electric vehicles, with marginal contribution at the end of the Outlook period. No specific growth or mandatory blend rate assumed for biofuels. Vehicle fuel efficiency standards implemented via maximum greenhouse gas (GHG) emissions standard for light-duty vehicles (LDVs).
Energy supply mix	Crude oil exports continue throughout the Outlook period. More expensive development of oil and natural gas reserves in the medium term. Modest long-term shale gas and shale oil development.
Power mix	Major capacity additions and retirements based on PRODESEN 2018-2032, including two new nuclear reactors (project CN001) assumed to come online.
Renewables	Additions according to PRODESEN 2018-2032 and *Prospectiva de Energias Renovable*s 2017-2031.
Energy security	No explicit energy security policies or targets. Self-sufficiency in oil but net importer of natural gas, coal and most oil products.
Climate change	NDC to the UNFCCC targets a 22% reduction of GHG emissions by 2030 from the 2013 level (not achieved in the BAU).

Notes: CONUEE = *Comisión Nacional para el Uso Eficiente de la Energía*. Outlook period = 2016-50. PRODESEN = *Programa de Desarrollo del Sector Electrico Nacional*. NDC = Nationally Determined Contribution. UNFCCC = United Nations Framework Convention on Climate Change. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Mexico's final energy demand (FED) grows by 42% over the Outlook period under the BAU, from 122 Mtoe in 2016 to 173 Mtoe in 2050, with demand increasing in all sectors (transport, industry, buildings and agriculture). While transport remains the primary final energy consumer, with demand increasing from 53 Mtoe to 69 Mtoe between 2016 and 2050 (Figure 11.1), its share of FED decreases, from 43% to 40%. Industry sector energy demand claims the second-largest share, growing from 35 Mtoe in 2016 to 47 Mtoe in 2050 at a CAGR of 0.88%. Buildings sector demand grows more strongly (almost 70%), from 22 Mtoe to 37 Mtoe, but its share remains relatively small (roughly 20%) over the Outlook compared with other APEC economies, reflecting Mexico's moderate climate. Energy demand in the agriculture and non-specified sector increases steadily at a 1.6% CAGR to 2050, while non-energy demand increases marginally (by 3.2 Mtoe).

Figure 11.1 · Mexico: Final energy demand by sector and fuel, 2000-50

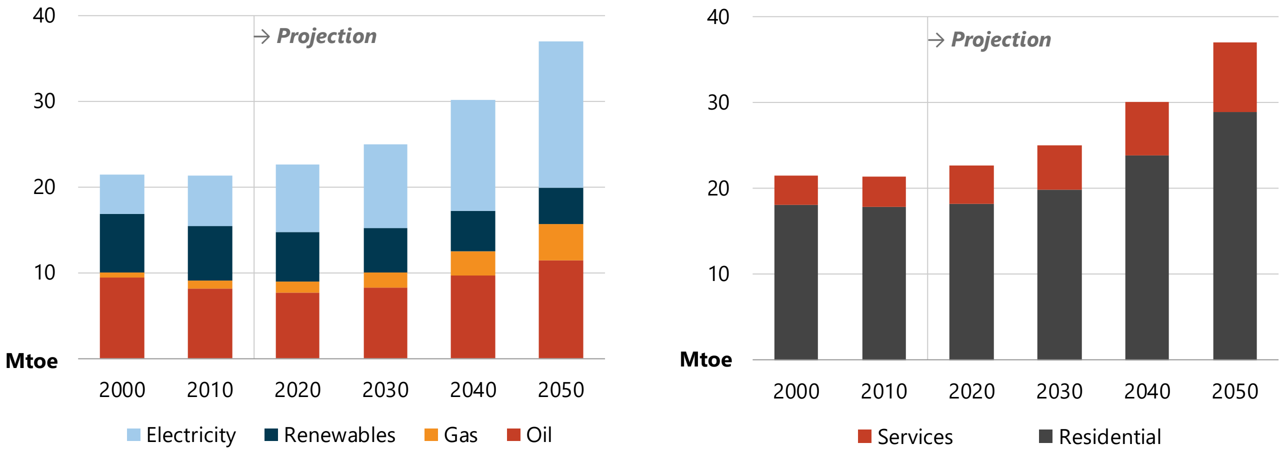


Sources: APERC analysis and IEA (2018a).

BUILDINGS: ELECTRICITY DEMAND RISES QUICKLY TO OVERTAKE OIL

Buildings remains the third-largest final energy consumer in 2050 under the BAU. However, it grows rapidly—by 70% from 2016 to 2050—particularly after 2030 as more low-income households and businesses acquire appliances and air conditioners, especially in the north, which is drier and warmer than the rest of Mexico (Figure 11.2). Reflecting economic development, more than 73% of this growth occurs in the residential subsector, which remains more than three times larger than the services subsector through the Outlook. Electricity demand more than doubles and natural gas demand quadruples over the projection period. These fuels replace oil (mostly LPG) to some extent but mainly meet demand growth and substitute traditional biomass in low-income households. These changes result from three main assumptions: population growth, steady economic expansion and better living conditions for low-income households.

Figure 11.2 · Mexico: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

As a result of Mexico's mild climate and unequal income distribution, energy demand is still low for space cooling and negligible for space heating compared to other APEC economies like Australia or Russia. While weather varies across regions, temperatures below zero degrees Celsius (°C) are atypical in most of Mexico, even on the coldest winter days. Regions with temperatures above 35°C contain only a handful of large population centres, and even in these regions, income limitations hinder access to air conditioning. In all, only 13% of households in Mexico have air conditioning and less than 3.0% have heating (INEGI, 2016).

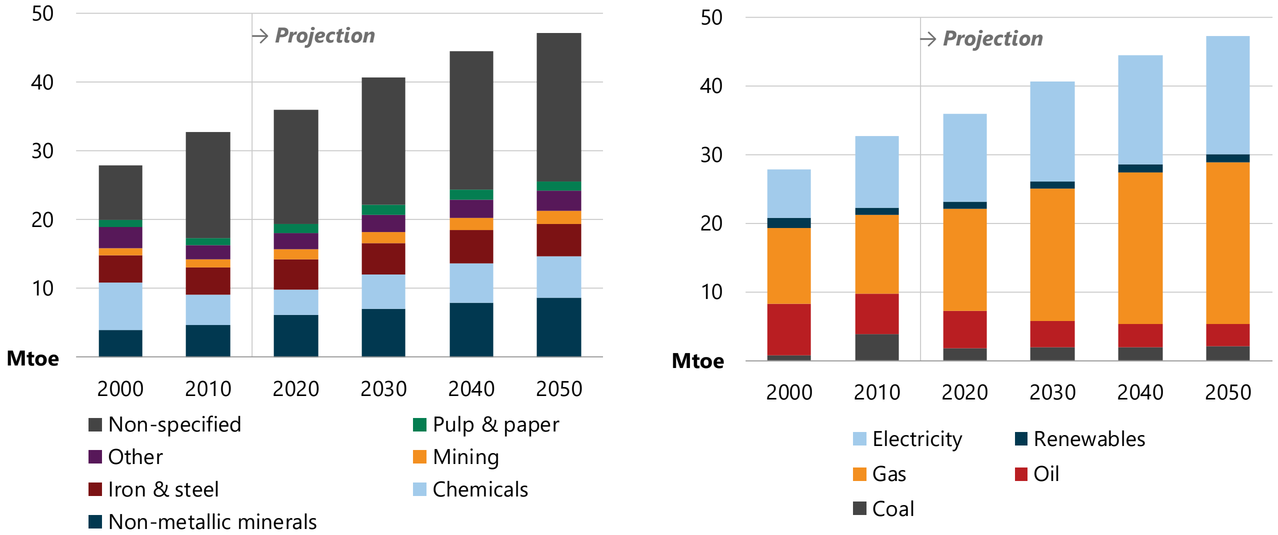
Traditional biomass remained the dominant fuel in residential buildings in 2016, meeting around 37% of energy demand, especially in impoverished rural and suburban areas (SENER, 2018d). However, the second most important fuel source for residential buildings was oil (34%) in 2016, mainly LPG in urban areas. Under the BAU the use of traditional biomass, mostly fuelwood but also charcoal, decreases 44% by 2050 as households transition to modern fuels (e.g. LPG, natural gas and electricity), mainly for cooking and water heating. Although demand for modern renewable sources in the buildings sector, especially solar power, more than quadruples over the Outlook period, it does not keep pace with declining use of traditional biomass, resulting in renewables shrinking by 35%. Mainly as the result of switching away from traditional biomass, oil demand (LPG) grows by 63% over the Outlook period.

Electricity demand more than doubles from 2016 to 2050, and its share rises from 33% to 46% of buildings demand. This is driven by demand for more appliances, space cooling and lighting in both residential and services, reflecting economic and population growth and declining poverty. Natural gas demand more than quadruples as transmission and distribution networks expand to increase access for consumers and businesses.

INDUSTRY: STEADY GROWTH FUELLED BY NATURAL GAS AND ELECTRICITY

Industry energy demand rises 35% from 2016 to 2050 (CAGR 0.88%) under the BAU—slower than the 1.5% CAGR of 2000-16 (Figure 11.3). Natural gas was the main fuel (36% share; 13 Mtoe) in 2016 and grows at a CAGR of 1.8% to almost double by 2050 as readily available US shale gas imports continue to compete with slowly growing domestic production to dampen prices. Natural gas covers industrial energy demand growth and displaces oil and coal to a certain extent. Industry electricity demand also continues to grow but at a slower pace than natural gas, increasing at a CAGR of 0.93% over the projection period. The iron and steel, non-metallic minerals, and chemical and petrochemical subsectors, the three largest industrial energy consumers, accounted for 39% of industry demand in 2016, rising to 41% by 2050.[54]

Figure 11.3 · Mexico: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Non-metallic minerals (mainly cement and glass) remains the largest subsector, with energy demand growing by 55% as construction activities (for buildings and infrastructure) continue to increase at a rate similar to that of the past 10 years. Mexico's cement industry is highly energy intensive and is controlled by a small number of producers. This oligopolistic structure causes overpricing in the domestic market and does not provide sufficient incentives for energy efficiency improvements (Vásquez, B., & Corrales, 2017)

Over the Outlook period, iron and steel demand grows by 11% as a result of economic and manufacturing growth, particularly in the highly intensive steel-consuming automobile sector, one of Mexico's main industries. Energy demand in the chemical and petrochemical subsector grows by 57% as domestic crude oil production increases slowly but steadily.

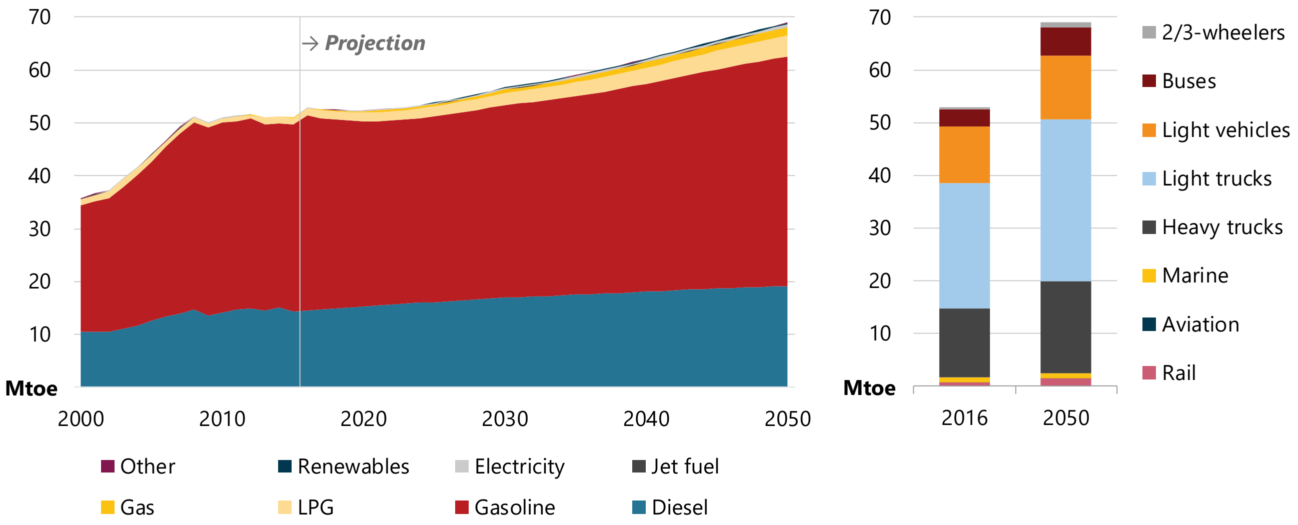
In 2016, according to official data, around 46% (16 Mtoe) of reported industry energy demand is labelled as non-specified (SIE, 2018). This category is acting as a catch-all for energy use that cannot be disaggregated by subsector. This lack of disaggregation creates a significantly higher degree of uncertainty around these projections and represents an area of opportunity for Mexico to expand data collection and enhance data quality to allow more robust analysis.

TRANSPORT: ROAD TRANSPORT KEEPS LEADING DEMAND GROWTH

Domestic transport has historically been the largest of the energy demand sectors and was the fastest-growing (48%) in 2000-16. Energy demand in this sector grows 30% by 2050 under the BAU, from 53 Mtoe to 69 Mtoe (Figure 11.4). The main drivers are population and economic growth and the dominance of private car ownership, reflecting insufficient public transport (especially in Greater Mexico City).

[54] Oil and gas industry energy consumption is included in the Energy Transformation and Supply section below.

Figure 11.4 · Mexico: Domestic transport sector final energy demand by fuel and mode, 2000-50



Note: No historical data are available for domestic air travel, making it impossible to disaggregate and project domestic and international air travel energy demand more precisely.
Sources: APERC analysis and IEA (2018a).

Road transport remains the dominant mode of transport energy demand by far (96% in 2050 from over 97% in 2016). Oil products, predominantly gasoline and diesel, used mainly in internal combustion engine vehicles, have made up over 99% of transport fuel demand for at least 25 years, and the trend remains almost unchanged over the Outlook period, although diesel displaces some of gasoline's share. Despite the lack of major infrastructure development in modes other than road transport, energy demand also rises for rail (94%) and marine transport (9.4%), which also predominantly consume oil products, mainly diesel and fuel oil.

Gasoline demand increases by 18% over the Outlook period as vehicle stock keeps growing and despite the enforcement of light-duty vehicle (LDV) fuel efficiency standards. Diesel demand grows by 32% by 2050, mainly owing to rising demand for heavy-duty trucks and buses. LPG more than doubles over the Outlook, mainly in light- and heavy-duty trucks.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Mexico has historically been a major crude oil producer (the 11th-largest in the world in 2016) with oil traditionally accounting for roughly half of total primary energy supply (TPES) (IEA, 2017c). TPES has grown steadily since 2000 and has been dominated by oil and to a lesser extent, natural gas, with production of those fuels peaking in the early 2000s and falling since. Energy use in Mexico's transformation sector has also increased in general since 2000, but it has evolved quite differently across sectors. Oil and gas extraction energy own-use has been roughly stagnant over this period, while the refining sector has decreased rapidly since 2014. Conversely, electricity generation increased by more than 56% from 2000 to 2016, responding to fast growing demand via an oil-to-natural-gas shift and renewables additions.

ENERGY INDUSTRY OWN-USE: MORE IMPORTS COVER RISING OIL PRODUCTS DEMAND

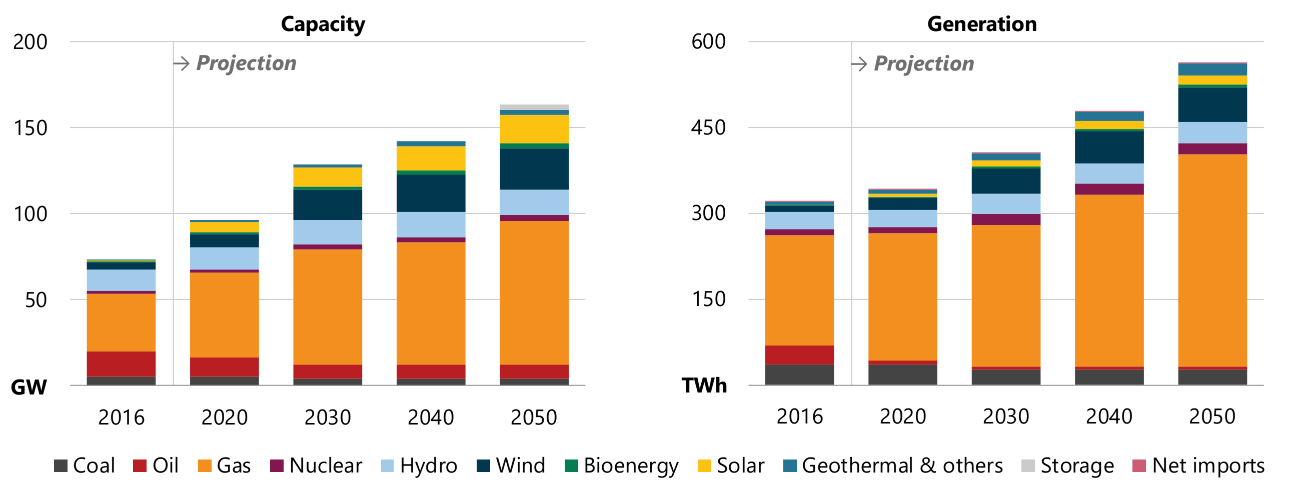
Mexico's energy transformation sector is quite energy intensive and includes oil and natural gas extraction, oil refining, natural gas treatment facilities, liquefied natural gas (LNG) regasification plants and power plants, among other facilities. Mexico's nameplate refining capacity is 1.6 Mbbl per day (77 Mtoe per year) from six refineries, all owned by Pemex. This is, theoretically, enough to meet domestic oil products demand, but production is far lower in practice— around 1.0 Mbbl per day (47 Mtoe) in recent years (SENER, 2017c). This owes mainly to two factors: all six refineries were originally designed to process light oil, and Mexico currently produces mostly heavy crude; as well as ageing infrastructure and insufficient maintenance that have caused failures and effective capacity reductions (Pemex, 2018). Under the BAU, production of oil products, at a 25-year low in 2016, grows by 40% to 67 Mtoe by 2025, similar to the levels seen in 2004. Actual refining capacity increases modestly as infrastructure is modernised and refurbished, without any major new refining additions.[55] Overall demand for all refined products (gasoline, diesel, LPG, jet fuel and others) grows 75% over the Outlook period, however, resulting in continued growth in imports.

POWER SECTOR: ELECTRICITY GENERATION DOUBLES, FUELED BY NATURAL GAS AND RENEWABLES

Mexico's electricity sector is undergoing a profound transition from a monopolistic structure dominated by state-owned utility CFE to a competitive electricity market. The Mexican Wholesale Electricity Market is now operational and CFE, unbundled vertically along the value chain, now competes with other generation companies. The Mexican government also created a system for granting clean energy certificates to non-fossil fuel-based energy generators, and the Ministry of Energy requires all load-serving entities to use a certain percentage of clean energy. Non-compliers must procure a required number of clean energy certificates from certified clean energy generators or buy them in a market that was expected to be fully operational by 2019, but has been delayed (IEA, 2016b). From 2006 to 2016, renewable power generation capacity expanded at a CAGR of 4.3%: solar PV increased 34% and wind power increased 110%. Additionally, the 2015 Energy Transition Law established a goal that 25% of electricity generation must be 'clean' by 2018, 35% by 2024 and 50% by 2050.[56]

Under the BAU, electricity generation increases 75% over the Outlook period (Figure 11.5). Installed capacity more than doubles from 74 GW to 163 GW by 2050, underpinned by an additional 51 GW in gas-fired capacity and an almost six-fold increase in wind capacity (20 GW). Conversely, installed oil-fired capacity shrinks, from 15 GW to 8.0 GW, most of which are peaking power plants.

Figure 11.5 · Mexico: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

[55] The Dos Bocas refinery project, officially announced in December 2018, is not included in this analysis as it was officially announced after the last modelling runs of this Outlook.

[56] This law considers renewable energy and 'highly efficient' gas-fired combined heat and power (CHP) generation as 'clean' energy, whereas this Outlook and most international institutions consider CHP to simply be a form of gas-fired power generation that is disaggregated from renewable or 'clean' energy. As of June 2018, 24% of electricity generation came from 'clean' sources, but only 2.8% of it came from 'highly efficient' CHP.

Power generation has been the main driver of Mexico's rising natural gas demand, with gas-fired generation accounting for 60% of the power mix (192 terawatt-hours [TWh] of 320 TWh) in 2016. Natural gas-fired generation grows by 93% over the Outlook period, but its shares in both total capacity and electricity generation remain similar. Oil currently accounts for 20% (15 GW) of installed capacity and 11% (34 TWh) of power generation but shrinks to 4.8 TWh (0.86% of total generation) in 2050 owing to its higher costs and displacement by natural gas and renewable sources.

Under the BAU, renewable power capacity more than triples, from 19 GW in 2016 to 61 GW in 2050, with wind accounting for the largest share (24 GW). Other technologies also expand substantially: solar by around 16 GW, bioenergy by 2.1 GW and geothermal by 1.8 GW. The intermittency and lower utilisation rates of wind and solar energy mean the impact is less impressive in terms of generation. By 2050, renewables account for 38% of total capacity but generate 24% of electricity. An additional 1.4 GW of nuclear-based generation capacity is assumed to be operational by 2030, although no concrete projects have been publicly announced (SENER, 2018e). Consequently, the power generation mix becomes considerably more diverse by 2050, with a 66% share of natural gas, 11% wind, 6.5% hydro, 4.7% coal, 3.5% nuclear, 2.9% solar and the remaining by other renewables and oil. These diversification falls short, however, of the government's 50% clean energy goal by 2050 established in the Energy Transition Law.

TOTAL PRIMARY ENERGY SUPPLY: FOSSIL FUELS REMAIN DOMINANT WITH GAS ON TOP

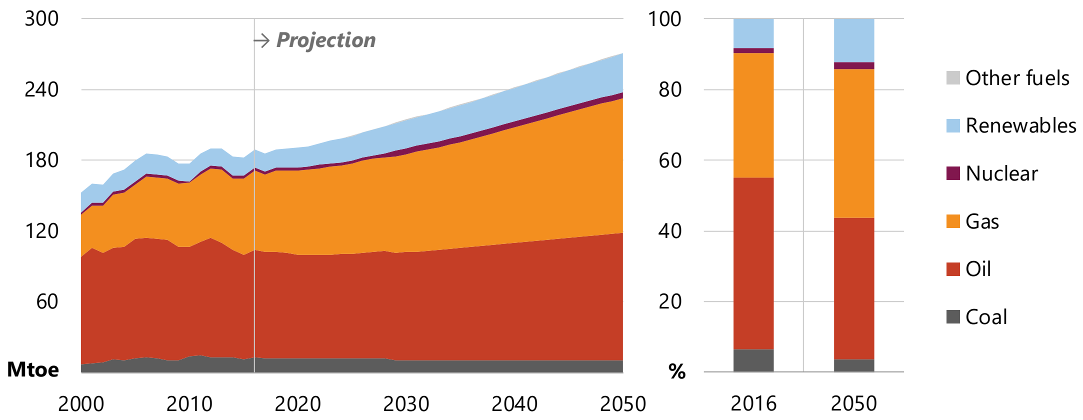
As a major crude oil producer, oil has traditionally accounted for roughly half of Mexico's TPES (IEA, 2017c). Production is projected to be more than sufficient to meet domestic demand through 2050, with Mexico remaining a net crude oil exporter. Oil only remains the dominant fuel in primary supply until around 2040, however, when it is surpassed by natural gas. Since 2005, natural gas has been the fastest-growing fuel in Mexico's TPES in absolute terms, rising from 46 Mtoe to 67 Mtoe in 2016. The primary impetus for this ongoing oil-to-natural-gas shift is power generation, resulting in natural gas supply growing 71% while oil supply grows by 18% by 2050. Although natural gas demand has been growing steadily, production fell 29% from 2010 to 2016 and, unlike for crude oil, Mexico has been a net natural gas importer for at least the past 25 years. As a result, natural gas supplies have been met mainly with low-priced pipeline imports from the United States, especially since 2008 (Box 11.1).

Box 11.1 · Mexico: Natural gas pipeline network expansion

Natural gas demand has expanded rapidly in Mexico since 2008. Domestic natural gas production and the pipeline network, however, did not keep up, and insufficiency and lack of redundancy caused severe saturation of the network in 2012 and 2013, resulting in natural gas shortages for power generation and industrial users. Since 2011, 25 new natural gas pipeline projects have been launched in Mexico and 6 in the United States—an investment of USD 12 billion for more than 8 500 km (over 75%) of expanded network. This includes the addition of 8 interconnections with the United States, increasing import capacity by 94 bcm per year (85 Mtoe) and increasing total natural gas import capacity to 114 bcm per year (103 Mtoe) by 2019. In November 2018, 25 new pipelines were operational and 8 were still under construction (SENER, 2018b).

TPES expands 44% over the Outlook period, from 189 Mtoe to 272 Mtoe (Figure 11.6). While all fuels are projected to grow, natural gas increases the most, from 67 Mtoe to 114 Mtoe. The strongest growth occurs in renewable energy, which more than doubles over the Outlook period. Solar increases more than eight-fold and wind by almost six-fold, while geothermal more than triples which together more than offsets a 32% decrease in traditional biomass.

Figure 11.6 · Mexico: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Mexico's relatively low level of coal in the energy mix (6.5% in 2016) compared with other APEC economies further decreases to 3.7% over the Outlook period, as coal-fired electricity generation is displaced. Uranium supply grows by 85% in 2031 with the increase of 1.4 GW of nuclear power generation capacity. As a result of these changes, TPES diversity increases gradually through 2050 under the BAU. The share of oil drops from 49% to 40%, natural gas rises from 35% to 42% and non-hydro renewables increase from 6.9% to 11%.

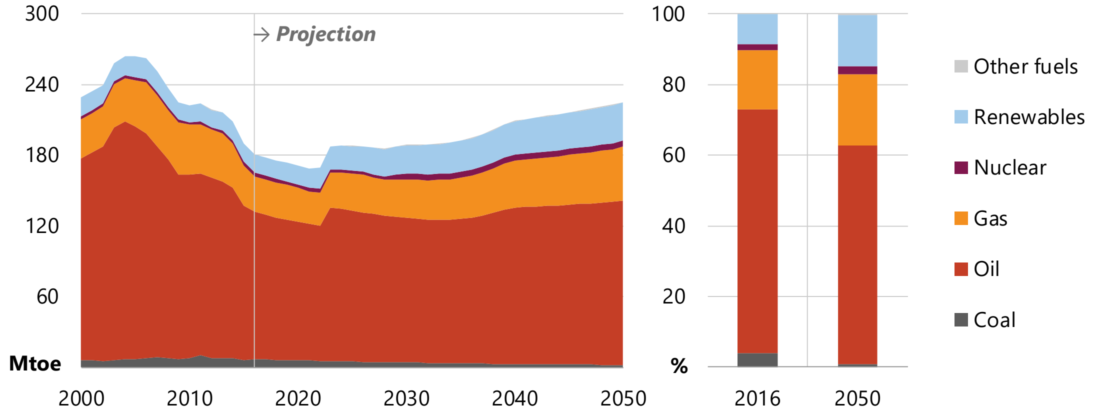
ENERGY PRODUCTION AND TRADE: RENEWABLES AND GAS GROW

Oil production, still dominated by Pemex in 2016, has been in steady decline since it peaked at 202 Mtoe (3.4 Mbbl per day) in 2004 (Figure 11.7). From 2004 to 2016, production fell 38% to 125 Mtoe (2.0 Mbbl per day) due mainly to the depletion of Mexico's largest asset, the Cantarell supergiant field. Oil production continues decreasing until 2022 as a result of the insufficient resources allocated to exploration but begins to recover in 2023, then expands modestly to 139 Mtoe (2.3 Mbbl per day) by 2050. This results from the 2013 energy reform (and despite declining production in existing conventional fields) that has already resulted in awarding more than 110 exploration and production contracts to over 70 companies, more than USD 318 million in government revenue, and a still marginal but rapid increase in oil production (representing around 4% of total oil production[57] (CNH, 2019).

Mexico has long been a net exporter of crude oil, and is the third-largest crude exporter to the United States after Canada and Saudi Arabia (EIA, 2018). However, exports have been shrinking since 2011, mainly because of the rapid rise in US tight oil production and falling production in Mexico. In 2016, Mexico exported 66 Mtoe (1.0 Mbbl per day) of crude oil—38% less than in 2005, but to a more diverse set of customers, including other APEC economies (China, Japan and South Korea). Crude oil exports continue to decline until 2022, when a boost in production from projects undertaken since the reform underpins an increase to 66 Mtoe by 2050. Mexico remains a net crude oil exporter throughout the Outlook period.

[57] As of March 2019.

Figure 11.7 · Mexico: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Natural gas production peaked in 2009 at 44 Mtoe (51 bcm) but fell to 30 Mtoe (35 bcm) in 2016, a 30% decrease. Moreover, Mexican natural gas production competes with low-cost US natural gas imports, which have been covering rising demand and compensating for declining production. Until 2013, Pemex monopolised the natural gas industry and about 75% of natural gas production was associated with oil (IEA, 2016b). Lack of investment in exploration and infrastructure modernisation has been even more significant in the natural gas sector, since Pemex historically prioritised oil production. For instance, because of a lack of infrastructure, poor planning or negligence, natural gas flaring represented 7.0% of total production from 2010 to 2016 (SIE, 2018). Natural gas production drops to a minimum of 28 Mtoe (32 bcm) in 2021 under the BAU, when, similar to oil production, new exploration and development resulting from the 2013 reform stimulates a steady rise to 46 Mtoe (53 bcm) by 2050.

Mexico is currently a net importer of natural gas, as the gap between decreasing domestic production and growing demand has widened in the past decade, mainly driven by power generation. Natural gas imports increased from 7.7 Mtoe in 2005 (8.7 bcm) to 36 Mtoe (41 bcm) in 2016, registering a record high every year from 2008 (SIE, 2018). The vast majority (88%) of these imports are piped from the United States (see Box 11.2), and the remainder is imported as LNG, mainly from Peru and the United States, to one of Mexico's three regasification terminals.

Box 11.2 · Mexico: US natural gas imports

US natural gas imports have more than quadrupled since 2005, reaching 31 Mtoe (37 bcm) in 2016 (59% of total US natural gas exports). Mexico is the main destination for US natural gas exports, making this one of the largest gas trade flows in the world—greater than all piped natural gas imported by China, and higher than Indonesia's total natural gas demand and Algeria's total LNG exports in 2016 (BP, 2017).

Despite robust crude oil production and a domestic refining capacity of 1.6 Mbbl per day (77 Mtoe per year), Mexico is a major net importer of some oil products, mainly gasoline, diesel and LPG. In 2016, oil product imports were 43 Mtoe, of which 22 Mtoe was gasoline. In that same year, around 60% of gasoline, 47% of diesel and 48% of LPG consumed in Mexico were imported (SENER, 2018a). Under the BAU, Mexico remains a net importer of these oil products, despite a 41% overall decrease in net imports by 2030 resulting from market liberalisation and improvements in domestic refinery performance. Gasoline, diesel and LPG imports however, continue to increase from around 2025, resulting in stable import volumes throughout the Outlook period.

ALTERNATIVE SCENARIOS

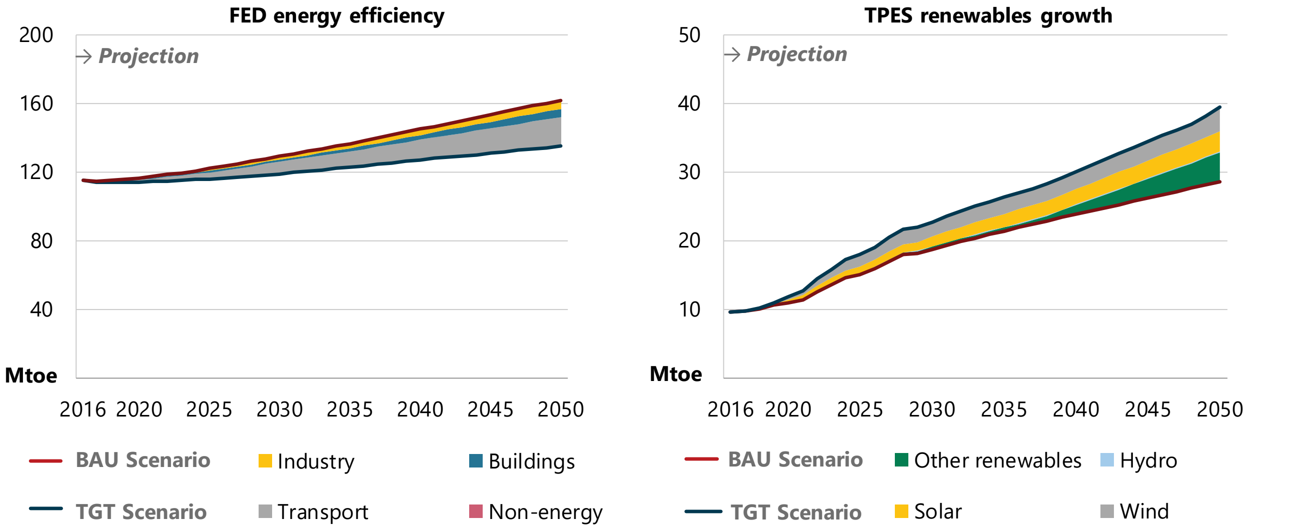
While the BAU Scenario is intended to be representative of Mexico's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and carbon dioxide (CO_2) emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 15% lower while CO_2 emissions are 20% lower under the TGT by 2050. Under the 2DC, Mexico's FED is 30% lower and CO_2 emissions are 51% lower. The share of renewables in TPES is 18% in the TGT and 23% in the 2DC, compared with 12% in the BAU.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. In the TGT, energy demand increases in all sectors over the Outlook period except for transport. Despite this, Mexico's FED is still dominated by transport (35%) and industry (30%).Renewable energy grows, from 8% (16 Mtoe) of TPES in 2016 to 18% (44 Mtoe) in 2050, compared with 12% under the BAU. Power generation, mainly from wind and solar PV, dominates renewables use (82% of TPES in 2050).

The greatest reduction in energy demand under the TGT comes in the transport sector when compared with the BAU (Figure 11.8). In contrast with the BAU, in which domestic transport energy demand grows throughout the projection period, it declines until 2030 and then slowly grows to 52 Mtoe in 2050, an overall 1.2% decrease compared to 2016. This comes as a result of stricter energy efficiency standards in road transport, mainly for gasoline-fuelled LDVs and, to a lesser extent, diesel buses and heavy-duty trucks. Some switching from oil to electricity and natural gas in road transport also contributes to substantially increase consumption of those fuels compared with the BAU, but together, they account for only 5.3% of road transport energy demand by 2050. There is limited potential for more renewable energy in transport as the share of biofuels (mostly biodiesel) reaches only 0.81% of the total in 2050.

Figure 11.8 · Mexico: Energy efficiency and renewables development, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewable growth shows the additional renewables in TPES by type in the TGT compared with the BAU, excluding biomass in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Industry demand increases by 21% between 2016 and 2050 (compared with 35% under the BAU). Most of the reduction comes from the non-metallic minerals sector (21% less than in the BAU) as electricity and renewables replace coal and fuel oil for the most energy-intensive cement processes. Energy efficiency improvements and technological advances in the iron and steel subsector also contribute to energy consumption decreasing by 13% (compared with an 11% increase in 2050 in the BAU).

Buildings energy demand grows 47% in the TGT (compared with 70% under the BAU). Most of the reduction results from technological improvements and stricter efficiency standards for water heating, appliances and lighting. However, similar to the BAU, the use of traditional biomass drops more than 39%, offsetting gains in modern renewable energy (six-fold growth in solar water heaters) and resulting in an overall 26% decrease in renewable energy over the Outlook.

Historically, Mexico has driven energy efficiency improvements, particularly in buildings, by implementing minimum energy performance standards (MEPS). In industry, results of PRONASGE,[58] a program that helps industrial energy consumers implement voluntary energy management systems, are promising, with more than 50 companies participating and energy demand reductions expected to be over 25% by 2020 (APEC, 2017). Numerous challenges remain, however, especially in transport; Mexico has no energy efficiency labelling system for road transport or fuel efficiency standard for heavy-duty vehicles (APEC, 2017).

Under the TGT, power generation increases 61% between 2016 and 2050, (compared with 75% under the BAU). However, the share of renewable power generation increases from 15% to 41% (compared with 24% under the BAU), mainly as a result of 36 GW of wind and 47 GW of solar power capacity additions over the Outlook. Non-fossil fuel electricity accounts for 45% of total generation. However, if a 5.2% share from gas-fired combined heat and power is accounted as 'clean energy', as established in the government's goal detailed in the BAU section, Mexico achieves its 50% share goal of 'clean energy' by 2050 under the TGT.

[58] Programa Nacional para Sistemas de Gestión de la Energía, led by CONUEE.

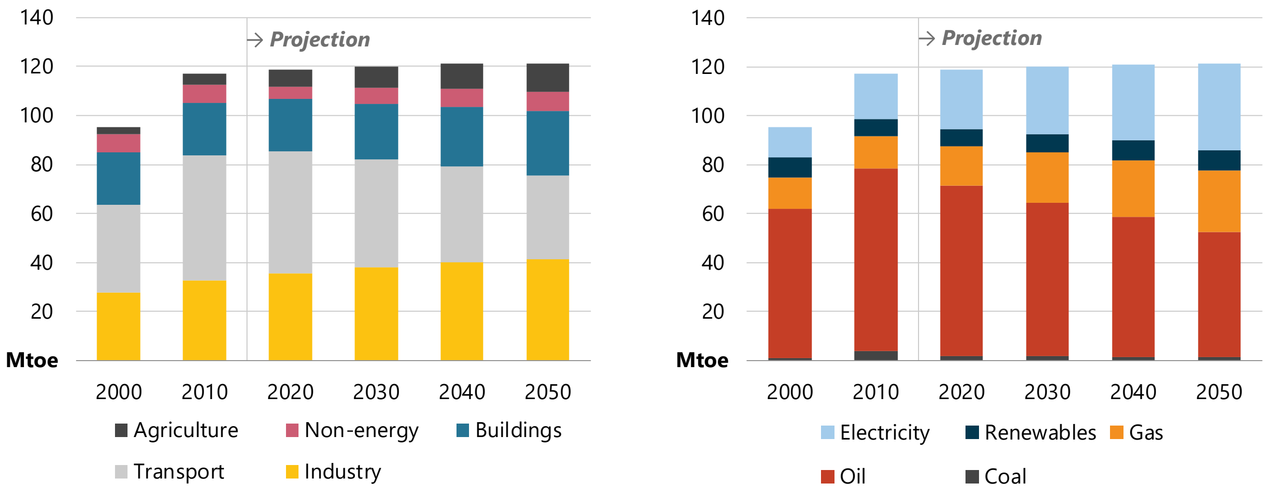
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Mexico will have to undergo significant decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017c). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Under the 2DC, FED remains flat around 121 Mtoe over the Outlook period, unlike in the other scenarios in which it grows through 2050. Transport undergoes the most significant sectoral change in the 2DC, decreasing by 35% and being overtaken by industry as the largest energy demand sector by 2040 (Figure 11.9). Strong improvement in fuel efficiency for all types of road transport, particularly LDVs, underpins this reduction. This scenario assumes: a) behavioural change, whereby better planning and logistics reduce the amount of travel; and b) expanded and enhanced public transport systems, especially rail and bus, reducing private car use, particularly of LDVs. Advanced and alternative-fuel vehicles, mainly electric but also hydrogen-fuelled, provide an opportunity to transition away from fossil fuels and account for around 2.7% of road transport energy demand in 2050.

Figure 11.9 · Mexico: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Under the 2DC, industry energy demand grows 18% over the Outlook period (compared with 35% in the BAU and 21% in the TGT). Natural gas use increases 50% to dominate industrial demand by 2050 (46% share), while electricity demand expands by 25%. These changes assume larger penetration of electric arc furnaces in the iron and steel subsector and wider access to natural gas, as well as greater switching away from coal and oil products in energy-intensive industries, such as non-metallic minerals and chemicals.

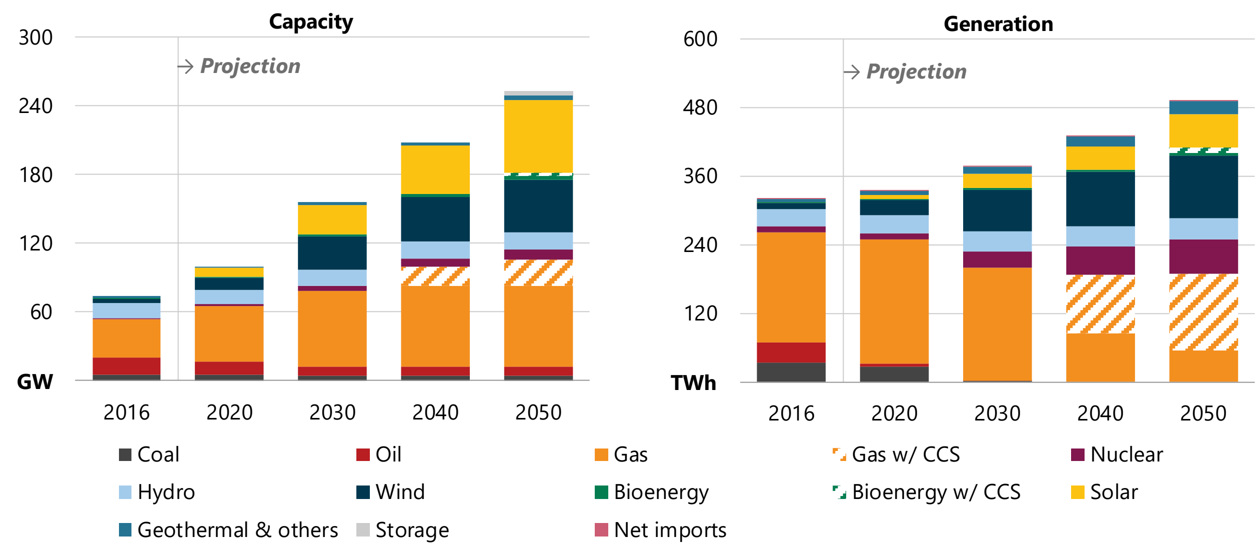
As with industry, buildings demand grows more slowly in the 2DC, reaching 26 Mtoe by 2050 (from 22 Mtoe in 2016) compared with 32 Mtoe in the TGT and 37 Mtoe in the BAU. Slower growth results from energy efficiency measures and the gradual phase-out of oil (mainly LPG) and traditional biomass, particularly for cooking and space heating. However, given that the population increases by almost 40 million and per-capita GDP more than doubles, even effective deployment of ambitious energy efficiency measures will be insufficient to fully curb demand growth.

TRANSFORMATION AND SUPPLY IN THE 2DC

Under the 2DC, electricity generation grows by 53% by 2050 (compared with 75% in the BAU and 61% in the TGT) as a result of lower demand in all sectors, except for transport. The power generation mix also diverges considerably from the BAU over the Outlook period but is similar to the TGT: by 2050, non-fossil fuels account for 61% of electricity generation, with renewables accounting for 49% of the total (Figure 11.10).

In 2050, wind is the leading renewable power generation technology (22% of the fuel mix), followed by solar (12%). Nuclear generation also increases significantly under the 2DC, accounting for 12% of the fuel mix in 2050 (compared with 3.5% under the BAU and 3.8% under the TGT). While gas-fired power generation continues to be the leading source of electricity by 2050 at 39% of the fuel mix, 71% of gas-fired power generation comes from plants equipped with carbon capture and storage (CCS) technology (24 GW), which significantly reduces CO_2 emissions towards the end of the projection period. Additionally, by 2050 there is 3.2 GW of biomass with CCS capacity. While obstacles to widespread CCS deployment remain, in 2017 Mexico launched a CCS pilot project in the Poza Rica power plant and established a carbon capture, utilisation and storage research centre. (SENER, 2018f) [59]

Figure 11.10 · Mexico: Power capacity and electricity generation in the 2DC by fuel, 2016-50

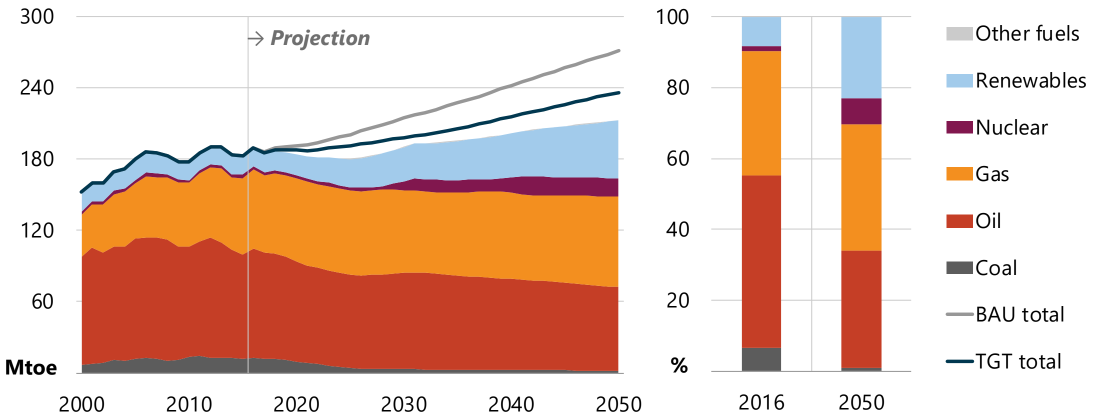


Note: CCS= carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

TPES grows 13% (24 Mtoe) by 2050, showing a trend similar to the BAU and the TGT but increasing at a slower pace (Figure 11.11). The fuel mix is quite different, however, with fossils fuels accounting for 69% of the 2050 total, compared with 86% in the BAU and 79% in the TGT. In the 2DC, coal practically disappears from TPES, accounting for only 2.0 Mtoe in 2050 (less than 1.0% of the total). The share of oil falls to 33% and natural gas rises slightly to 36% by the end of the period as renewable and nuclear shares expand. Natural gas overtakes oil as the main fuel after 2040 in all scenarios. The 2DC has the largest renewable energy share of the scenarios, reaching 23% of TPES in 2050.

[59] Some recent milestones and challenges surrounding CCS technology are discussed in Chapter 4 of Volume I.

Figure 11.11 · Mexico: Total primary energy supply in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy production does not change substantially across scenarios over the Outlook period: natural gas is the same in 2050 in all scenarios at 46 Mtoe, oil production is similar (12% lower by 2050 in the 2DC compared with the BAU and TGT), and coal production is 41% lower in the 2DC than in the other scenarios due to lower demand from the electricity and industry sectors. Overall energy trade declines however; as demand is lower in the 2DC, energy imports for all fuels also decrease over the Outlook. Crude oil exports are 20% lower in 2050 than in the BAU, as global oil demand falls as the rest of the world also works to reduce CO_2 emissions. At the same time, lower energy demand resulting from efficiency gains means less imports are required. In the 2DC, natural gas imports peak at 42 Mtoe by 2021, then decrease to 30 Mtoe by 2050, similar to the import volume in 2015. Oil product imports, mostly gasoline, fall to 4.5 Mtoe by 2050, around a fifth of gasoline imports under the BAU. A less carbon intensive energy sector not only helps reduce pollution and CO_2 emissions but it also contributes to reducing dependency on international markets and easing energy security concerns.

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

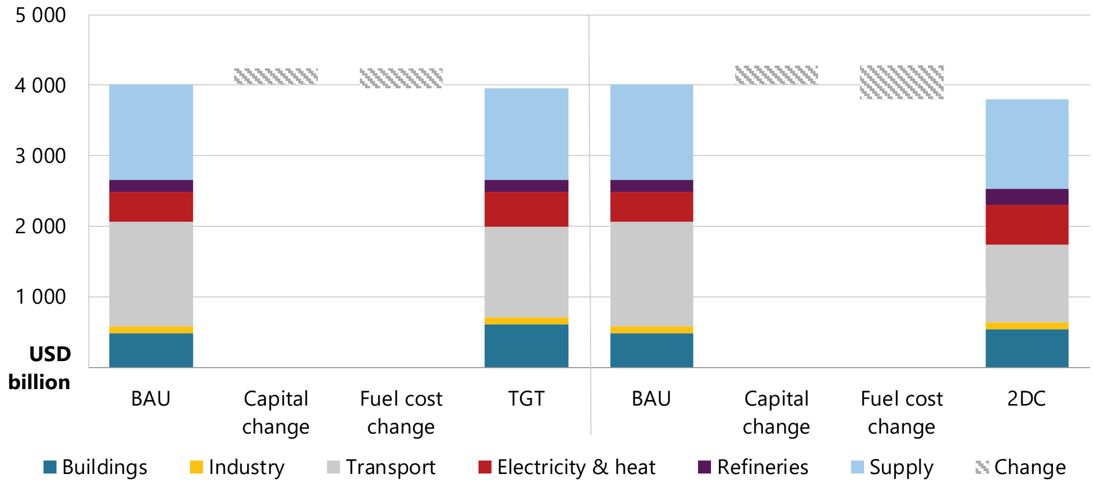
The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[60]

Total cumulative investment in Mexico's energy sector is around USD 4 007 billion in the BAU (Figure 11.12). Energy investments are split almost evenly between capital costs (USD 1 938 billion) and fuel costs (USD 2 069 billion). More than half of capital investment is destined for the upstream oil and gas sector, where the landmark 2013 energy reform results in a capital inflow of USD 1 150 billion over the Outlook period. The midstream natural gas sector attracts investment of more than USD 118 billion by 2050. Mexico's dynamic electricity sector attracts more than USD 357 billion of investment between 2016 and 2050, of which 28% is allocated to renewable energy, with USD 39 billion in wind and USD 42 billion in solar power generation capacity.

[60] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Total demand-side investment accounts for only 7.6% of total investment. Fuel costs amount to USD 2 069 billion, with the majority in transport (63%) and buildings (17%).

Figure 11.12 · Mexico: Energy sector capital and fuel costs, 2016-50



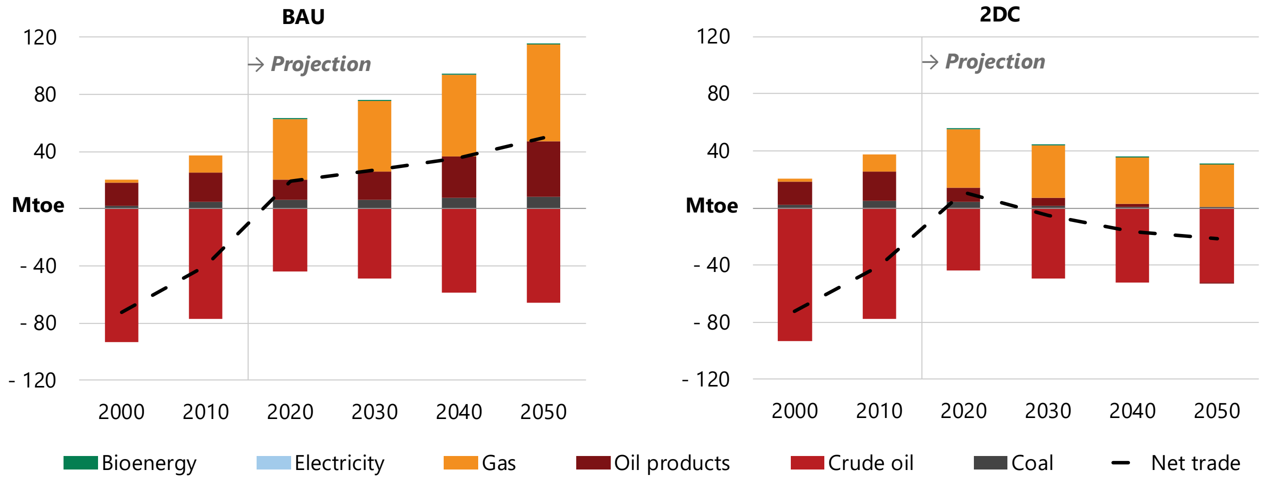
Sources: APERC analysis and IEA (2018a).

Under the TGT, total investment decreases marginally to USD 3 962 billion. While capital investment increases to USD 2 166 billion, this is outweighed by fuel efficiency improvements which reduce fuel costs by 13%. Demand-side capital investments increase by 59% compared with the BAU, underpinned by a 23% increase in investment in the electricity sector compared with the BAU (to increase renewables penetration). Total investment decreases further in the 2DC, to USD 3 797 billion, as a result of a 23% savings in fuel costs (USD 1 586 billion) when compared with the BAU. Capital investment, however, surges by 14% compared with the BAU, reaching USD 2 211 billion. Investment in power increases to USD 517 billion, compared with USD 357 billion in the BAU, as expensive gas-fired power plants with CCS and renewables-based power plants require financing. Total demand-side investment also increases, from USD 306 billion in the BAU to 488 billion, accounting for a 13% share of total investment.

ENERGY TRADE AND SECURITY

Three major energy trade changes have occurred in Mexico from 2005 to 2016: net crude oil exports fell 38%; net oil product imports more than doubled (mainly gasoline, but diesel and LPG too); and net natural gas imports increased more than fourfold (Figure 11.13). These three dynamics revolve around trade with the United States. In 2016, 50% of crude oil exports were sent to the United States, while 90% of natural gas imports and 64% of gasoline imports came from the United States (SENER, 2018d) While the asymmetrical and profound interdependence of the two economies is not a problem *per se*, Mexico's growing domestic demand, coupled with declining production and insufficient storage capacity, has dramatically increased dependency on US energy imports and raised energy security concerns among Mexican stakeholders. Increasing storage infrastructure, diversifying energy trade partners and boosting efficiency measures on the supply and demand sides remain challenges to enhancing energy security in Mexico.

Figure 11.13 · Mexico: Net energy trade in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Because of the highly competitive prices offered by US natural gas producers, growing demand in Mexico, and expanding transport and import infrastructure, 53% of Mexico's natural gas consumption was imported in 2016—88% from US pipeline imports. Under the BAU scenario, Mexican natural gas imports are projected to continue growing rapidly (90% by 2050), increasing concerns over lack of supply diversification. Mexico's natural gas self-sufficiency decreases in the BAU, stabilising at 46% from 2030 to 2050 (Table 11.4). Similarly, fossil fuel resources show an increasing reserve gap over the Outlook period across scenarios; however, the 2013 reform established a favourable framework for increasing investment in upstream oil and natural gas activities that could translate to rising reserves and production.

Table 11.4 · Mexico: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	60	66	75	77	59	71	85
Coal self-sufficiency (%)	56	40	41	56	19	21	56
Gas self-sufficiency (%)	46	40	46	47	40	51	60
Crude oil self-sufficiency (%)	100	100	100	100	100	100	100
Primary energy supply diversity (HHI)	0.39	0.34	0.33	0.33	0.36	0.32	0.27
Coal reserve gap (%)	0.68	10	10	7.5	16	16	11
Gas reserve gap (%)	8.8	117	117	117	314	314	314
Crude oil reserve gap (%)	10	140	140	140	336	336	328

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

The exponential rise in oil product theft through illegal tapping of Mexico's pipelines[61] is another major energy security concern: occurrences increased from 324 in 2007 to 10 364 in 2017 (Reuters, 2018). This has resulted in an annual loss of USD 1.6 billion for Pemex, owner of most of the pipelines and still the dominant oil product trader (Pemex, 2017). The government has taken some actions on tackling down this theft, but secure pipeline transportation of oil products (predominantly diesel and gasoline) is a growing challenge (SENER, 2019).

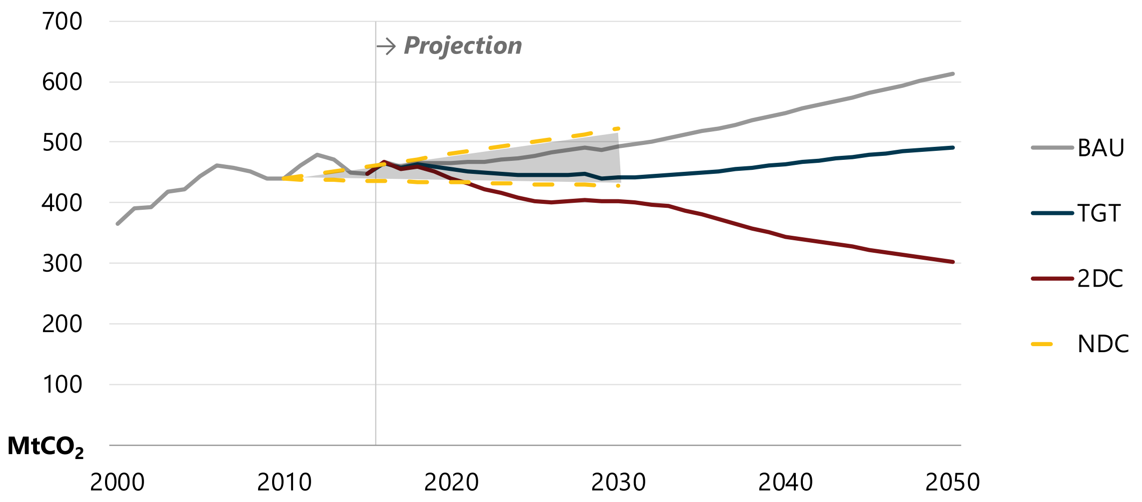
[61] For more information about illegal tapping by organised crime syndicates in Mexico, see: The Refinery Racket investigation (Reuters, 2018).

SUSTAINABLE ENERGY PATHWAY

Mexico's total greenhouse gas (GHG) emissions were 683 million tonnes of CO_2 ($MtCO_2$) (1.4% of total global emissions) in 2015, of which 71% were energy-related (INECC. 2018). Mexico's Nationally Determined Contribution (NDC)[62] commits the economy to an unconditional 25% reduction in GHG emissions from the 2013 level by 2030 and a 40% reduction conditional on a global agreement to address mitigation measures (UNFCCC, 2015). In addition, legislation mandates a 50% reduction of GHG emissions from the 2000 level by 2050.

Mexico's NDC does not explicitly detail emissions reductions by sector, but a substantial portion would clearly have to occur in the energy sector to achieve the goals. The three scenarios demonstrate very different trajectories for energy-related CO_2 emissions (Figure 11.14). Under the BAU, they increase 31%, from 467 $MtCO_2$ in 2016 to 613 $MtCO_2$ in 2050. In the TGT, they decrease marginally to a minimum in 2030, then rise gently to 2050, registering an overall rise of 5.2% over the Outlook period. This trajectory results from stricter energy efficiency standards in road transport and decreased fossil fuel-based electricity generation, offset after 2030 by expanded vehicle stock in transport. In contrast, energy-related CO_2 emissions drop 35% by 2050 in the 2DC, thanks to lower energy demand in transport resulting from improved vehicle technology and behavioural change that curtails travel. The complete phase-out of coal and oil in power generation and the introduction of CCS technology for most gas-fired electricity generation also contribute significant emissions reductions in the 2DC.

Figure 11.14 · Mexico: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the Intergovernmental Panel on Climate Change (IPCC). Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions, and land use, land-use change and forestry (LULUCF) are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

Mexico's energy reform has highlighted significant opportunities for further action to support an increasingly reliable, affordable and clean energy sector, and utilise Mexico's abundant natural resources (for example, its wind and solar potential). At present, the pre-2013 legal framework, CFE's limited investment capabilities, some

[62] The Nationally Determined Contributions (NDCs) reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), or 'COP21 Paris Agreement'.

local community opposition to projects, and ineffective access to and/or congestion of transmission lines (especially with intermittent wind and solar power generation during peak demand times) have tempered renewables expansion. However, Mexico has a great opportunity to promote and develop domestic renewable energy resources through innovative and effective schemes including the long-term energy auctions that it has recently hosted. As international experience shows, strengthening the legal and institutional energy framework with autonomous and specialised supervisory agencies such as CNH, CRE, CENACE, CENAGAS and ASEA are also key factors in energy market development.

Mexico’s new legal framework has resulted in major hydrocarbon discoveries (such as Zama and Ixachi). The economy should continue its work in administering attractive and transparent tendering procedures; regulatory bodies should be strengthened with human, technical and economic resources; and courts should be adequately resourced to provide certainty by enforcing the rule of law. Along with these efforts, Mexico should continue its efforts to participate as a global stakeholder in the hydrocarbon industry and strengthen its regulatory institutions to guarantee transparency, environmental protection and universal access to the benefits of a more efficient oil and gas sector.

Mexico’s refinery production has fallen steadily and utilisation rates have dropped in recent years, resulting in rising dependence on imports from the United States. In order to reverse this trend, the economy should explore the potential for increasing its refining capacity and corresponding utilisation rates, taking into account the complexities of the global refining industry and the close proximity of refineries in Texas. Mexico should also strive to increase energy security by exploring avenues for increasing import source diversity and reducing demand for transport fuels. In this process, the elimination of inefficient subsidies for gasoline and diesel should be prioritised with consideration of the resulting impacts on vulnerable populations (OECD, 2019b).

While Mexico has increased the length of its natural gas pipeline network by a remarkable 75% in the past 10 years, there is substantial opportunity for continued expansion, particularly in southern Mexico and in residential buildings. Construction on at least six pipelines has been delayed for more than two years because of opposition from local communities, environmental groups, or indigenous groups resulting from concerns of surrounding the Free Prior Informed Consent processes. The government should redouble efforts to promote key infrastructure projects by engaging relevant stakeholders, such as companies, institutions and consumers.

Traditional biomass still accounts for an important share of Mexico’s energy demand (5.1 % of FED and 29% of energy demand in buildings), concentrated among the most impoverished households in rural areas. This translates into inefficient energy consumption, higher local air pollution and public health issues for the most vulnerable sections of the population. While traditional biomass use decreased by 10% from 2000 to 2016, continued efforts should be made to ensure universal access to modern forms of energy, reduce reliance on traditional biomass (particularly through electrification using renewable energy such as solar PV and wind power) and introduce distributed generation technologies in isolated regions.

Some energy efficiency policies, such as mandatory energy performance standards (MEPS) for appliances, have reduced energy demand significantly, especially in buildings; however, transport holds vast potential for greater energy efficiency. Mexico should harmonise efficiency standards for LDVs with the United States. As heavy-duty vehicles become one of the largest energy users in transport, Mexico should work with vehicle manufacturers and relevant stakeholders to adopt fuel efficiency standards as soon as possible.

12. NEW ZEALAND

KEY FINDINGS

- **FED continues to rise in the BAU, remains stable in the TGT and shrinks in the 2DC.** The buildings and transport sectors are the primary sources of divergence among the three scenarios.

- **Improving the thermal performance of buildings is essential for New Zealand to meet its CO_2 emissions reduction objectives.** Space conditioning is the largest consumer of energy in buildings, accounting for 38% of total in the BAU, 34% in the TGT and 32% in the 2DC.

- **EV potential is considerable.** In the 2DC, EV deployment increases exponentially from a small base to make up 48% of the light vehicle fleet by 2050.

- **New Zealand could achieve 100% renewable electricity by 2030.** Reduced demand and greater wind-powered generation in the 2DC enable early retirement of gas-fired generation.

- **The 2DC requires 11% less investment than the BAU to reach New Zealand's NDC and put its energy sector on a 2°C pathway.** The fuel savings from efficiency improvements across all sectors offset the additional capital expenditure in the 2DC.

ECONOMY AND ENERGY OVERVIEW

Situated in the South Pacific, New Zealand comprises a North Island and a South Island as well as several inhabited outer islands. It has a total land area of 267 710 square kilometres (similar to the Philippines), but relative to its land mass it has a small population of 4.7 million concentrated primarily in urban centres (86%) (The World Bank, 2018). One-third of the population (1.4 million) lives in Auckland, the largest city (Statistics New Zealand, 2017).

New Zealand's economy is mature and open to trade, relying strongly on primary industries such as agriculture, horticulture, fishing and forestry. Exports from these industries account for 30% of gross domestic product (GDP), with agricultural commodities (dairy, meat and forestry products) dominating (Immigration Service, 2018). The manufacturing and service sectors are also important contributors to GDP. The economy was relatively insulated from the global financial crisis of 2008, growing at a compound annual growth rate of 3.5% from 2000 to 2007, but contracted by only 1.5% in 2008 (Table 12.1). The economy has since returned to steady growth, and GDP per capita reached USD 38 437 in 2016. New Zealand has a high standard of living and well-developed energy infrastructure, with electrification rates and access to energy near 100%.

The government has indicated it plans to strengthen efforts to reduce carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions by improving and expanding the current emissions trading scheme (ETS) (MFE, 2018). Reducing emissions will remain a challenge for New Zealand, as less than half (40%) of its emissions come from energy. Agricultural emissions, especially methane from livestock and nitrous oxide from urine and fertilisers, make up almost half of total gross emissions (49%) and are much more difficult to address. Industry (6%) and waste (5%) make up the remainder (MFE, 2018).

Table 12.1 • New Zealand: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	114	149	179	199	256	323	402
Population (million)	3. 9	4. 4	4. 7	4. 8	5. 2	5. 5	5. 7
GDP per capita (2016 USD PPP)	29 461	34 119	38 437	41 139	49 143	58 753	70 324
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	17	19	22	22	24	26	27
TPES per capita (toe)	4.5	4.3	4.6	4.6	4.6	4.6	4.8
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	154	126	121	112	95	79	68
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	13	13	15	15	16	17	18
FED per capita (toe)	3.4	3.0	3.1	3.1	3.1	3.1	3.2
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	114	87	82	75	62	53	46
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	31	32	34	32	33	33	36
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.

Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018), and World Bank (2018a and 2018b).

ENERGY RESOURCES

New Zealand has abundant renewable resources, which fuel almost all electricity generation, along with large coal reserves, and more modest amounts of natural gas and oil. Gas production currently meets all domestic demand, and the economy produced 24% of the oil it consumed in 2017 (MBIE, 2017a). Production is concentrated in the Taranaki region, from fields that produce gas and associated oil and condensates. Oil is sourced from 18 fields, from which production has been falling since 2007 as no significant new discoveries have been developed. Although gas production expanded 24% from a low base in 2005 with the opening of the Pohokura and Mangahewa gas fields and the application of enhanced recovery techniques in the Maui gas field between 2011 and 2014, it is now in decline. As of 1 January 2017, it was estimated that New Zealand's gas supply would last just over 11 years at the 2016 demand level (MBIE, 2017a). Exploration has found possible hydrocarbon deposits (especially gas) in other sedimentary basins, but these are yet to be developed (GIC, 2017).

Coal is New Zealand's most abundant fossil fuel resource, with reserves estimated at 15 billion tonnes, predominantly of lignite (MBIE, 2017a). Production has dropped in recent years, to 2.9 million tonnes (Mt) in 2017 (compared with 5.3 Mt in 2010). In 2016, the government-owned coal producer, Solid Energy—responsible for 68% of production—went into voluntary administration after years of falling revenue due to low coal prices. Solid Energy's assets were sold to private-sector interests, effectively ending government involvement in the sector (MBIE, 2017a).

Renewable energy resources are particularly bountiful: hydro and geothermal potential is considerable; a myriad of sites are suitable for generating wind power; large volumes of biomass are available from plantation forest harvesting, wood processing and farm and sewage wastes; and solar potential is strong in some regions. As an economy that has vast tracts of land devoted to forestry plantations and a large agriculture sector, New Zealand's potential to produce and use solid biomass and liquid biofuels is high. Commercial biodiesel is already produced from feedstock such as tallow (a meat industry by-product) and used cooking oil (EECA, 2017).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

The Ministry of Business, Innovation and Employment (MBIE) is New Zealand's main energy policy agency. It develops policies and strategies on all energy matters in partnership with other agencies such as the Energy Efficiency and Conservation Authority, the Ministry of Transport, the Ministry for the Environment, the Electricity Authority, the Ministry of Foreign Affairs and Trade, and the Ministry of Primary Industries.

Released in 2011, the *New Zealand Energy Strategy 2011-21: Developing Our Energy Potential* (the NZES) is the economy's overarching energy policy document (MBIE, 2011). It focuses on four priorities for a strong energy future: diverse resource development; environmental responsibility; efficient use of energy; and energy security and affordability (Table 12.2). The NZES accompanying document, the *New Zealand Energy Efficiency and Conservation Strategy 2017-22* (NZEECS), was released in 2017 (replacing the 2011 version). It identifies three priority areas for action, each with a key target (MBIE, 2017b):

- Renewable and efficient use of process heat – industrial emissions intensity falls by at least 1% per year on average between 2017 and 2022.
- Efficient low-emissions transport – electric vehicles (EVs) make up 2% of the vehicle fleet by the end of 2021.

- Innovative and efficient use of electricity – 90% of electricity comes from renewable sources by 2025.

New Zealand's energy markets are open to private-sector investment and competition, with the exception of transmission and distribution networks for both gas and electricity, which are regulated natural monopolies. The Electricity Authority is the electricity market watchdog tasked with ensuring fair competition and supply security, but does not dictate investment decisions.

In October 2017, a new Labour-led coalition government came into power with the ambitious objective of making New Zealand a world leader in climate change action. Policy actions towards this goal include targeting net-zero carbon emissions by 2050, establishing an independent Climate Change Commission to recommend energy targets and actions, and strengthening the ETS that has been in existence for several years. Furthermore, the government has announced it will no longer issue offshore exploration and mining permits, but will honour existing permits (MFE, 2018). Onshore exploration and mining permits will be limited to the Taranaki region. The limitations on exploration make the likelihood of significant oil and gas discoveries considerably lower. The government has also recently announced the Healthy Homes Guarantee Act 2017, which requires all properties under new tenancy agreements to meet minimum insulation and heating standards by July 2019 (New Zealand Parliament, 2017a)

Box 12.1 • New Zealand: Labour's election win and impacts for the energy sector

The September 2017 election resulted in the formation of a Labour-led coalition government in cooperation with the New Zealand First party, and a confidence and supply agreement with the Green Party of Aotearoa New Zealand. Labour leader Jacinda Ardern became New Zealand's 40th prime minister. This change in power is likely to affect the energy sector significantly, as the new government's environmental and social objectives involve transport, climate change, renewable energy and energy efficiency (New Zealand Parliament, 2017). Although energy sector policy has not been finalised, government statements and the election manifestos of the governing parties indicate that the government will:

- Aim to make New Zealand carbon-neutral by 2050.
- Strengthen the ETS and include agriculture in the scheme by reducing the free credits granted to certain sectors, and eliminate the two-for-one credit-surrendering deal currently in place.
- Establish an independent Climate Change Commission.
- Stop issuing offshore oil and gas exploration permits.
- Expand mass public transport infrastructure in key regions.
- Extend housing insulation programs for both energy savings and health benefits.

The final versions of these policies are yet to be determined, but further energy sector reforms are expected in the near term.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy assumptions and projections for New Zealand under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 12.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 12.2 • New Zealand: Key assumptions and policy drivers under the BAU

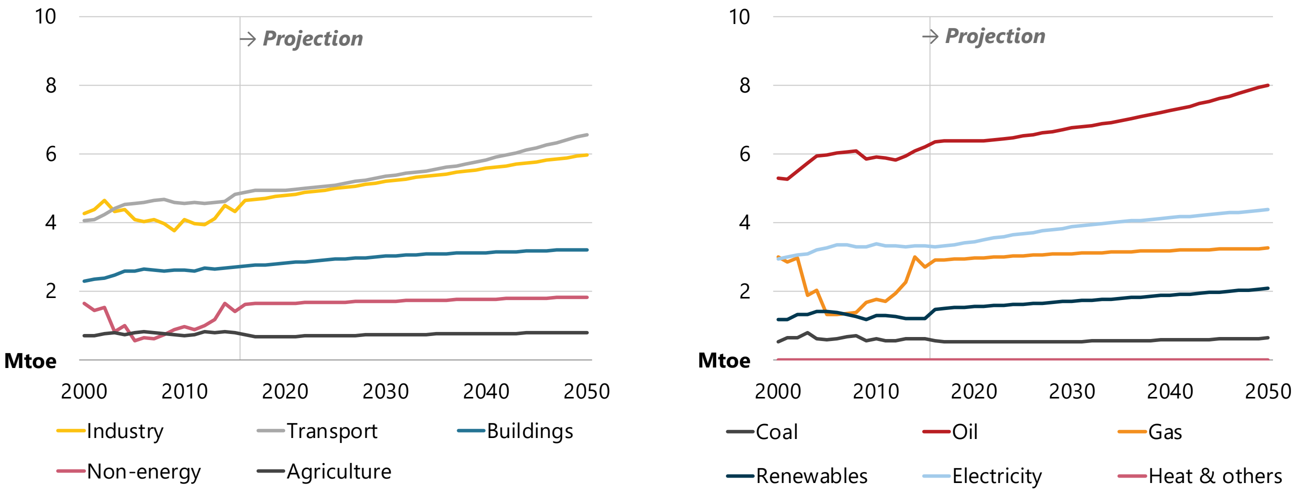
Buildings	The share of adequately insulated buildings continues to expand slowly. The use of heat pumps for space heating increases and the switch to LED lighting continues.
Industry	Cost-effective technologies and energy efficiency improvements are implemented.
Transport	All vehicles are imported, many second-hand, so fleet fuel efficiency improves steadily and hybrids and EVs are gradually deployed. Biofuel blend rates reach 2% for gasoline and 3% for diesel.
Energy supply mix	Nuclear energy generation remains illegal throughout the Outlook period. Climate-change goals drive efforts to reduce fossil fuel use.
Power mix	Coal-fired generation is phased out. Gas discoveries support current level of consumption throughout the period. Wind- and geothermal-based generation expand significantly.
Renewables	Efforts to reach 90% renewables-based power generation by 2025 continue.
Energy security	No explicit energy security policies or targets are in place aside from IEA requirements.
Climate change	Efforts are made to uphold the NDC commitment to reduce GHG emissions to 30% below the 2005 level by 2030, but it is not achieved in the BAU. The domestic target of a 50% GHG emissions reduction (or a proposed net-zero target) by 2050 is also not achieved.

Notes: Outlook period = 2016-50. EV = electric vehicle. IEA = International Energy Agency. NDC = Nationally Determined Contribution. GHG = greenhouse gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

In the BAU, New Zealand's final energy demand (FED) rises from 15 Mtoe in 2016 to 18 Mtoe in 2050 as demand increases for electricity (32%), oil (26%) and the direct use of renewables (40%), while gas and coal remain stable, resulting in overall growth of 25% over the Outlook (Figure 12.1). The transport sector records the largest increase in energy demand (34%) as the population continues to grow and economic development boosts demand for freight. Industry FED rises 28% and that of non-energy sectors increases 12%, whereas buildings demand grows by only 18% owing to energy efficiency improvements in the housing stock.

Figure 12.1 • New Zealand: Final energy demand by sector and fuel, 2000-50



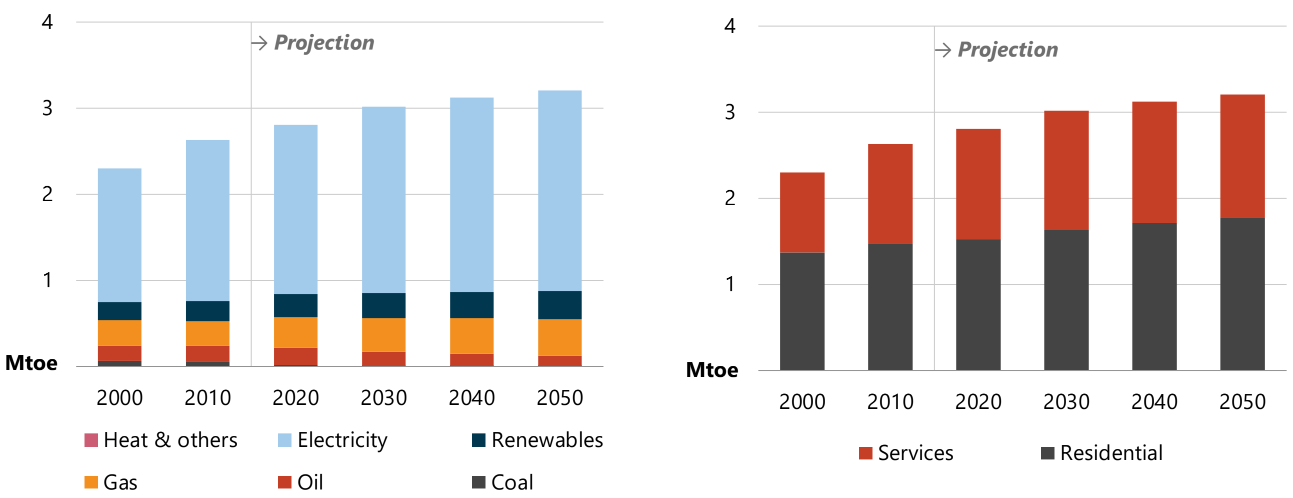
Sources: APERC analysis and IEA (2018a).

BUILDINGS: ENERGY DEMAND DRIVEN BY POPULATION AND ECONOMIC GROWTH

Energy demand in buildings increases from 2.7 Mtoe in 2016 to 3.2 Mtoe in 2050, with electricity remaining the dominant form of energy, meeting over 69% of sectoral demand in 2016 and 73% in 2050. It accounts for 24% of demand growth over the projection period, while natural gas accounts for 34%. Direct-use renewables expand 23%, largely in the form of solar water heating, to meet 14% of total energy demand in buildings in 2050.

Energy demand growth in buildings is driven by the residential subsector. Population growth of 23% during the Outlook period and an assumed 11% reduction in average household size result in a 37% increase in the number of households. This growth is somewhat offset by improved building envelope performance in the building stock, which slows the growth in residential energy demand to 19% by 2050 (Figure 12.2). Energy demand in the service buildings subsector also increases (17%) as population growth and higher incomes result in floor space increasing by 62%—from 89 million square metres (m^2) in 2016 to 145 million m^2 in 2050. More schools and other educational institutions, more office space for a larger workforce and increased retail space are all required to meet the needs of a growing population.

Figure 12.2 • New Zealand: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

In the residential buildings subsector, space heating accounts for 31% of total energy demand, and water heating for 30%. The remaining 39% is consumed for all other end-uses, including a wide range of appliances. The main end-uses remain stable during the Outlook period, with two notable exceptions:

- Lighting consumption falls from 12% in 2016 to 5% in 2050 as incandescent lighting is replaced with LED and compact fluorescent technology.
- Space cooling consumption rises from less than 1.1% to 5.5% as heat pumps are much more widely deployed. While heat pumps are generally installed for heating purposes, they can also be used for cooling during warmer periods.

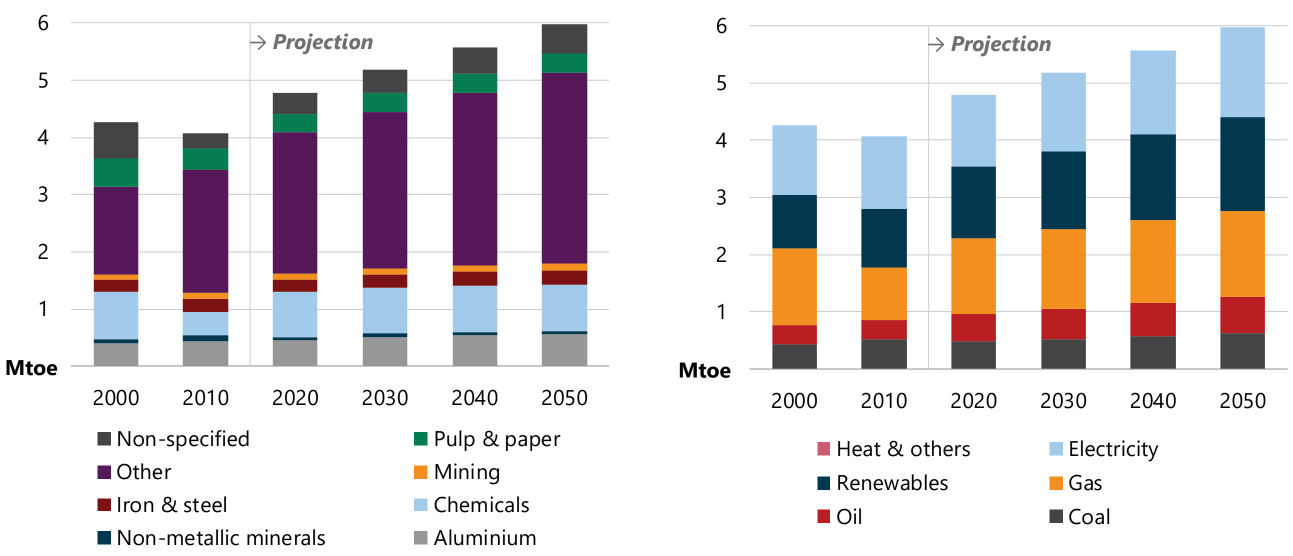
Space conditioning (heating and cooling combined) accounts for the greatest share of end-use consumption in service buildings (8%). The share of other end-uses, including office equipment, refrigeration and cooking appliances, is 32%. As the energy performance of buildings improves over the Outlook period, the share of demand for space heating and cooling falls to 9.0%, while demand for other end-uses rises to 40%.

INDUSTRY: STEADY GROWTH LED BY OTHER SECTORS

Industry energy demand increases by 28% between 2016 and 2050, with subsector shares remaining relatively stable. The 'other' subsector[63] has been the source of most industry energy demand growth in recent years, expanding 54% between 2000 and 2016, but consumption slows to an increase of 0.96 Mtoe (31%) over the projection period. The fuel shares in this subsector hold steady with renewables (45%) remaining dominant followed by electricity (17%) and gas (17%).

In the remaining subsectors, a small number of large consumers account for most of the rest of industry energy demand: one steel mill, one aluminium plant, two cement plants, one refinery, and four pulp and paper plants. Energy demand fell marginally between 2000 and 2010, mainly because of the global financial crisis and the expiration of gas contracts for methanol manufacturing (Figure 12.3). It has since recovered, however, partly due to gas reserve reassessments that resulted in new methanol production contracts.

Figure 12.3 • New Zealand: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

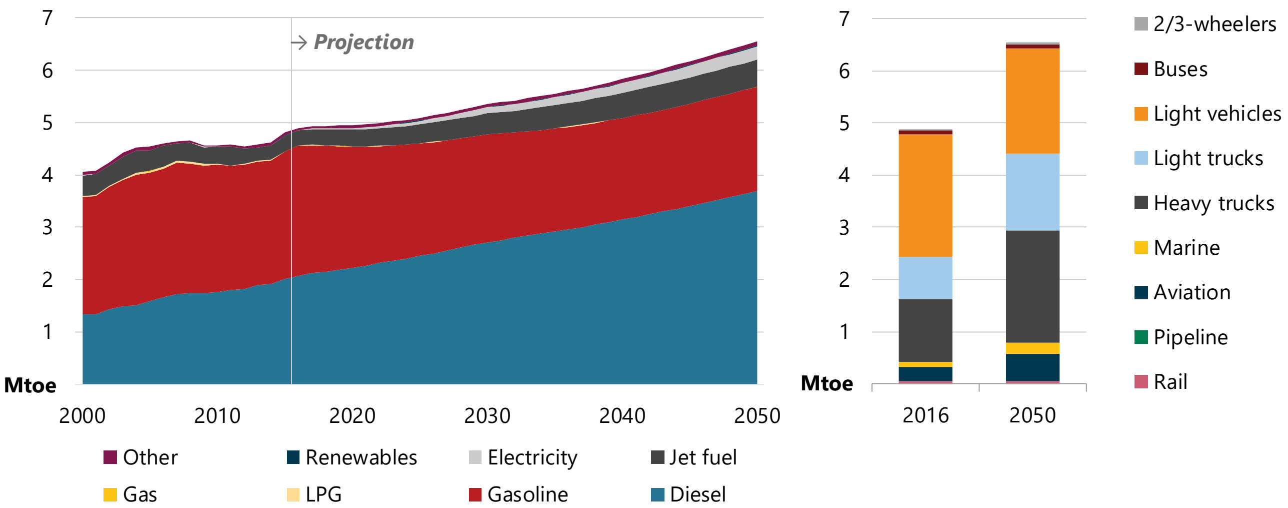
[63] Includes non-ferrous metals except aluminium; transport equipment; machinery; food and tobacco; wood and wood products; construction; and textiles and leather.

The uncertainty surrounding methanol production (included in the 'other' subsector and accounting for 50% of gas consumption in 2016) is particularly acute. This industry is currently insulated from GHG pricing because it is eligible for free emissions credits, but the discontinuation of new offshore oil and gas exploration permits make the discovery of significant gas resources onshore or in a small area off the coast of Taranaki essential. Without new discoveries, domestic gas prices are likely to rise to a level that results in the methanol industry becoming uncompetitive and having to stop production. Although domestic CO_2 emissions would fall if the plant stops operating, production would be displaced to somewhere outside New Zealand and coal feedstock could be used instead, so production may be higher-emitting (MBIE, 2018). This Outlook assumes gas discoveries are sufficient to maintain domestic supply for all sectors through 2050.

DOMESTIC TRANSPORT: DIESEL DEMAND GROWS STEADILY

Road transport continues to dominate domestic transport energy demand during the Outlook period, growing from 4.9 Mtoe (81%) in 2016 to 6.6 Mtoe (76%) by 2050, largely owing to demand from domestic freight (Figure 12.4). Light-duty vehicle (LDV) fleet efficiency continues to improve with wider EV availability and as international efforts (such as Japan's Top Runner Program) make imported vehicles more efficient (Ministry of Transport, 2018). These changes, combined with a small shift (4.1%) towards air transport, result in a 38% reduction in energy consumed per passenger-kilometre. However, a 3.3% shift to road transport in total freight share results in growth in energy intensity of 4.4% over the projection period. FED for air transport increases from 0.28 Mtoe in 2016 to 0.57 Mtoe in 2050 as the population becomes wealthier and more people travel. Sea and rail transport energy demand also rise strongly (by 125% and 32%) as freight demand increases, although their shares remain small (13% and 15% of tonne-kilometres in 2050) compared with road transport.

Figure 12.4 • New Zealand: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Oil products continue to dominate the transport fuel mix, with all other fuels combined making up less than 3.2% by 2050. Electricity has the largest proportional increase in share of the transport fuel mix, at 49-times higher in 2050 than in 2016. However, the electricity share starts so small that the total contribution in 2050 is still just 3.0% of transport FED. Similarly, biofuels demand in transport triples over the Outlook period but still makes up only 0.15% of the total in 2050.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

The energy transformation sector remains relatively unchanged throughout the Outlook period as demand for oil and gas plateaus, although fossil fuel trading is affected. The share of renewables in the power sector continues to expand, especially through geothermal plants, leading to less fossil fuel-based generation.

ENERGY INDUSTRY OWN-USE: REFINING CONTINUES TO DOMINATE

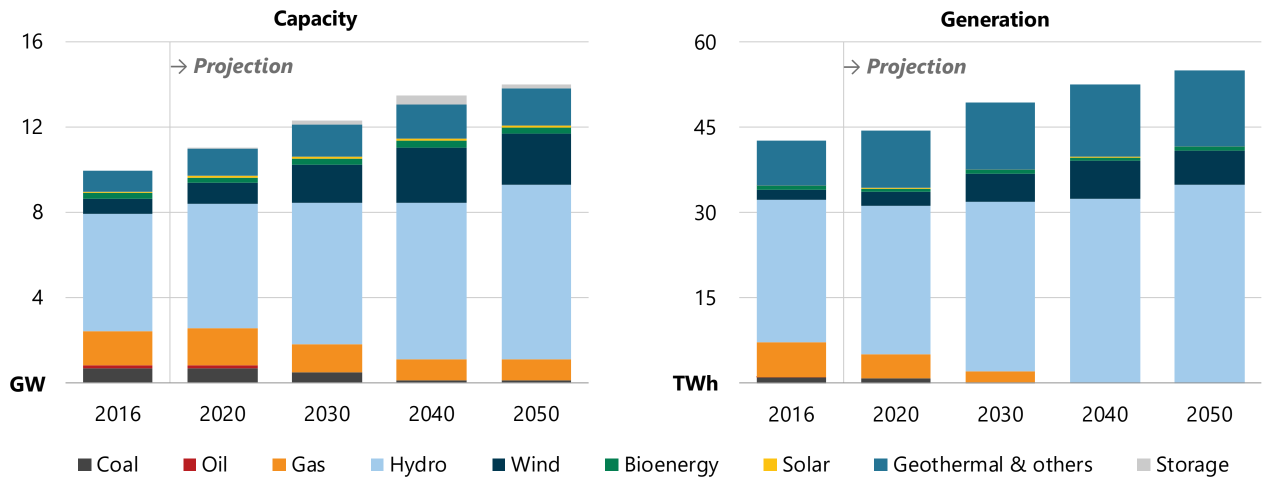
Energy industry own-use consumption remains largely unchanged over the projection period, as Marsden Point continues to be the only operational refinery in New Zealand. In 2016, it supplied around 60% of all oil products consumed domestically, produced mainly from imported crude, although the proportion of supply varies somewhat with demand. The most recent expansion, completed in 2015, raised capacity by 8.0% and reduced fuel losses by 15% (Refining NZ, 2016). While some refinery upgrades may be made so that it can process a range of fuels at different specifications, no further expansions are assumed under the BAU.

POWER SECTOR: RENEWABLES CONTINUE TO EXPAND

Renewables are the primary energy source used in New Zealand's power sector, with large hydro power plants producing 59% of electricity in 2016, complemented by geothermal generation at 18%, wind at 4.3% and bioenergy at 1.4%, for a renewables total of 83%. Natural gas provided important baseload support at 15% of generation, and New Zealand still has 480 megawatts (MW) of capacity capable of burning coal, though gas may also be used. Coal supplied only 2.2% of generation in 2016, and coal use in the power sector is to be completely phased out by 2030—or as early as 2025 if market conditions permit (Genesis Energy, 2018).

Given the outstanding renewable resources available and the government's focus on renewable electricity, the share is projected to increase to 100% by 2050, largely through the addition of wind and geothermal capacity. Solar photovoltaic (PV) also expands rapidly, but from a very low base, to make up 0.17% of generation at the end of the Outlook period (Figure 12.5). Total electricity generation increases by 30%, led by rising electricity demand for buildings and transport. In the BAU, New Zealand reaches its 90% renewable electricity target by 2025. The government's ETS is a key area of uncertainty; depending on the emissions price imposed on generators, some fossil fuel-fired generation capacity may be retired before the end of its technical lifetime. However, grid reliability with higher shares of renewables is a concern, particularly for dry years when hydro-based generation is constrained.

Figure 12.5 • New Zealand: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

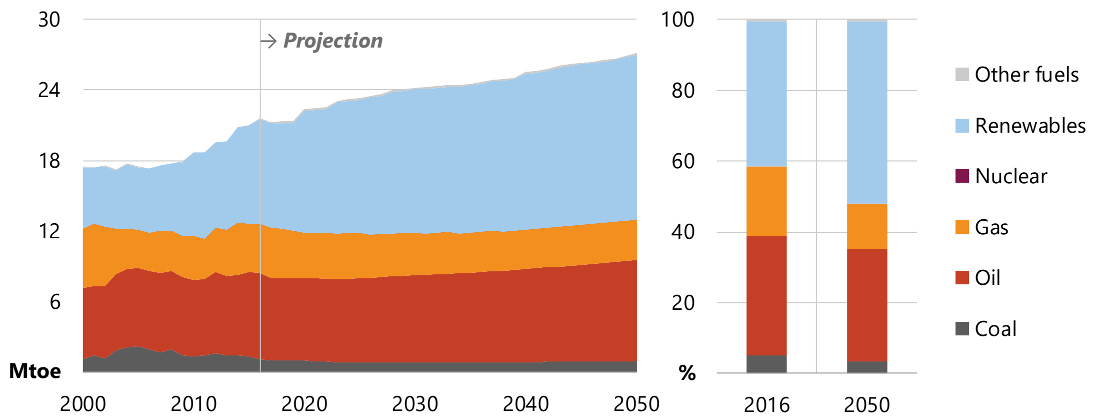
EV deployment also poses generation mix, transmission and distribution network challenges. Because EVs can store power and inject it back into the grid, they could be used to balance variable renewables-based generation; however, they may also present large, difficult-to-control loads. The transmission network operator, Transpower, has identified a number of grid management challenges, including climate change, distributed storage and generation, a smarter grid, greater urbanisation, and the electrification of process heat, industry and transport (Transpower, 2018).

TOTAL PRIMARY ENERGY SUPPLY: GROWTH MET BY RENEWABLES

Total primary energy supply (TPES) in New Zealand expands from 22 Mtoe to 27 Mtoe (27%) over the Outlook period, mostly due to growing renewable electricity generation to meet rising demand. The largest share of TPES in 2016 is renewable energy (41%), followed by oil (34%). Of the 5.6 Mtoe supply increase, the majority comes from geothermal electricity generation, which expands eight-fold (3.3 Mtoe). The efficiency of geothermal electricity generation is low (14% of total heat), so it meets only a modest portion of FED additions (and it also produces CO_2 during extraction). Wind-based electricity generation also increases by 39%. Renewables account for nearly 51% of TPES in 2050 (Figure 12.6). Reliance on oil continues, however (32% of supply in 2050), especially for transport activities, as suitable substitutes will not yet be mature. Similarly, industry remains reliant on natural gas and some coal for process heat.

In contrast, shares of coal and gas shrink in response to policy and regulatory measures to reduce GHG emissions. The most notable reduction is coal (-18% over the Outlook), as the main generation plant is gradually decommissioned: two of the four 250 MW Rankine units owned by Genesis Energy have already been decommissioned and the remaining two are slated to cease burning coal by 2030 .This will be achieved sooner (by 2025) if normal market conditions persist—i.e. no economic shocks and normal hydrological conditions (Genesis Energy, 2018). Limited amounts of coal-fired generation will remain after 2030, embedded in industry in the form of cogeneration.

Figure 12.6 • New Zealand: Total primary energy supply by fuel, 2000-50



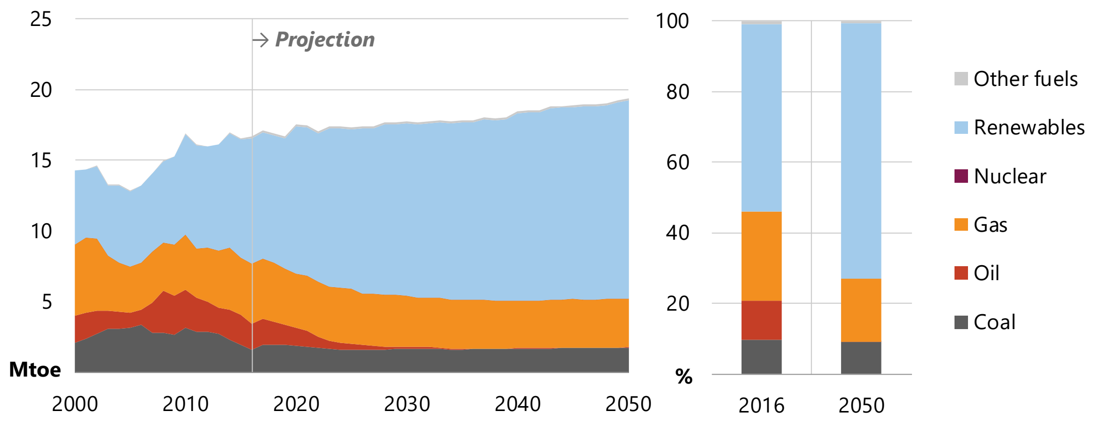
Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: OIL IMPORT DEPENDENCE GROWS

New Zealand produced 1.8 Mtoe of oil in 2016, representing approximately 28% of oil FED (Figure 12.7). During the Outlook period, production falls to virtually nothing in 2050 as existing reserves are exhausted and no discoveries are made, exacerbating import dependence. Transport growth drives a 28% increase in TPES of oil. The economy already depends heavily on imported crude and oil products: 5.6 Mtoe of imported crude oil was processed at the Marsden Point refinery in 2016 to meet 67% of domestic demand. Of this imported crude, 82%

was sourced from the Middle East. A further 2.7 Mtoe of refined oil products were imported to meet demand, mostly from Singapore and Korea (MBIE, 2018).

Figure 12.7 • New Zealand: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Potential for natural gas production is somewhat higher than for oil, however, as the Taranaki basin where much of the exploration and development has been focused has historically yielded more gas deposits (GIC, 2017). The BAU Scenario therefore assumes that modest findings of gas maintain the current production level but do not change market dynamics. New Zealand has traditionally been a net exporter of coal, especially of high-grade coal for steelmaking to Japan and India. The industry has struggled with low international prices in recent years (MBIE, 2018), however, and production dropped significantly from 3.1 Mtoe in 2010 to 1.6 Mtoe in 2016; it is projected to remain at a similar level to 2050

ALTERNATIVE SCENARIOS

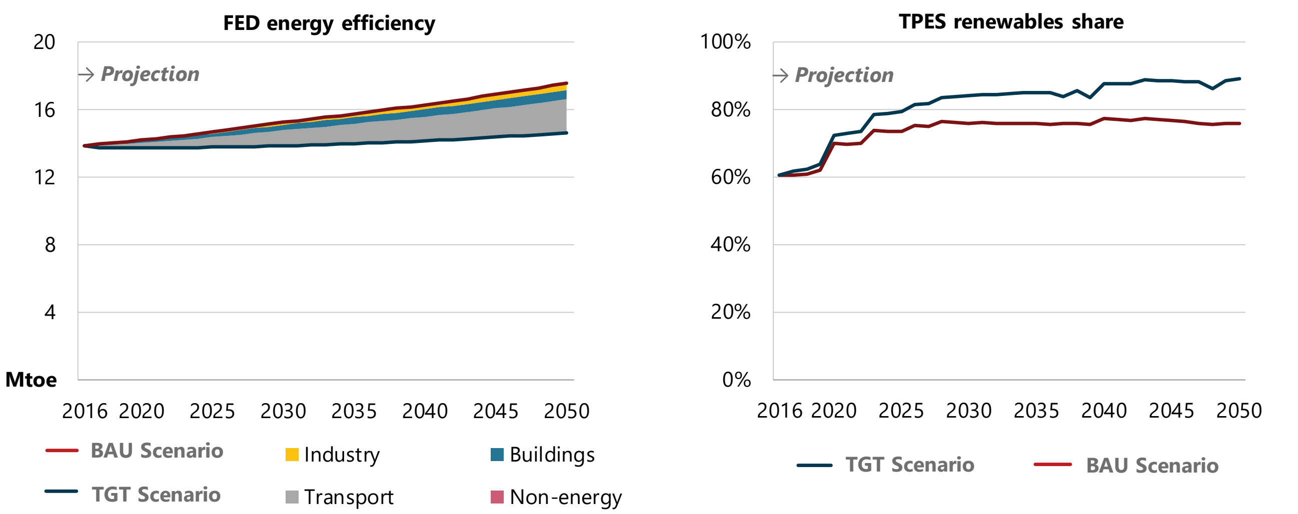
While the BAU Scenario is intended to reflect New Zealand's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Asia-Pacific Economic Cooperation (APEC) Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, New Zealand under the TGT shows a 16% reduction in FED in 2050 while CO_2 emissions are 25% lower. Under the 2DC, the NDC is achieved in 2030 and by 2050, the economy's FED is down by 30% and CO_2 emissions are 44% lower. The share of renewables in TPES is 5.5% higher in the TGT and 9.3% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the share of modern renewables in the energy system. Measures implemented under the TGT reduce FED nearly 16% by 2050 compared with the BAU. The transport sector provides the greatest reduction, at 29% of the total. Advanced vehicles such as hybrids and EVs, which are more energy efficient than conventional vehicles, are deployed to make up over 61% of the total fleet, compared with under 23% in the BAU. Similarly, a partial shift in passenger and freight transport from road to rail reduces kilometres travelled by heavy-duty vehicles (-3.5%).

The buildings sector has a cumulative decline of 18% from the BAU (Figure 12.8). Reductions are concentrated in space conditioning (heating and cooling), which accounts for 60% of the drop in residential FED and 52% of the decline in service buildings. Building envelope improvements cut overall heating intensity per square metre by 34% in residential buildings and 67% in the services subsector, and wider use of newer, more efficient technologies and appliances such as heat pumps, water heaters, air conditioners and LED lighting also reduces FED. Of the remaining sectors, industry contributes 13% of the FED reduction in 2050 under the TGT by further adopting best available technologies (BATs) for processes. Non-energy uses contribute 1.2% of the FED reduction owing to the more rapid adoption of BATs in the industries (no efficiency assumptions are made for agriculture, however).

Figure 12.8 • New Zealand: Energy efficiency and renewables, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU.
Sources: APERC analysis and IEA (2018a).

The share of renewable energy in TPES increases from 41% in 2016 to 57% in 2050 under the TGT, a 5.5% larger share than the BAU by 2050. However, as TPES decreases in response to efficiency improvements, the absolute amount of renewables is marginally lower in the TGT (13.8 Mtoe) than in the BAU (14.0 Mtoe) because energy efficiency reduces the need for electricity system capacity additions (especially geothermal), and some gas capacity is retired early. The intersection of improved energy efficiency and larger shares of renewables can be complicated, as lower energy demand can also limit renewable energy additions to the grid. Alternately, lower demand can lead to the early retirement of fossil fuel-based electricity generation and, in turn, boost growth in the share of renewables.

In New Zealand, EVs are a possible means of synchronising the two objectives of reducing demand and expanding renewables. Because EVs are much more efficient than internal combustion engines, they reduce demand for fossil fuels, and collectively they offer considerable battery storage that can be used to integrate higher shares of variable renewable energy such as wind and solar into the power system. Battery storage can represent a new source of electricity demand as well as flexible storage capacity. A smart-grid system can control these functions to balance grid loads and optimise renewable energy deployment.

Direct use of renewables increases in the TGT—by 58% in transport (through increased use of biofuels) and 13% in buildings (mainly through solar water heating), over 2016-50. Given the low base from which renewables start in these sectors, the absolute amounts added are very small compared with those for renewable electricity generation. Although the share of renewables in New Zealand's electricity system is already considerable (renewables supplied 83% of electricity demand in 2016), in the TGT this share increases to 100% by 2036, largely through the addition of wind and geothermal capacity, as well as early retirement of some gas capacity.

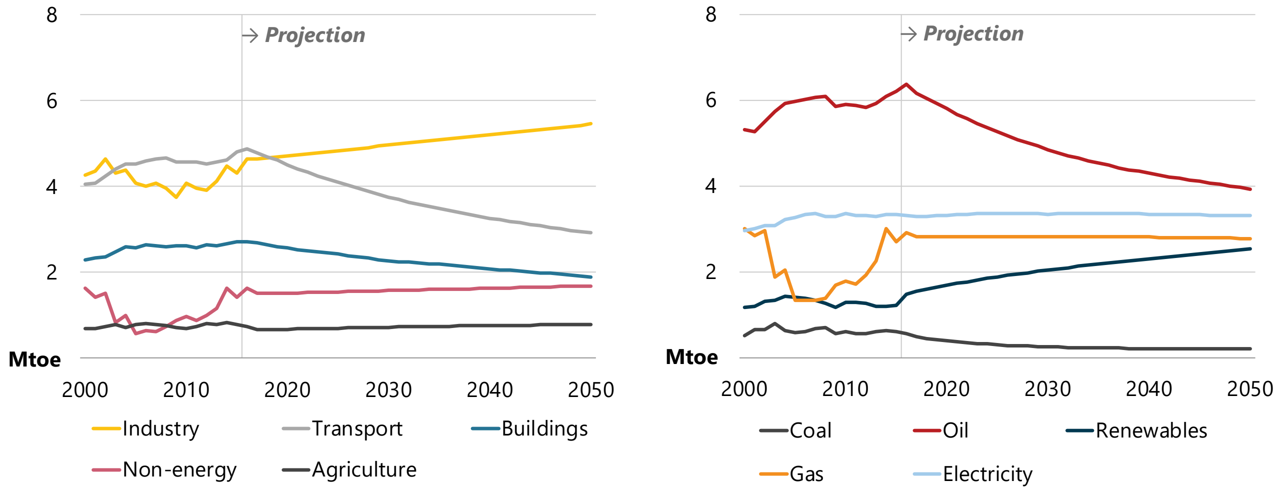
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in New Zealand have to undergo significant decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective. This is the only scenario in which the Nationally Determined Contribution (NDC)[64] of a 30% reduction in GHG emissions by 2030 is achieved.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

The efficiency gains achieved in the 2DC produce a further 17% (2.7 Mtoe) reduction in FED in 2050 compared with the TGT, and 30% (5.6 Mtoe) compared with the BAU. These decreases come from wider adoption of emerging technologies such as EVs in transport and heat pump water heaters in the residential subsector. Renewable energy use grows steadily through the Outlook mainly due to increased demand from industry. End-use electrification is another particularly effective way to reduce emissions in New Zealand, as power generation emissions on a per-unit basis are already among the lowest in APEC. In the 2DC, demand for electricity remains stable (0.34%), while oil (-46%), coal (-24%) and natural gas (-17%) all decrease (Figure 12.9).

Figure 12.9 • New Zealand: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

[64] The NDCs reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement'.

By the end of the Outlook period, over 91% of energy demand in buildings is met by either electricity or renewables in the 2DC—a 12% increase from 2016, and 8.3% higher than in the BAU in 2050. For the residential subsector the share is almost 99%, practically eliminating natural gas and coal from household heating. Lighting shows the greatest proportional demand reduction in residential buildings, down 63% by 2050 owing to the uptake of LEDs. Space and water heating provide the largest absolute decrease, together accounting for 64% of the subsector's FED reduction compared with the BAU (although ultimately they still account for around 60% of total residential demand). Measures such as better insulation and double glazing on windows cut heating and cooling intensity by 34%. In the services subsector, accelerated adoption of building standards leads to 0.78 Mtoe lower FED in the 2DC than in the BAU in 2050. Oil products are largely phased out in favour of electricity, but gas remains important at 23% of energy demand in 2050. Another important assumption under the 2DC is that total service buildings floor area expands by 32% (to 103 million m^2) by 2050, compared with a 65% expansion (to 129 million m^2) in the BAU.

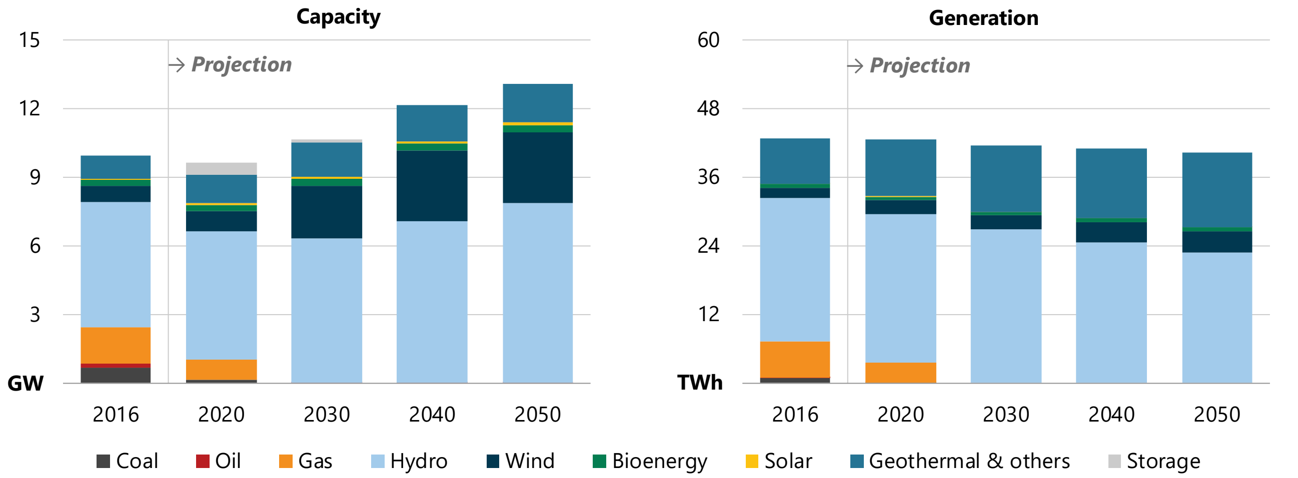
Transport provides the largest FED reduction in the 2DC: over 2.0 Mtoe (60%) from 2016 to 2050. This is 44% (3.6 Mtoe) less than the BAU and results from a combination of rising internal combustion engine fuel economy and wider deployment of modern vehicle technologies (such as much more efficient hybrid EVs). In the 2DC, the proportion of LDVs using modern technology expands from less than 1% in 2016 to almost 84% in 2050 (nearly 3.2 million vehicles). Furthermore, over 57% of advanced vehicles are electric-only, running on 100% renewable electricity. The energy intensity of road passenger transport falls from 2.1 megajoules per passenger kilometre (MJ per passenger-km) to just over 0.83 MJ per passenger-km as a result—a 61% reduction. As this sector currently depends almost completely on petroleum products, demand for these products drops by 67% under the 2DC. Jet fuel demand increases over the Outlook, however, as aviation efficiency gains are more limited and cannot counterbalance greater air travel demand.

Government programs have long targeted the largest energy users in New Zealand's industry sector, the potential for further reductions is therefore smaller than for other sectors (EECA, 2018). In the 2DC, industry FED grows by only 17% over the Outlook period, compared with 28% in the BAU and 20% in the TGT. The largest decrease occurs in non-metallic minerals production, as one of New Zealand's two cement plants shuts down early in the Outlook period. Compared with the TGT, however, the largest demand reduction is in iron and steel, as the adoption of BATs reduces the energy intensity of manufacturing.

TRANSFORMATION AND SUPPLY IN THE 2DC

Electricity demand drops sufficiently to warrant the retirement of all gas- and coal-fired generation capacity by 2030 in the 2DC, making New Zealand's electricity 100% renewable (Figure 12.10). Geothermal energy additions are increased in this scenario along with low-cost wind generation which complements the large existing hydro base. This shrinks the share of hydro in 2050 from 64% in the TGT to 57% in the 2DC. Wind expands rapidly, reaching 10% of generation by 2030; from there it remains steady with capacity additions keeping pace with demand growth. These developments are in line with the government's objective to become a carbon-neutral economy by 2050 (MFE, 2018).

Figure 12.10 • New Zealand: Power and electricity in the 2DC by fuel, 2016-50

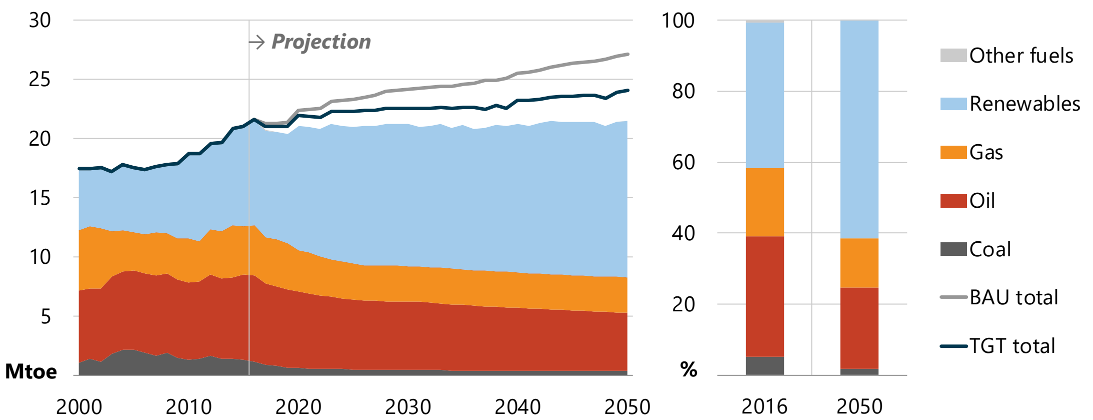


Sources: APERC analysis and IEA (2018a).

Demand reductions resulting from energy efficiency in the 2DC also reduce the absolute contribution of renewables to TPES only fractionally, to 13.2 Mtoe in 2050, compared with 13.8 Mtoe in the TGT and 14 Mtoe in the BAU (Figure 12.11). The small decrease reflects lower demand for electricity generation: demand for geothermal power especially falls, while wind and hydro remain more stable. Bioenergy with carbon capture and storage is introduced in 2040, and relying on forestry plantations for feedstock enables carbon-negative electricity production (IEA, 2018b).

In the 2DC, TPES of oil in 2050 falls by 34% from the 2016 level and by 27% compared with the TGT. Gas supply is 7.1% lower than in the TGT, as more gas-fired electricity generation is either phased out or replaced with renewables-based generation. The decline in coal (18% less than in the TGT) is small, as reductions in coal demand are already seen in the other scenarios. The share of renewables reaches 61% of TPES in 2050, from 41% in 2016, a 9.3% increase on the BAU and 3.8% increase on the TGT.

Figure 12.11 • New Zealand: TPES in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018).

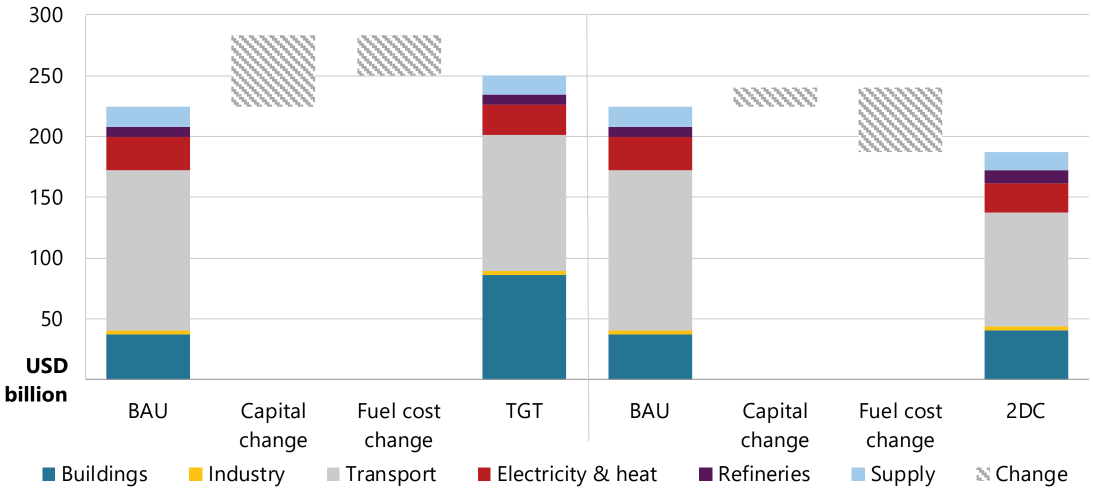
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[65]

Total cumulative investment in the BAU for 2016-50 is close to USD 225 billion (Figure 12.12). The largest portion of capital investment occurs in the electricity sector (USD 27 billion), for new generation capacity—particularly geothermal and wind which together make up 24% of total capital investment in the sector. Transport accounts for the largest share of total investment (USD 132 billion) over the BAU, most of which is fuel costs (83%).

Figure 12.12 • New Zealand: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018).

Capital investment requirements are USD 58 billion (66%) higher in the TGT than in the BAU, due to increased investment in the buildings sector to satisfy more stringent energy efficiency standards and carry out deeper renovations of the existing building stock. These increased costs are partially offset by lower investment requirements for electricity generation capacity and vehicle purchases as well as decreased fuel demand. Overall, fuel cost savings in the transport and buildings sectors due to increased efficiency amount to USD 32 billion from 2016-50.

Total investment requirements are significantly lower in the 2DC: USD 63 billion less than in the TGT (-25%), and USD 37 billion less than in the BAU (-17%). Buildings sector total investment is USD 3.6 billion higher in the 2DC than in the BAU, reflecting the greater spending on more stringent energy efficiency standards that is not fully recovered in fuel savings. However, significant savings are made in transport; total investment is reduced by USD 38 billion due to fuel savings of USD 47 billion. Along with the lower costs there are also significant improvements in GHG emissions (-61%) in the sector. This shows that over a longer term, actions to mitigate climate change in the sector can actually lower total costs. Improved energy efficiency is reflected in 2DC fuel

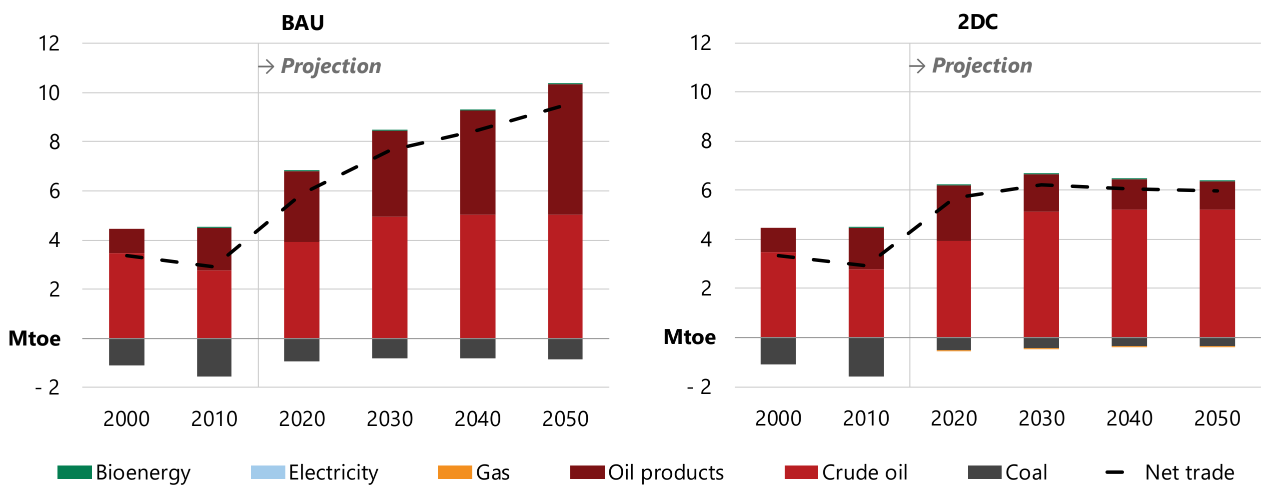
[65] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

costs, which are the lowest of the three scenarios at USD 84 billion, compared with USD 137 billion in the BAU and USD 10 billion in the TGT.

ENERGY TRADE AND SECURITY

New Zealand remains a net energy importer throughout the Outlook period in all scenarios. Oil imports grow by 0.95 Mtoe between 2016 and 2030, then flatten for the remainder of the BAU. Coal exports of less than 1.0 Mtoe continue through the Outlook, but remain a minor commodity in comparison with oil. In the 2DC, lower demand causes oil product imports to shrink, and the Marsden Point refinery meets a larger portion of domestic liquid fuel demand (Figure 12.13). This raises dependency on crude oil imports and New Zealand's single refinery. Reliance on one single supplier may jeopardise energy security. Diversifying supply sources for both crude oil and products, particularly within the APEC region, would help address this concern. Coal industry activity wanes further in the 2DC as domestic demand falls significantly, and low international prices continue to make investment unattractive.

Figure 12.13 • New Zealand: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Domestic natural gas production is assumed to keep pace with domestic demand, but new reserves will have to be developed over the course of the Outlook period (Table 12.3). Greater reliance on hydro power in the 2DC does raise some security concerns, as generation depends on rainfall and snow melt in catchment areas to fill reservoirs. Even at the current level of fossil fuel-based backup generation, climate events (such as El Niño) that affect rainfall patterns and lead to dry years can disrupt electricity markets. With the phase-out of coal and gas generation, ensuring security of electricity supply will require new policies (discussed below). This is particularly important as the residential and transport sectors become increasingly dependent on electricity in the 2DC compared with the BAU and TGT Scenarios. As New Zealand has no international electricity connections and no liquefied natural gas terminals, these commodities have no trade implications.

Table 12.3 • New Zealand: Energy security indicators under the BAU, TGT and 2DC, 2016-50

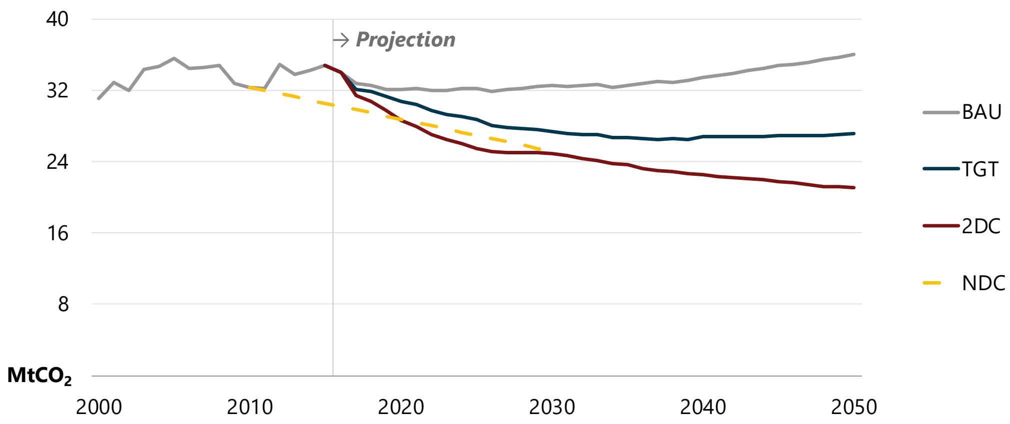
	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	75	71	73	73	68	73	77
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Crude oil self-sufficiency (%)	32	2.7	4.6	2.6	0.2	1.6	0.2
Primary energy supply diversity (HHI)	0.24	0.28	0.30	0.30	0.28	0.30	0.33
Coal reserve gap (%)	0.06	0.77	0.65	0.53	1.8	1.2	1.0
Gas reserve gap (%)	8.0	116	110	102	251	235	221
Crude oil reserve gap (%)	24	158	169	158	169	199	169

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

New Zealand's NDC commitment to reduce GHG emissions 30% from the 2005 level by 2030 is an economy-wide target covering all sectors, including agriculture, which has the largest emissions. New Zealand just achieves the NDC goal with a 30% reduction in energy-related emissions from 2005 levels in the year 2030 in the 2DC, while the other scenarios fall short. Energy-related CO_2 emissions fall by 39% from 2016 to 2050 (44% lower than in the BAU in 2050) in the 2DC (Figure 12.14). The largest decrease comes from lower oil consumption in transport, resulting in a drop of almost 13 million tonnes of CO_2, or 68% of all energy-related emissions in 2016. Significant declines also result from lower coal demand (emissions are 66% below 2016, or 58% below the BAU. Emissions from natural gas decrease by only 16% compared with the BAU, due to industry displacing demand from electricity generation.

Figure 12.14 • New Zealand: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

The energy sector in New Zealand contributes a smaller proportion of emissions than in most other APEC economies (IEA, 2016). Almost half of emissions currently come from agricultural methane (which is a relatively short-lived pollutant) and nitrous oxide from urine and the use of nitrogenous fertilisers. This energy analysis covers only CO_2, however, and the already-high proportion of renewables in electricity generation significantly limits potential CO_2 emissions reductions in that sector. Therefore, if New Zealand is to set more stringent emissions reduction targets, agricultural emissions will have to be cut significantly along with further improvement in the energy sector.

OPPORTUNITIES FOR POLICY ACTION

New Zealand can achieve 100% renewable electricity and its NDC goal by following the 2DC Scenario's combination of aggressive implementation of energy efficiency policies to reduce overall demand, significant electrification in the buildings and transport sectors, and the increased deployment of hydro, geothermal and wind resources (plus some solar and bioenergy) for electricity generation. However, the economy falls short of its carbon-neutral goal in all scenarios, demonstrating that further policy action is necessary in all sectors.

The main challenge to achieving 100% renewable energy is being able to integrate variable renewable energy into the system in sufficient quantities—ideally without requiring fossil fuel-based backup generation during periods of low hydrological flow—while still delivering power at a reasonable cost to consumers. Ensuring that markets are structured in ways that reasonably price demand response and storage technologies may help to deal with a changing fuel mix in the electricity sector.

Transport, which relies almost completely on oil, presents the greatest CO_2 emissions reduction opportunities—and at a negative cost. Implementing stringent fuel efficiency standards may entail some up-front costs, but they are outweighed by fuel cost savings over the lifetime of the vehicle. Historically, this type of policy has met opposition on the grounds that it limits choice, but the government could consider revisiting this option as part of its strong commitment to emissions reductions and climate change mitigation.

The intersection of transport and electricity (i.e. EV deployment) is an opportune area for energy policy. High-efficiency EVs and a near-100% renewable electricity sector as modelled in the 2DC is an ideal combination for reducing emissions. Much can be achieved with the current electricity generation mix (83% renewables as of 2016) and the government's goal to deploy 64 000 EVs by the end of 2021. The government needs to rapidly begin implementing measures, such as a rebate scheme, a contestable fund and procurement across private- and public-sector fleets, including targets for EV usage (MOT, 2018), if high penetration rates are to be achieved. These measures are all effective and well tested in other economies.

There is also significant energy demand and CO_2 emissions reduction potential in the buildings sector, particularly involving better building performance and enhanced space and water heating appliance efficiency. Previous governments have already been active in this area, and the current government introduced minimum heating and insulation standards with the Healthy Homes Guarantee Act in December 2017, but there is still much room to improve building envelope performance. Although the benefits of energy efficient housing are considerable in the long run, the risk of regressive impacts from higher housing costs could become problematic.

13. PAPUA NEW GUINEA

KEY FINDINGS

- **FED in Papua New Guinea more than doubles in the BAU, from 2.4 Mtoe in 2016 to 5.0 Mtoe in 2050.** Transport is the main energy-consuming sector, accounting for 44% of demand in 2050.

- **Energy intensity, which is well below the APEC average, falls in all three scenarios.** Energy demand per capita remains the lowest in APEC throughout the Outlook period.

- **Power generation more than doubles in all scenarios as electricity access expands and GDP growth drives demand.** Renewables grow from 32% of the 2016 electricity generation mix to 75% of the 2050 mix in the BAU, and 98% in the TGT and 2DC.

- **Gas production and LNG exports grow in all scenarios as the Papua LNG plant is assumed to begin operating in the 2020s.** LNG exports rise to 9.0 Mtoe by 2025, as the new plant becomes fully operational.

- **The NDC goal of 100% renewable energy by 2030 is not achieved in any of the scenarios.** Emissions reach 17 $MtCO_2$ in 2050 in the BAU, from 9.0 $MtCO_2$ in 2016, but only 11 $MtCO_2$ in the 2DC.

ECONOMY AND ENERGY OVERVIEW

Papua New Guinea, situated in the south-western Pacific region with a land area of 462 840 square kilometres (km^2), became a fully independent Commonwealth realm in 1975. It occupies the eastern half of the island of New Guinea (sharing a land border with Indonesia), and approximately 600 small islands are also part of its territory. It has a tropical climate, so temperature and humidity are high throughout the year. As it is situated along the Ring of Fire, earthquakes and volcanic eruptions are frequent.

Papua New Guinea had a population of 8.1 million in 2016 and is one of the most culturally diverse countries in the world, with hundreds of tribes and over 800 indigenous languages spoken. Most of the population (85%) lives in rural areas (UNDP, 2018), and provision of basic services continues to be a challenge, with less than 23% of households having access to electricity in 2016 (World Bank, 2018c).

The economy is well endowed with natural resources, including gold, copper, oil, gas, timber and agricultural products (coffee, cocoa, tea, oil palms and copra). The two main economic drivers are the export-earning sector (i.e. minerals extraction and energy) and the labour-intensive sector (i.e. agriculture, forestry and fishing). Mining and petroleum accounted for more than one-quarter of gross domestic product (GDP) in 2016 (PNG Industry News, 2018) and underpinned strong economic growth between 2010 and 2016, with GDP rising at a compound annual growth rate (CAGR) of 5.3%. Despite this growth, GDP per capita in 2016 remained the lowest among Asia-Pacific Economic Cooperation (APEC) member economies, at USD 4 074 (Table 13.1).

Table 13.1 • Papua New Guinea: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	16	24	33	39	68	116	186
Population (million)	5. 6	7. 1	8. 1	8. 8	10	12	14
GDP per capita (2016 USD PPP)	2 929	3 405	4 074	4 469	6 525	9 502	13 420
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	1.4	1.9	4.4	4.8	6.5	7.5	8.5
TPES per capita (toe)	0.26	0.27	0.55	0.55	0.62	0.62	0.62
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	88	79	135	123	96	65	46
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	1.4	1.9	2.4	2.6	3.2	4.0	5.0
FED per capita (toe)	0.26	0.27	0.30	0.30	0.31	0.33	0.36
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	88	79	73	67	47	34	27
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	1.9	2.7	9.0	10	12	14	17
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	12	20	14	20	35	50	60

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.

Sources: APERC analysis; EGEDA (2018); IEA (2018a); IPCC (2018); OECD (2018); UN DESA (2018); World Bank (2018a, 2018b).

ENERGY RESOURCES

Papua New Guinea's small oil reserves (0.20 billion barrels) (WEC, 2016) are being rapidly depleted and are expected to run completely dry in the 2020s unless new reserves are discovered (DPE, 2017). The economy imports 1.4 million tonnes of oil equivalent (Mtoe) per year for its only refinery (Napanapa refinery) and another 1.0 Mtoe of petroleum products.

At the end of 2017, the economy had proved gas reserves of 0.19 trillion cubic metres (BP, 2018). Since the first liquefied natural gas (LNG) export terminal began operating in 2014, gas exports have become an important source of export revenue. Costing USD 19 billion, the PNG LNG Project is the largest private development undertaken in Papua New Guinea (PNG LNG, 2018), but not all of the expected economic benefits materialised (ABC, 2018). Led by ExxonMobil, the project began commercial operations in 2014 with a nameplate capacity of 6.9 million tonnes per annum (Mtpa) (8.5 Mtoe) at its Caution Bay facility near the capital, Port Moresby. Gas for the project is sourced from seven fields: the Hides, Angore and Juha gas fields, and associated gas in the Oil Search-operated Kutubu, Agogo, Moran and Gobe Main oil fields, which provide approximately 20% of PNG LNG Project gas (Exxon Mobil, 2018). Over 254 billion cubic metres (228 Mtoe) of gas is to be produced over the project's lifetime.

A second LNG export project, known as Papua LNG, has been proposed as a joint venture between France's Total SA and Papua New Guinea's state-owned oil and gas company, Kumul Petroleum. In February 2018, project partners for both the PNG LNG and Papua LNG projects broadly agreed on plans to double gas exports from Papua New Guinea. The additional 8.0 Mtpa (9.9 Mtoe) of LNG exports will come from three new LNG trains: two from the Papua LNG project (with gas from the Elk-Antelope fields) and one from expansion of the PNG LNG Project (from existing PNG LNG fields and P'nyang field). A final investment decision on the project is scheduled for 2019.

Papua New Guinea has a wealth of untapped renewable energy that could be used to develop a low-carbon economy. Current installed renewables capacity falls far below the economy's potential, however. For example, less than 5.5% of economically feasible hydro has been installed (230 megawatts [MW] out of 4 200 MW), even though it is currently the most dominant renewable resource (IRENA, 2013). The government has therefore implemented a plan to raise power generation from renewable sources to 100% by 2050 (PNG, 2011).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

After nearly three decades of independence, Papua New Guinea formulated its first long-term development strategy in October 2009, known as Vision 2050 (PNG, 2011). Vision 2050, which aims to map out the next 40 years of the economy's strategies and policy directions, focuses on seven key pillars, with energy developments falling under the Environmental Sustainability and Climate Change pillar. The pillar of Wealth Creation, Natural Resources and Growth Nodes may also influence energy system development as infrastructure evolves and consumption grows. Key energy-related objectives are:

- 100% electricity generation from renewable and sustainable sources by 2050.
- Electricity access for 100% of the population, including in rural areas, by 2050.
- Greenhouse gas emissions reduced 90% from the 1990 level by 2050.

Subsequently, the Development Strategic Plan (DSP) 2010-2030 was released in March 2010 to translate Vision 2050 into specific programs and targets (DPM, 2010). Notably, the DSP established an interim target of 70%

electrification by 2030. In 2014, the National Strategy for Responsible Sustainable Development (StaRS) 2010-2030 introduced an addendum to the DSP highlighting the government's desire to reduce reliance on non-renewable resource extraction and encourage the development of environmentally sustainable industries and low-carbon technologies in pursuit of a more inclusive economic growth path (ADB, 2015). Together with Vision 2050, this new approach led to the economy's first Medium-Term Development Plan (MTDP). This and subsequent MTDPs are to be aligned with the economy's five-year political cycle (DPM, 2014).

The PNG National Energy Policy 2017-2027 (NEP) lays out energy sector development plans in unprecedented detail and signals significant reforms, particularly in the electricity sector. These include two new governing and regulatory bodies, the National Energy Authority of Papua New Guinea (NEA) and the Energy Regulatory Commission (ENERCOM). Reporting to the Minister for Petroleum and Energy, the NEA will be responsible for domestic energy provision and for developing and implementing energy policy. This includes oil exploration and development regulation, energy transport and distribution, renewables development, electricity distribution and transmission infrastructure, and energy data collection. ENERCOM will be responsible for fostering competition in domestic energy markets by setting tariffs and licensing market participants, and for setting and enforcing electrical and petroleum safety standards across the petroleum industry.

The government will support the following work of these new bodies through an energy fund:

- Energy infrastructure development.
- Energy sector environmental disaster mitigation and response.
- Hydroelectricity disaster risk mitigation.
- Energy efficiency and conservation programs.
- Promotion of renewable energy initiatives.

The government also plans significant reforms to the state-owned enterprise PNG Power Limited (PPL). The NEP was highly critical of PPL for the slow growth of the electrification rate, low quality of electricity infrastructure and high price of electricity. The NEP aims to realign PPL objectives and make it more commercially orientated with long-term plans for establishing a competitive electricity market.

Other NEP objectives for each sector are to:

- Intensify primary data acquisition for oil and gas and make it available to investors.
- Promote intensive coal exploration to provide low-cost electricity generation.
- Enhance community engagement in all aspects of the energy sector and promote local landowner participation in planning.
- Include energy-related subjects in all higher education curricula.
- Promote private investment and public-private partnerships in energy sector development and more competition in the energy supply.
- Work towards establishing minimum energy performance standards and appliance labelling for electrical equipment.
- Establish an energy research institute for research, development and demonstration.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Papua New Guinea under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 13.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 13.2 • Papua New Guinea: Key assumptions and policy drivers under the BAU

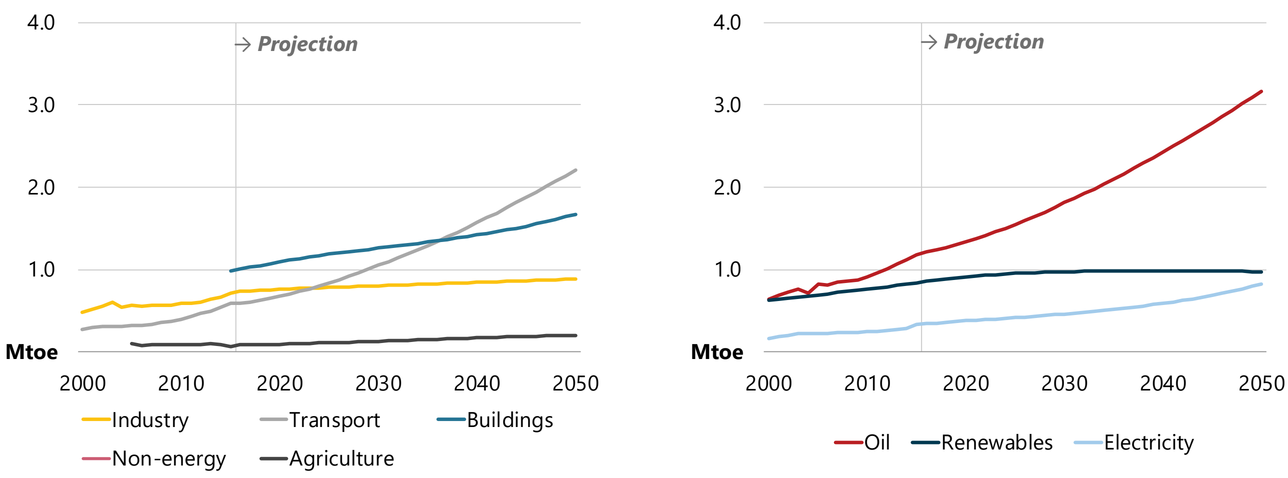
Buildings	Cooking remains the largest end-use of energy. Appliance penetration increases gradually with economic development but remains low by regional standards.
Transport	Growth of road transport energy demand remains low (below 3.0% throughout the Outlook period), consistent with the National Transport Strategy (DT, 2013).
Energy supply mix	Oil remains the main fuel in primary energy supply despite reserve depletion. LNG exports grow with the addition of the Papua LNG Project.
Power mix	Use of renewable sources, particularly hydro and geothermal, expands in response to Vision 2050.
Renewables	
Energy security	Energy security improves as renewables replace oil imports.
Climate change	The economy works towards, but does not achieve, a transition to 100% renewable energy by 2030, contingent on funding as stated in Papua New Guinea's NDC to the UNFCCC.

Notes: Outlook period = 2016-50. NDC = Nationally Determined Contributions. UNFCCC = United Nations Framework Convention on Climate Change. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies. Due to data unavailability, transport sector modelling covers road and air transport only.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Under the BAU, final energy demand (FED) in Papua New Guinea more than doubles over the Outlook period (2016-50), from 2.4 Mtoe to 5.0 Mtoe. Domestic transport energy demand overtakes that of the buildings sector, rising from a 25% share of FED in 2016 to 44% in 2050 (Figure 13.1). Demand in the industry sector increases, from 0.73 Mtoe to 0.89 Mtoe, because of rising energy consumption for mining, light manufacturing and agricultural processing. Oil demand continues to grow robustly to become by far the largest source of FED in 2050 at 3.2 Mtoe.

Figure 13.1 • Papua New Guinea: Final energy demand by sector and fuel, 2000-50

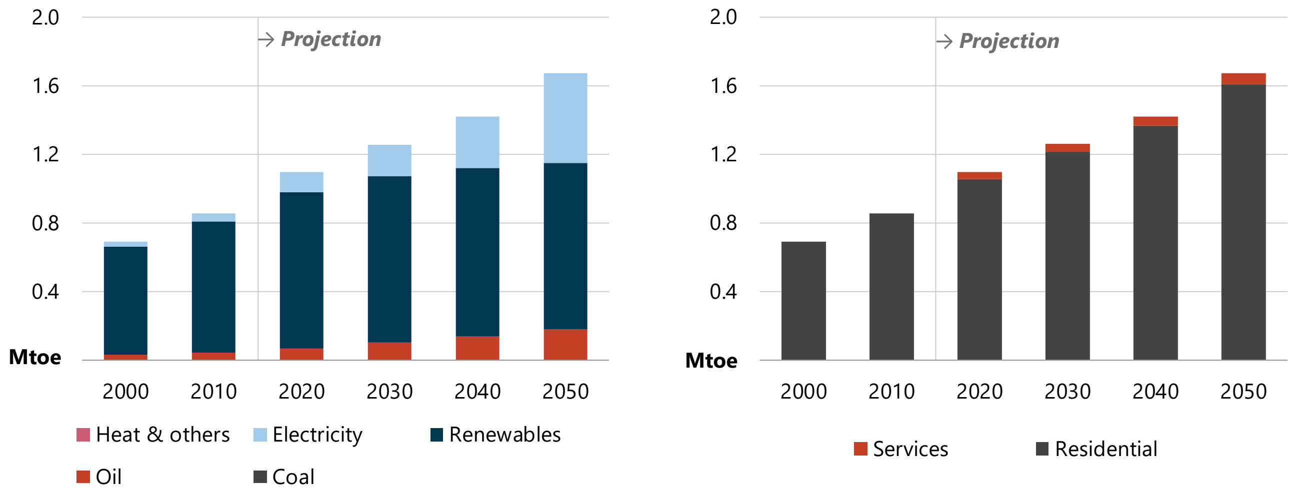


Note: No historic series is provided for buildings because of data unavailability.
Sources: APERC analysis and EGEDA (2018).

BUILDINGS: RISING DEMAND DRIVEN BY THE RESIDENTIAL SUBSECTOR

Buildings energy demand increases at a moderate CAGR of 1.5%, from 1.0 Mtoe in 2016 to 1.7 Mtoe in 2050 (Figure 13.2). Because a large portion of the population lives in rural areas, the residential subsector continues to account for over 95% of the sector's overall energy consumption through the Outlook. Renewables remain the main source of fuel demand (85%), primarily because biomass is widely used for cooking. As the economy develops, however, oil and electricity use expand, reducing the share of renewables to 58% by 2050. The share of oil almost doubles, from 5.8% (0.058 Mtoe) to 11% (0.18 Mtoe) in 2050, and electricity triples, from 9.3% of the sector's FED (0.09 Mtoe) to 31% (0.52 Mtoe) by 2050, as electrification increases under the Rural Electrification Policy and the National Electrification Rollout Plan (NEROP)[66].

Figure 13.2 • Papua New Guinea: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and EGEDA (2018).

In the residential subsector, cooking accounts for the bulk of FED: 60% in 2016, declining slightly to 54% in 2050. Biomass is the traditional cooking fuel in rural areas, while liquefied petroleum gas is more common in urban areas (APERC, 2017). Water heating is the second-largest end-use for the sector at 36% of FED. Energy demand for lighting increases gradually, from 0.008 Mtoe in 2016 to 0.067 Mtoe in 2050, as the population gains electricity access and uses less traditional lighting, such as kerosene lamps, battery-powered torches, candles and firewood. Papua New Guinea spends between USD 120 million and USD 150 million per year on off-grid lighting (IFC, 2014). A key motivation in transitioning to electricity is the cost of kerosene in rural areas, which rose 30% between 2009 and 2014, retailing at double the cost of other economies (IFC, 2014). Appliance energy use remains low (consuming only 0.082 Mtoe in 2050), especially before 2030, due to low household income and electrification. The services subsector accounts for less than 5% of total buildings FED over the Outlook period, but this projection is highly uncertain because of poor data availability.

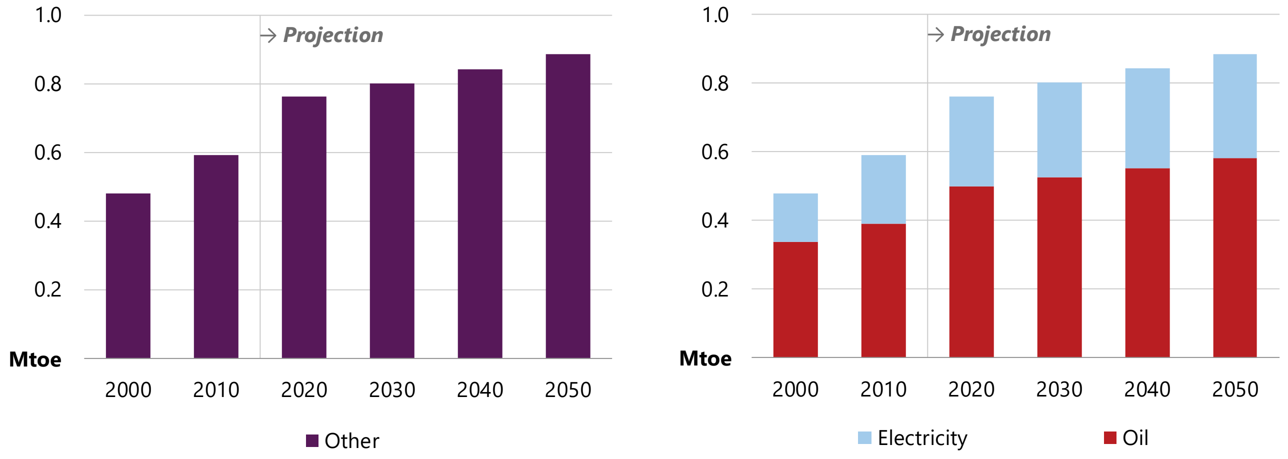
INDUSTRY: STEADY DEMAND GROWTH IS DIFFICULT TO CATEGORISE

Industry sector energy demand increases 21% over the Outlook, from 0.73 Mtoe in 2016 to 0.89 Mtoe in 2050 (Figure 13.3). The available data, however, classify all energy use under the 'other' subsector. Light manufacturing (such as food), agricultural processing industries (which enable the economy to export coffee, palm oil, cocoa, copra, tea, rubber and sugar) and mining (particularly copper and gold) account for the bulk of exports and are

[66] Further details on the NEROP are provided in the power sector trends section below.

the economy's main sources of industrial energy use. Oil and electricity remain the primary fuel sources over the Outlook period.

Figure 13.3 • Papua New Guinea: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and EGEDA (2018).

TRANSPORT: ROAD TRANSPORT CONTINUES TO DRIVE ENERGY DEMAND

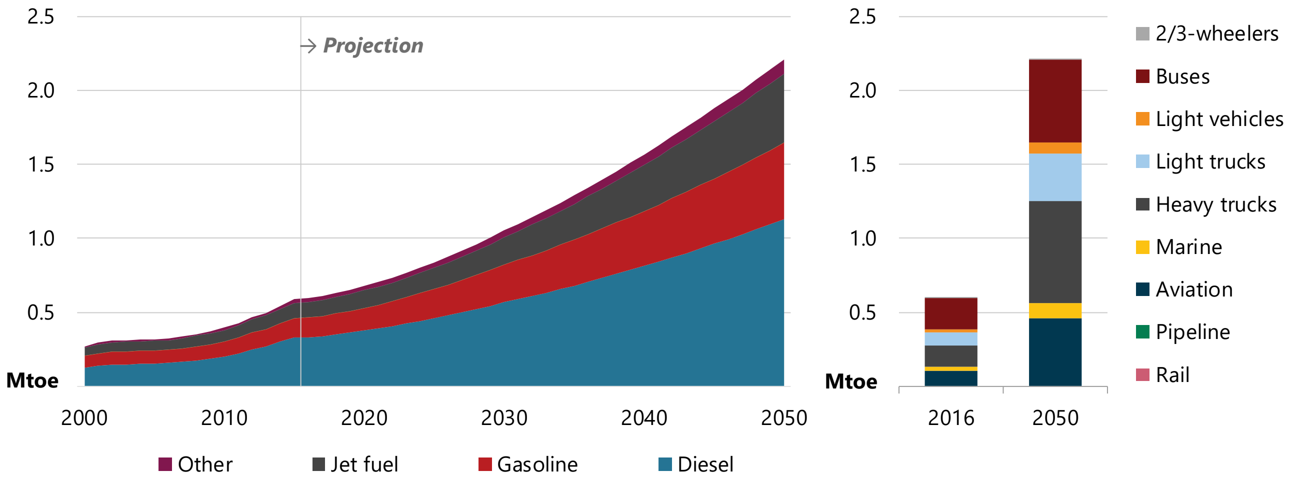
Papua New Guinea's population of 8.1 million is among the most isolated in the world. Population density is low with an average of 15 people per square kilometre (km^2). However, there is significant regional variation; compared to this average, the highest density is in the Eastern Highlands which is twice as high, and the lowest is in the western province which is less than a fifth (DT, 2013). One-third of the population lives more than 10 km from a state-owned road and 17% has no road access at all (ADB, 2011).

In 2013, the National Transport Strategy (NTS), issued by the Department of Transport, laid out development plans for transport over the next 20 to 30 years in alignment with Vision 2050 and the DSP. In assessing the success of the previous National Transport Development Plan 2006-2010, the NTS noted that 'relatively few of the policy actions were implemented' and highlighted that its actual annual expenditure of PKG 400 million (USD 120 million)[67] was insufficient to avoid deterioration of the transport network—and was far below the PKG 5.0 billion per year (USD 1.5 billion) suggested in the MTDP. The NTS places maintenance of state-owned roads as transport's highest priority (DT, 2013).

While transport comprises land, marine and air transportation, historical data are available only for land and air, so marine demand is assumed. Demand for gasoline, diesel and jet fuel increases over the Outlook period (at 3.9% CAGR) to reach 2.2 Mtoe in 2050, driven mainly by demand from heavy trucks, light vehicles, 2- and 3-wheelers and air transport modes (Figure 13.4). Road transport development has been inhibited by the daunting terrain of most inland areas, so there is much scope for infrastructure expansion.

[67] Papua New Guinea kina (PKG) are converted to USD at: PKG 3.3 per USD.

Figure 13.4 • Papua New Guinea: Domestic transport FED by fuel and mode, 2000-50



Sources: APERC analysis and EGEDA (2018).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Increasing LNG capacity in Papua New Guinea results in rising industry own-use consumption, natural gas production and exports through to 2050. In the electricity sector, all of the capacity growth comes from renewables, predominately hydro and wind, which hold a majority share by 2050. Total primary energy supply (TPES) remains fairly evenly split among oil, natural gas and renewables through the Outlook period.

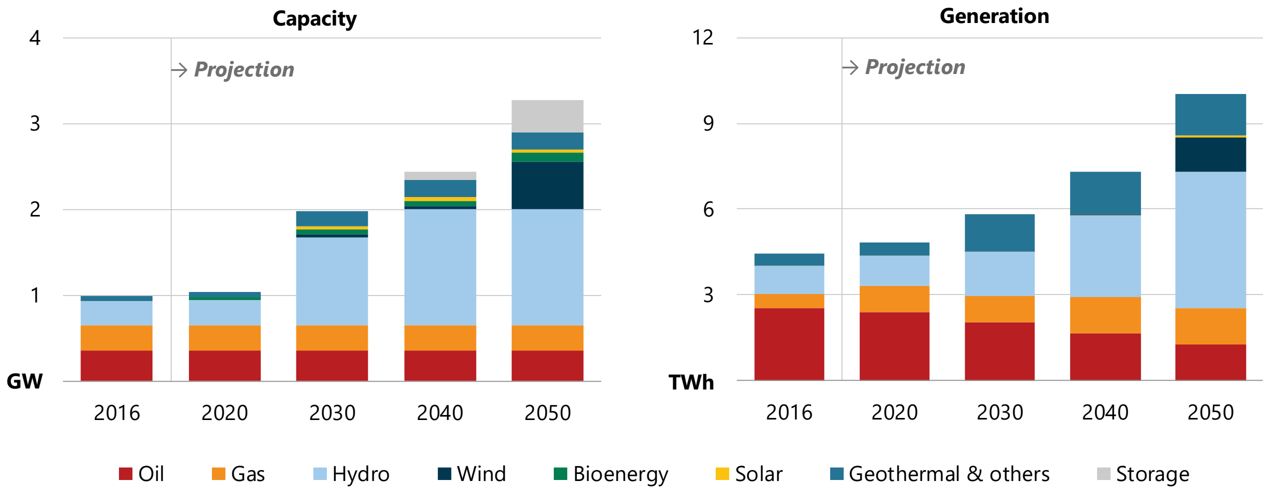
ENERGY TRANSFORMATION: OWN-USE CONSUMPTION RISES WITH LNG PRODUCTION

Energy demand for energy industry own-use has historically been minimal, with just a small amount of oil industry and refinery own-use consumption. This changed in 2014, however, with the start-up of the PNG LNG Project, which consumes 1.3 Mtoe of energy per year for extraction, processing, compression and liquefaction. This increases to 1.8 Mtoe in 2025 when the Papua LNG project is assumed to begin operations and continues rising moderately to 2.0 Mtoe by the end of the Outlook period as plant throughput is optimised.

POWER SECTOR: HYDRO DOMINATES CAPACITY ADDITIONS

Electricity generation in Papua New Guinea his historically been dominated by oil and hydro and smaller amounts of gas and geothermal. Electricity transmission and distribution infrastructure on New Guinea is islanded, with the most extensive network in the Eastern Highlands and smaller networks around other population centres like Port Moresby. In the outer islands, community generation sources tend to supply small micro grids. Oil- and gas-fired capacity remains constant from 2016 to 2050 in the BAU, despite electricity generation more than doubling to 10 terawatt-hours (TWh), as hydro, biomass and geothermal sources expand (Figure 13.5). In addition, wind and solar power come online in 2030. While the government has outlined a transition to 100% renewable generation by 2050, this is an ambitious target, given the economy's lack of detailed policies and funding and its current state of development (APERC, 2017). The BAU therefore adopts a more conservative approach, whereby oil- and gas-fired generation still accounts for 25% of power generation in 2050 rather than being completely replaced by renewables-based generation.

Figure 13.5 • Papua New Guinea: Power capacity and electricity generation by fuel, 2016-50



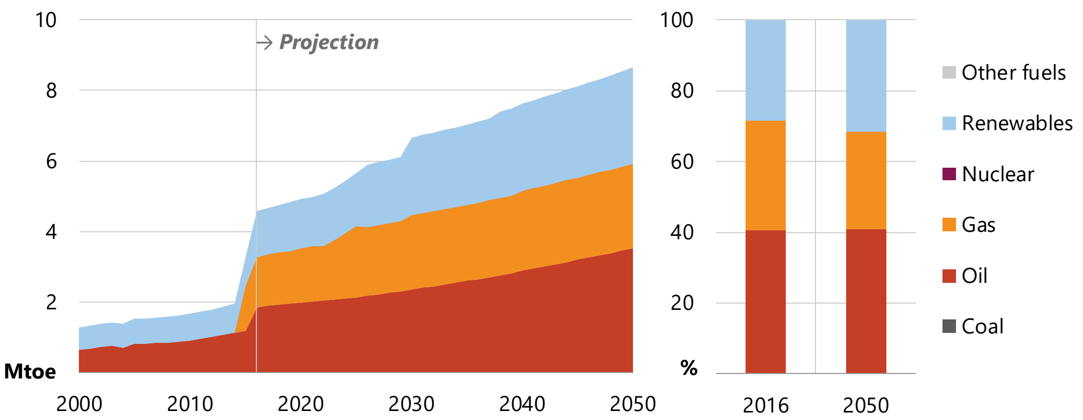
Sources: APERC analysis and EGEDA (2018).

Only 13% of the population currently has access to electricity. As the economy strives to increase electrification to 70% under the NEROP (Box 13.1), the additional power required comes from hydroelectric generation. Overall hydro capacity grows from 0.28 gigawatts (GW) to 1.4 GW over the Outlook period, and hydro generation rises from 1.0 TWh to 4.8 TWh at a CAGR of 4.7%.

TOTAL PRIMARY ENERGY SUPPLY: OIL, HYDRO AND GAS SUFFICE

In 2016, Papua New Guinea's TPES mix was fairly evenly divided among oil, at 42% (1.9 Mtoe), natural gas at 32% (1.4 Mtoe) and renewables at 29% (1.3 Mtoe) (Figure 13.6). These shares remain relatively unchanged through the Outlook period. Oil supplies 41% (3.5 Mtoe) of TPES in 2050 as strong transport demand underpins steady growth, while the share of renewables reaches 32% (2.7 Mtoe) in 2050 as hydro and geothermal electricity generation increases. The share of gas decreases marginally, to 28% (2.4 Mtoe) in 2050, despite growing in absolute terms as LNG exports increase with the expansion of the PNG LNG Project and the launch of the Papua LNG plant.

Figure 13.7 • Papua New Guinea: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and EGEDA (2018).

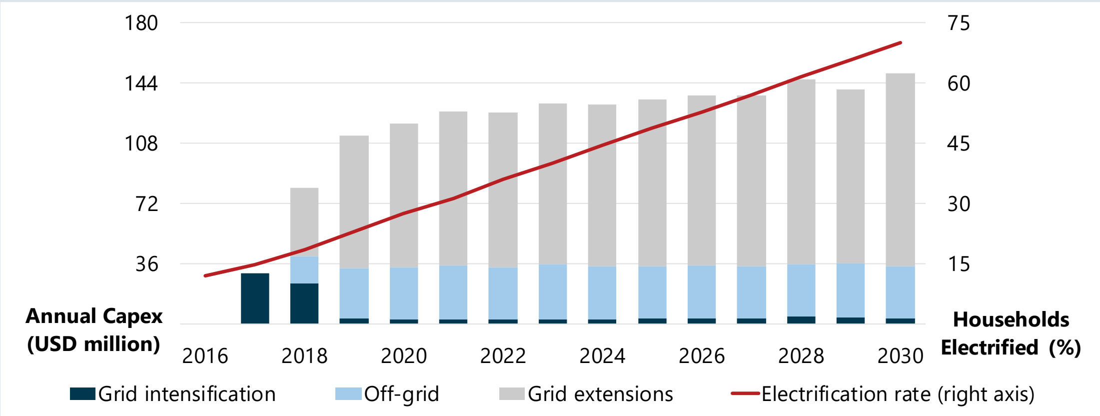
Box 13.1 • Papua New Guinea: National Electrification Rollout Plan

In 2016, the Papua New Guinea Government, with help from Columbia University in the United States, prepared the NEROP to map out plans for achieving 70% electrification by 2030 (Figure 13.6). The Department of Petroleum and Energy estimated USD 363 million (from government funds, development partner grants and concessional loans) would be required in the first five years, while the overall cost is estimated at USD 1.4 to 1.7 billion (APERC, 2017). The average per-household cost is USD 1 274.

The initial focus for the rollout is the 6% of households within 1 km of existing electricity distribution networks. Electricity supply to the remaining homes is more challenging, requiring significant grid extension in difficult terrain. An anticipated 75% of the population will have grid electricity and 25% will have off-grid access at the end of the project. Australia, Japan, New Zealand and the United States announced funding support for NEROP on the sidelines of the APEC Leaders meetings in November 2018. This will ease the pressure for funding the large capital investments required to achieve the electrification target (Freddy Mou, 2018).

Given the long wait for electricity supply for many communities, there are also programs providing off-grid solar lighting and phone charging systems to remote households and communities, which have a significant impact on productivity and education outcomes. They also reduce dependence on kerosene lanterns, battery torches and phone charging services, which come at a high cost (IFC, 2014).

Figure 13.6 • Papua New Guinea: Increasing electrification under the NEROP, 2016-30

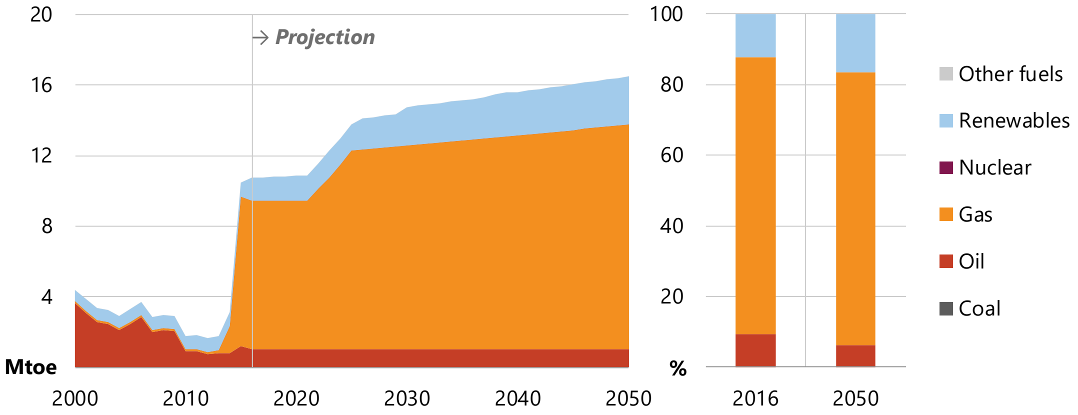


Source: World Bank (2017).

ENERGY PRODUCTION AND TRADE: LNG DRIVES GROWTH

Since the PNG LNG Project was launched in 2014, LNG exports have underpinned strong growth in primary energy production and become an important source of revenue for the economy (Figure 13.8). The plant has been operating above its nameplate capacity of 6.9 Mtpa (8.5 Mtoe), with gross LNG production reaching 8.3 Mtpa (10 Mtoe) in 2017 (Oil Search, 2018). It provides long-term LNG supply to four major customers in Asia: JERA and Osaka Gas of Japan, CPC of Chinese Taipei and Sinopec of China. With the Papua LNG export project assumed to commence operations in the next decade and the PNG LNG Project expanding, gas production continues to rise over the Outlook, from 8.4 Mtoe in 2016 to 13 Mtoe in 2050.

Figure 13.8 • Papua New Guinea: Primary energy production by fuel, 2000-50



Sources: APERC analysis and EGEDA (2018).

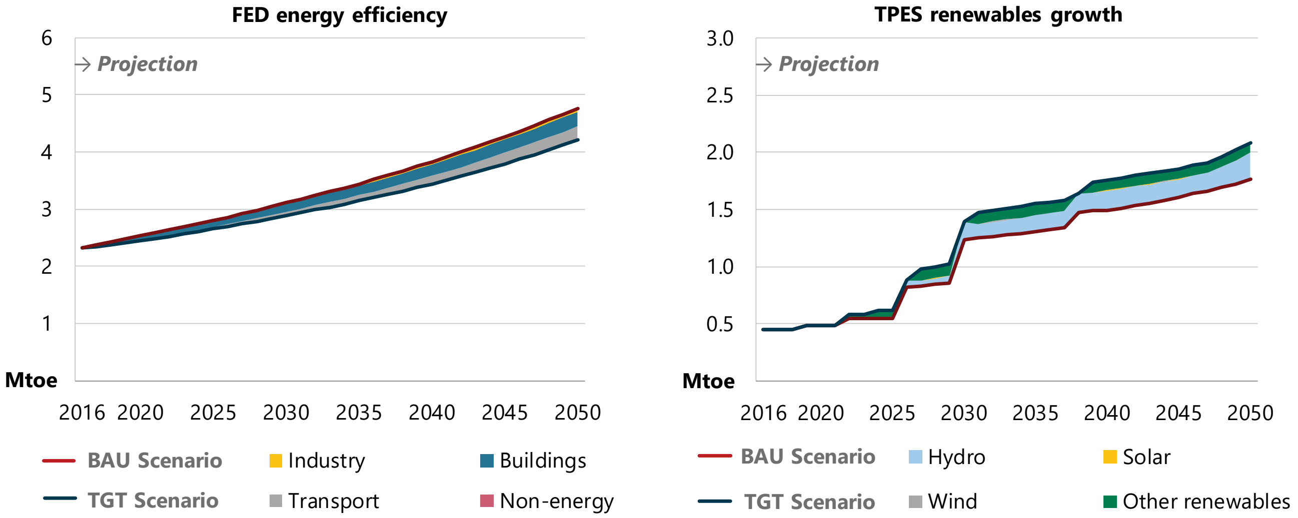
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Papua New Guinea's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increased renewables deployment, and reduced energy intensity and carbon dioxide (CO_2) emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that are sufficient, in unison with worldwide efforts, to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 11% lower while CO_2 emissions are 26% lower under the TGT. Under the 2DC, Papua New Guinea's FED is 22% lower and CO_2 emissions are 36% lower. The share of renewables in TPES by 2050 is 40% in the TGT and 33% in the 2DC, compared with 32% in the BAU.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. Assumptions required to achieve the TGT consist of several sector-level policy changes, such as stricter fuel efficiency regulations in transport and higher buildings and appliance standards. A greater share of renewables is achieved in this scenario through stronger government support that implicitly reduces deployment costs. FED grows to 4.4 Mtoe in 2050 in the TGT, compared with 5.0 Mtoe in the BAU (Figure 13.9).

Figure 13.9 • Papua New Guinea: Energy efficiency and renewables growth, TGT vs. BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewable growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and EGEDA (2018).

Actions taken in the TGT result in 15% lower buildings (0.26 Mtoe) and 11% lower transport (0.24 Mtoe) demand compared with the BAU. In buildings, most of the reduction is in water heating demand, with higher adoption of more efficient biomass water heating technologies and some switching to electricity. In transport, the main drivers are lower demand for air travel and a slightly more efficient passenger fleet.

Under the TGT, total supply of renewables is 2.7 Mtoe in 2050, a marginal 0.01 Mtoe (0.36%) increase from the BAU. The power sector is solely responsible for this increase. As electricity gradually displaces use of traditional biomass, overall use of renewables in buildings drops from 0.98 Mtoe to 0.77 Mtoe. All oil-fuelled (2.5 TWh) and gas-fired (0.51 TWh) power generation is completely replaced by renewables-based generation by 2050, raising the share of renewables to 98% by 2050, compared with 75% under the BAU. The renewables mix comprises hydro, wind, solar, biomass and geothermal sources. The TGT assumptions therefore practically achieve the Vision 2050 goal of being fully powered by renewables in 2050.

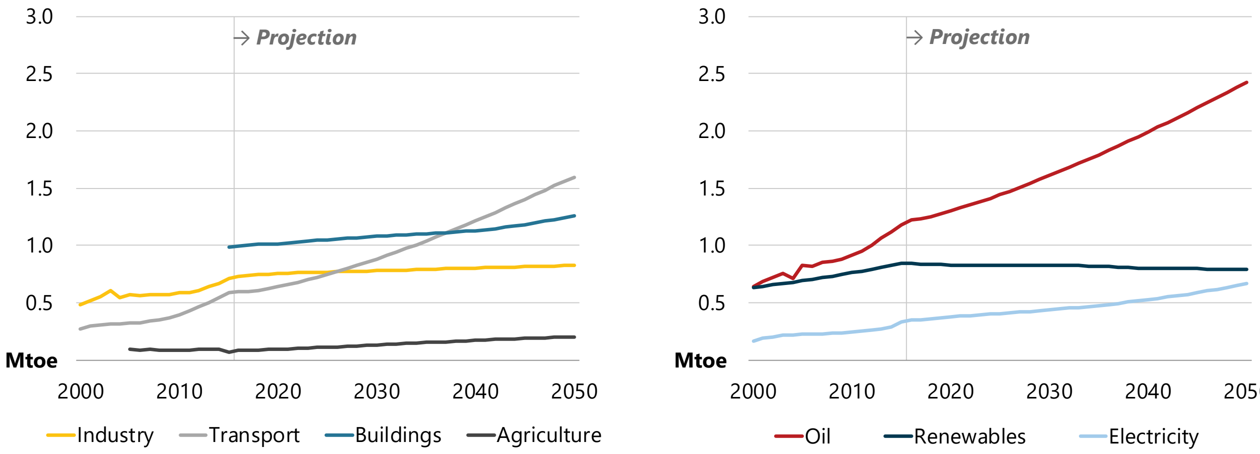
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Papua New Guinea will have to undergo greater decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

FED grows to 3.9 Mtoe by 2050 in the 2DC, from 2.4 Mtoe in 2016. Despite this strong growth, energy demand in the 2DC is 22% lower than in the BAU and 12% below the TGT level, mainly due to weaker demand growth in transport (1.6 Mtoe in the 2DC, compared with 2.2 Mtoe in the BAU) (Figure 13.10). The deployment of more fuel-efficient and smaller vehicles, as well as improved public transport, curtails energy use in this sector over the Outlook period.

Figure 13.10 • Papua New Guinea: Final energy demand in the 2DC by sector and fuel, 2000-50



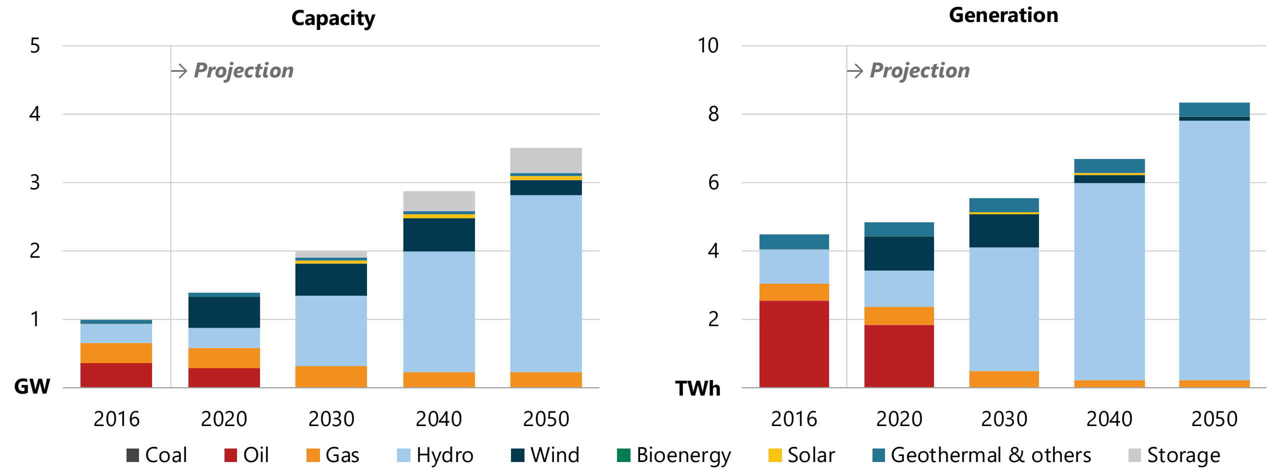
Sources: APERC analysis and EGEDA (2018).

Under the 2DC, buildings FED increases 27% (0.27 Mtoe) between 2016 and 2050, with the 2050 total being a 25% (0.41 Mtoe) decrease against the BAU. The difference between the scenarios results from greater electrification in the 2DC displacing use of biomass. However, biomass remains a dominant fuel in the 2DC, accounting for 60% of buildings FED. Industry demand grows moderately less in the 2DC (to 0.83 Mtoe in 2050, compared with 0.89 Mtoe in the BAU) due to slightly increased efficiency assumptions.

TRANSFORMATION AND SUPPLY IN THE 2DC

In the power sector, electricity generation increases from 4.5 TWh in 2016 to 8.3 TWh in 2050 under the 2DC—1.7 TWh less than in the BAU, owing to lower demand (Figure 13.11). The 100% renewable generation goal is not attained by 2030 in the 2DC. However, renewables (primarily hydro and geothermal) are the dominant fuel sources for power generation with a 90% share by 2030. Overall, hydro capacity increases most strongly, from 0.28 GW in 2016 to 2.6 GW in 2050, and hydro accounts for 74% of total power generation capacity in 2050. Oil-fired generation is completely phased out by 2027. Existing gas turbine generation is phased out by 2029 but new combined-cycle gas turbines constructed in the 2020s remain in operation.

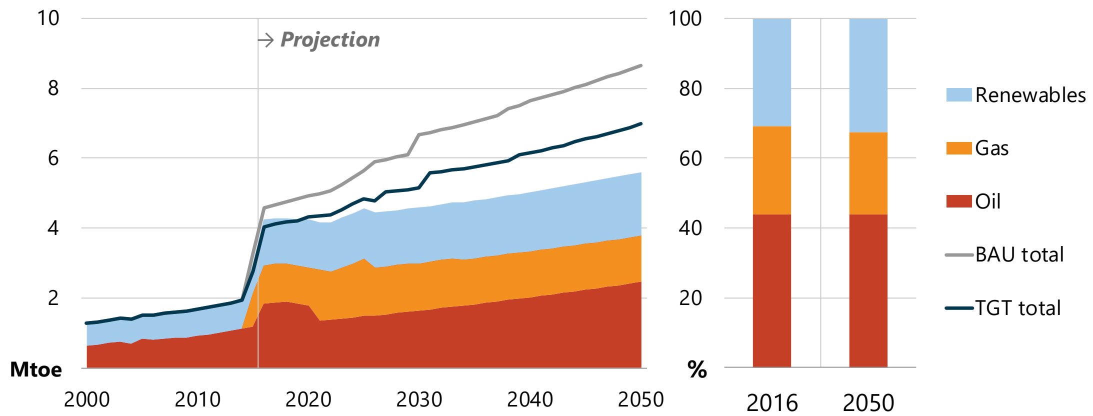
Figure 13.11 • Papua New Guinea: Power capacity and generation in the 2DC by fuel, 2016-50



Sources: APERC analysis and EGEDA (2018).

TPES under the 2DC is 1.4 Mtoe lower than the TGT in 2050, because of less supply from both oil (-0.46 Mtoe) and renewables (-0.92 Mtoe) (Figure 13.12).The primary difference in renewables supply comes from geothermal which is reduced by 1.0 Mtoe due to lower electricity demand in the 2DC. Fossil fuels continue to dominate TPES at 68% in 2050, mainly due to oil use in transport and gas use at LNG plants and production facilities; renewables account for the remaining share.

Figure 13.12 • Papua New Guinea: Total primary energy supply in the BAU, TGT and 2DC, 2000-50



Sources: APERC analysis and EGEDA (2018).

Production and trade remain dominated by natural gas in the 2DC, as in the BAU, despite lower global demand for LNG (which results in exports falling by 0.31 Mtoe compared with the BAU in 2050). Reduced demand in the 2DC in the transport sector results in less imports of oil products compared with the BAU, but crude imports are constant across scenarios as refinery capacity not able to meet domestic demand.

SCENARIO IMPLICATIONS

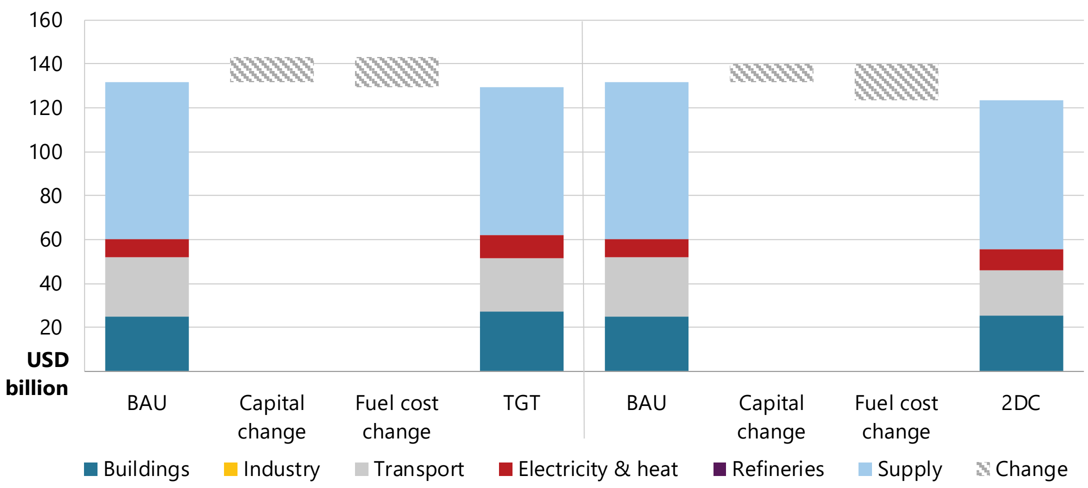
ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2015 technology mix is held constant and only additional energy investments are included in the projections.[68]

Total investment requirements over the Outlook period amount to USD 132 billion in the BAU Scenario (Figure 13.13). More than half (USD 72 billion) is earmarked for the supply sector for highly capital-intensive LNG export projects (both expansion at PNG LNG and the proposed Papua LNG). Other significant investment goes to the electricity sector to build new power plants to meet growing demand (USD 7.9 billion), and to buildings to increase electricity access and curb use of traditional biomass (USD 25 billion).

[68] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 13.13 • Papua New Guinea: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and EGEDA (2018).

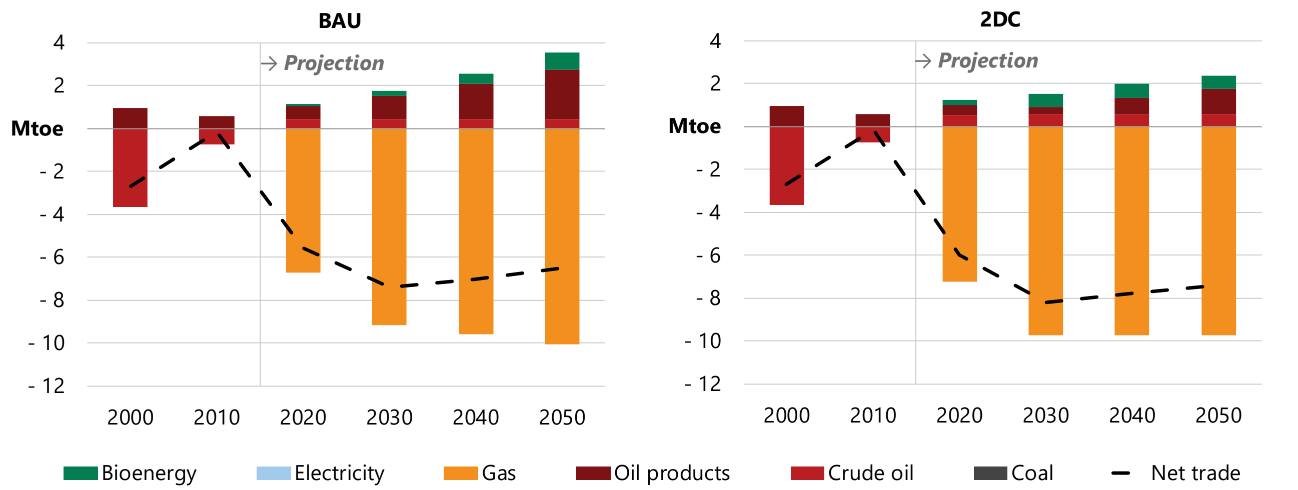
Capital investment in the TGT is USD 12 billion higher than in the BAU, but this extra cost is more than offset by the USD 14 billion worth of fuel saved with lower energy demand. The additional capital investment in this scenario is to cover higher expenditures in the electricity sector (USD 2.3 billion), mainly to increase electrification and renewable generation, and for buildings (USD 5.8 billion), which are more energy efficient over the Outlook period. More than half of the fuel cost savings occurs in the supply sector due to higher renewables penetration reducing fossil fuel use.

Although investment under the 2DC is USD 8.3 billion higher than in the BAU, fuel savings of USD 17 billion offset the extra capital cost. The behavioural changes assumed under the 2DC, such as decreased passenger- and tonne-kilometres in transport, and lower floor area requirements in service buildings, see capital expenditures in these sectors rise less and fuel demand drop more than under the TGT. Capital investment in the electricity sector under the 2DC is 1.6 billion higher than in the BAU because of higher spending on new renewable energy capacity.

ENERGY TRADE AND SECURITY

Although Papua New Guinea has historically been a net crude oil exporter, in 2012, dwindling reserves caused imports to exceed exports for the first time (Figure 13.14). To maintain refinery production, the economy began importing crude oil, mainly from the Middle East. Because of the start-up of the PNG LNG Project in 2014, gas exports grew rapidly to 6.9 Mtoe in 2016, with 0.99 Mtoe of associated condensate production. Papua New Guinea is therefore currently both a crude oil and condensate exporter and importer. Oil imports are projected to grow to 2.4 Mtoe by 2050 in the BAU as energy demand from transport increases. With the new Papua LNG plant projected to be built in the 2020s, gas production grows to 10 Mtoe in 2050 under all scenarios. The economy remains a crude oil importer (1.4 Mtoe per year) as growing domestic oil demand is met by imports rather than by domestically produced oil products.

Figure 13.14 • Papua New Guinea: Net energy imports and exports in the BAU and 2DC, 2000-50



Note: Crude oil includes condensate.
Sources: APERC analysis and EGEDA (2018).

Papua New Guinea is increasingly dependent on imported crude from the Middle East for its one refinery. In the BAU, oil remains an important part of the electricity supply sector and dependence increases in transport over the Outlook period. Crude oil self-sufficiency shrinks from 100% in 2015 to 27% in 2050 in the BAU. Security is improved in the TGT and the 2DC by the rapid growth of renewable electricity, and further in the 2DC by reduced dependence on oil from improved transport fleet fuel efficiency and greater use of public transport (Table 13.3).

Table 13.3 • Papua New Guinea: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	84	82	78	85	72	73	73
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Crude oil self-sufficiency (%)	70	70	61	61	70	67	61
Primary energy supply diversity (HHI)	0.29	0.33	0.32	0.31	0.32	0.32	0.31
Gas reserve gap (%)	4.4	76	76	75	202	202	193
Crude oil reserve gap (%)	5.1	64	56	56	148	132	129

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and EGEDA (2018).

SUSTAINABLE ENERGY PATHWAY

Papua New Guinea's aspirational Nationally Determined Contribution (NDC)[69] under the COP21 Paris Agreement is to transition the economy to 100% renewable electricity supply by 2030, contingent on funding being made available. The government also intends to improve energy efficiency in all sectors and reduce emissions in the forestry and transport sectors.

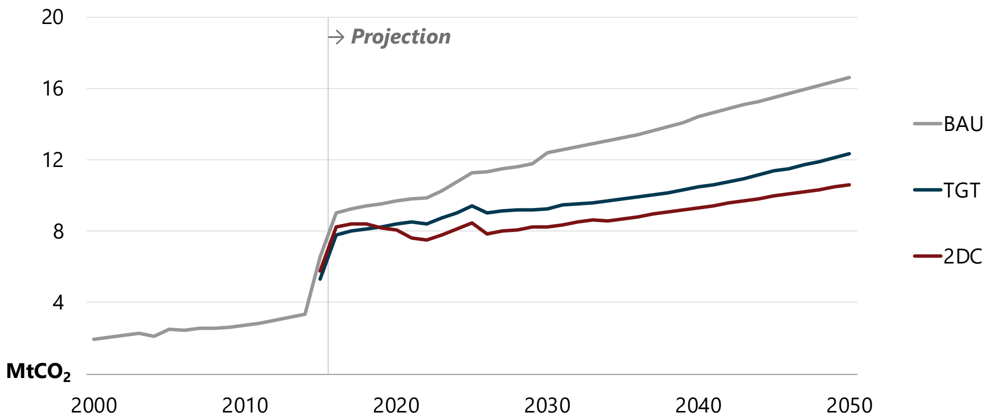
The economy's CO_2 emissions were among the lowest in APEC at 9.0 million tonnes of CO_2 ($MtCO_2$) in 2016, but compared with 3.4 $MtCO_2$ in 2014, growth is rapid (Figure 13.15). This jump came with the start-up of the

[69] The Nationally Determined Contributions (NDCs) reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement'.

PNG LNG Project, which caused CO_2 emissions to more than double by 2016. Emissions grow steadily from 2016 to 2050 in the BAU, with a bump around 2025 when the Papua LNG plant ramps up production, reaching 17 $MtCO_2$ by the end of the Outlook period. Greater CO_2 emissions due to growth in transport (6.6 $MtCO_2$ in 2050, from 1.8 $MtCO_2$ in 2016) are the main cause of rising emissions in the second half of the Outlook.

The NDC target of 100% renewable energy by 2030 is not achieved in any of the Outlook scenarios. However, under the TGT, CO_2 emissions are lower than in the BAU from 2025 onwards owing to power sector decarbonisation, which results in emissions of 11 $MtCO_2$ in 2050—6.0 $MtCO_2$ lower than in the BAU. In the 2DC, there is little potential for CO_2 emissions reduction beyond the TGT level because the power sector has almost entirely decarbonised and other end-use sectoral emissions are already low. Additional reductions are achieved mainly in the transport sector (1.9 $MtCO_2$ lower in 2050 compared with the BAU) through improved vehicle efficiency and greater use of public transport.

Figure 13.15 • Papua New Guinea: CO_2 pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and EGEDA (2018).

OPPORTUNITIES FOR POLICY ACTION

In 2010, 53% of Papua New Guinea's population lived below the economy's poverty line, and electricity access was at 13% in 2017 (PNG, 2011; DPE, 2017). The economy's vast untapped renewable resources and large gas reserves offer a means to improve living standards and boost economic growth. However, developing renewable energy is challenging because of Papua New Guinea's cultural diversity, land tenure system, rugged terrain and largely rural population.

Although gas exports became a mainstay of the economy in 2014 and are projected to continue growing, domestic use of gas is currently very limited. Papua New Guinea should invest in expanding gas use for domestic purposes, particularly in Port Moresby, to reduce its carbon footprint and reliance on imported oil.

The government's targets to achieve 100% renewables-based power generation and 100% electrification by 2050 are ambitious—perhaps overly so, as Papua New Guinea's current economic conditions and policy implementation progress indicate that these objectives may not be obtainable under the BAU. Furthermore, the needs of rural communities, where over 85% of the population live, are multiple and pressing (e.g. sanitation, roads, health issues, education, economic development), so expanding electricity access may not be a local priority (APERC, 2017). This misalignment with government objectives may therefore impede development.

However, electricity access is critical to addressing many of these issues, and efforts put into community engagement and communicating the benefits of electricity access may reduce resistance. Developing best practice through engaging with experts and utilising knowledge from other APEC economies, such as information gained from the Bitung (in neighbouring Indonesia) rural electrification development studied in a low-carbon model town project (APERC, 2016), may help foster better engagement. With the publication of the NEP, there should be a focus on establishing high-quality new organisations and instituting necessary reforms in existing organisations. Building human capital within these organisations is critical, given the considerable barriers and the massive growth needed to achieve electrification targets.

On the demand side, in all three scenarios, the transport sector offers the greatest potential for cutting energy consumption and CO_2 emissions. Papua New Guinea does not have a proper public transportation system in place (e.g. buses or rail); as it develops, more transport infrastructure will be needed to support the growing economy. Increased funding and government efforts to expand and restore road networks would be recouped through economic benefits.

14. PERU

KEY FINDINGS

- **Peru's FED grows 59% in the BAU Scenario, from 18 Mtoe in 2016 to 29 Mtoe in 2050.** Transport energy demand almost doubles, with road transport alone accounting for 50% of FED in 2050.

- **TPES increases 65% from 2016 to 2050, with growth in all fuel shares except coal.** Fossil fuels still account for 84% of TPES by 2050 under the BAU Scenario and gas surpasses oil as the dominant share in the fuel mix. Non-hydro renewables only represent 3.7% of TPES by 2050.

- **Energy production remains at the same overall level along the Outlook in all three scenarios.** Renewable energy production increases by 25% in the BAU, offsetting a similar fall in natural gas production.

- **Peru becomes a net natural gas importer around 2039 in the BAU** as demand rises rapidly and domestic natural gas production declines with the depletion of the Camisea field.

- **In the BAU, electricity generation grows 69% over the Outlook period due to rapid economic growth, while electricity capacity increases by 48%.** Peru's generation mix remains dominated by hydro power and gas-fired generation, with wind and solar power together accounting for 6.7%.

- **Peru's energy-related CO_2 emissions grow 66% over the Outlook period in the BAU,** from 54 $MtCO_2$ in 2016 to 90 $MtCO_2$ in 2050. Peru's energy-related emissions fails to meet both its conditional and unconditional NDC in the BAU and TGT scenarios but meets its NDC in the 2DC.

ECONOMY AND ENERGY OVERVIEW

Peru is a constitutional republic on the central west coast of South America, bordered by the Pacific Ocean to the west, Chile to the south, Ecuador and Colombia to the north and Brazil and Bolivia to the east. Its land area of 1.3 million square kilometres (km^2) comprises three main geographical regions: the western coastal region, the mountainous central highland region (Andes Mountains) and the jungle region of the Amazon Basin in the east. These regions are divided into 25 political/administrative regions.

In 2016, Peru had a total population of 32 million, an increase of 1.3% from the previous year (Table 14.1). Income inequality remains a challenge, as Peru had a Gini coefficient of 44[70] in 2016 (World Bank, 2018b). In 2015, approximately 20% of the population was considered poor and 3.8% extremely poor (INEI, 2017). Lima, the capital and main population centre, has about nine million people, or nearly one-third of the total population (INEI, 2015). The urbanisation rate was 78% in 2017 (INEI, 2018).

Table 14.1 • Peru: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	181	312	410	476	681	913	1 188
Population (million)	26	29	32	33	37	40	42
GDP per capita (2016 USD PPP)	7 003	10 623	12 891	14 304	18 496	23 062	28 550
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	12	20	24	27	30	34	40
TPES per capita (toe)	0.48	0.67	0.76	0.80	0.83	0.87	1.0
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	69	63	59	56	45	38	34
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	11	15	18	20	23	26	29
FED per capita (toe)	0.41	0.51	0.58	0.59	0.62	0.65	0.70
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	59	48	45	41	33	28	25
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	26	41	54	59	67	77	90
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	72	88	95	97	99	99	99

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

Between 2000 and 2016, the economy expanded rapidly at a compound annual growth rate (CAGR) of 5.2%. This rate dropped to 4.6% from 2010 to 2016 due to decelerating demand growth in other emerging economies (such as China) and global uncertainty. This resulted in negative growth of investments, both private (–5.7%) and public (–6.2%) in 2016 (BCRP, 2017). In 2016, Peru's gross domestic product (GDP) was USD 410 billion and GDP per capita was USD 12 891.

Structural reforms began in 1990 and led to the establishment of a market-oriented economy. In 2016, key sectoral contributors to GDP were services (49%), mining and energy (14%), manufacturing (13%) and trade

[70] The Gini index measures the extent to which the distribution of income among individuals or households within an economy deviates from a perfectly equal distribution; 0 represents perfect equality while 100 implies perfect inequality. Peru's Gini index is similar to that of Chile, Mexico, Turkey and Zimbabwe.

(11%) (BCRP, 2019). Mining is especially important because the economy is a major global producer of several metallic and non-metallic minerals, ranking third in silver, zinc, copper and tin; fourth in lead; and sixth in gold production (USGS, 2018). Consequently, minerals have consistently accounted for a significant share of export revenues, contributing 59% in 2016 (BCRP, 2019). During 2016, around 22% of Peru's USD 25 billion of foreign direct investment was dedicated to the mining sector and about 13% to the energy sector (Proinversion, 2016).

ENERGY RESOURCES

Peru has considerable natural gas reserves: 0.44 trillion cubic metres in 2016, the ninth-largest in the Asia-Pacific Economic Cooperation (APEC) region (Table 14.2). In 2004, the development of the Camisea gas field and associated 730 km pipeline to Lima drastically changed the Peruvian energy sector. This has allowed Peru to meet growing domestic demand and become a net natural gas exporter. All natural gas exports are sent as liquefied natural gas (LNG) through the Peru LNG Melchorita export terminal (4.4 million tonnes per annum), one of only two LNG export terminals on the Pacific coastline of the Americas (the other is Alaska's Kenai LNG terminal). In 2016, 41% of total natural gas production was exported via LNG.

Table 14.2 • Peru: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Oil (billion bbl) [a]	1.2	26	0.07	39	10
Natural gas (tcm) [a]	0.44	34	0.23	31	9.0
Uranium (tU) [b]	14 000	0.00	0.36	17	6.0

Notes: a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kilogram of uranium.
Sources: For oil and natural gas, BP (2018). For uranium, NEA (2018).

Peru has limited proved oil—1.2 billion barrels—and negligible coal reserves. There is no nuclear power generation in Peru or any concrete nuclear development plans, despite reserves of 14 000 tonnes of uranium. Renewable resources are abundant at 110 gigawatts (GW) of potential generation capacity, mostly for hydro power (70 GW) (Osinergmin, 2017a). There is also 22 GW of wind power potential, mostly in the coastal region, and another 10 GW of solar, 7 GW of biomass and 3 GW of geothermal. Despite this potential, the actual installed capacity of all non-hydro technologies combined was only 0.77 GW in 2016.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

As Peru's energy demand continues to increase with economic and demographic growth, the government faces the challenge of building sufficient infrastructure to provide secure and affordable energy access to all consumers. The Ministry of Energy and Mines (MEM) published its National Energy Plan 2014-2025 as the guiding policy document for the energy sector. However, it has not been updated or reissued since 2014. The economy's overarching energy policies and goals have not changed significantly since the last edition of this Outlook, highlighting the lack of a long-term and specific energy plan. Some of the Energy Plan's goals are to increase the share of natural gas to 35% of total primary energy supply (TPES) by 2025, expand access to natural gas networks, and raise the electrification rate to 99% by the same year (MEM, 2014).

The Energy Plan establishes that renewable resources (excluding large hydro power) should be used for at least 5% of total power generation; once this is achieved, the renewable generation goal should be revised every two years. The Energy Plan has no specific goals or timeline for energy efficiency, but it estimates energy demand reductions of 10% to 15% by 2025 as a result of energy efficiency measures enacted under an alternative scenario (i.e. alternative to business-as-usual operations) (MEM, 2014). Similarly, the Energy Plan does not quantify any fossil fuel subsidy goals but states that energy prices should 'reflect real costs' (MEM, 2014). It does not mention nuclear energy.

One of the Energy Plan's key aims is to promote investments to expand infrastructure for oil and natural gas exploration and production, electricity and natural gas transmission, and refining capacity. While there has been some progress with the Talara refinery being overhauled to process heavy oil and increase capacity by 2022, the same cannot be said for the expansion of Peru's natural gas pipeline network.

In 2015, the MEM awarded a construction contract for the 1 000 km, 32 inch Peruvian Southern Gas Pipeline (*Gasoducto Sur Peruano*), one of the largest infrastructure projects in the economy's history (El Peruano, 2014). Construction started in 2016, but in January 2017, with 40% of construction complete, the government terminated the contract after the consortium failed to meet its financial deadline (El Peruano, 2017). This occurred amid a corruption scandal with the main contractor, Brazilian company Odebrecht, which is currently involved in similar accusation across Latin America (El Peruano, 2017; El Pais, 2017). As of March 2019, construction has not resumed, leaving this key energy sector project in limbo.

Although Peru aims to become an energy hub by developing integration projects with Ecuador, Colombia and Chile in electricity, Brazil in hydro power and Bolivia in gas, no concrete projects have materialised to realise this vision.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Peru under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 14.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 14.3 • Peru: Key assumptions and policy drivers under the BAU

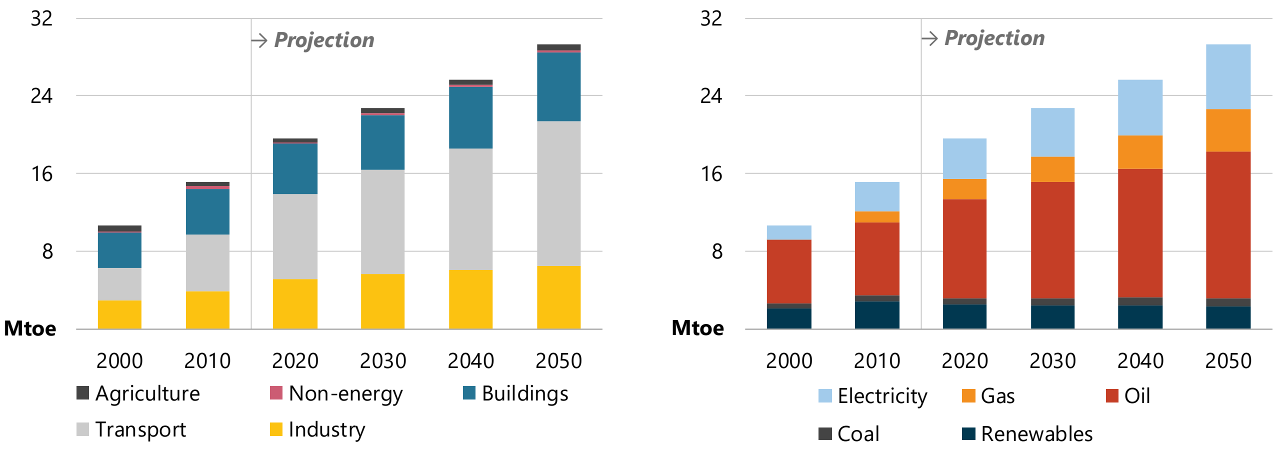
Buildings	Use of assumptions in the Reference Plan on Energy Efficiency issued by the MEM in 2008 and in Osinergmin's[71] 2015 Poll on Residential Energy Use.
Industry	Use of assumptions in the Reference Plan on Energy Efficiency.
Transport	Limited deployment of hybrid, CNG and EVs. Biofuel blending maintained at current levels of 5% for bioethanol and 2% for biodiesel. No vehicle fuel efficiency standards.
Energy supply mix	Major natural gas discoveries identified according to the National Energy Plan 2014-2025.
Power mix	Least-cost options for power generation. Committed renewables projects considered. No policy to develop nuclear energy.
Renewables	Reach 5% share (excluding large-hydro) by 2023.
Energy security	Law to ensure energy security and promote the development of the petrochemical industry.
Climate change	Work towards, but not achieve, the NDC commitment to reduce GHG emissions to 20% below the 2010 level by 2030 or 30% below if international financing is available.

Notes: CNG = compressed natural gas. EVs = electric vehicles. GHG = greenhouse gas. NDC = Nationally Determined Contributions. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Peru's final energy demand (FED) grew 73% in 2000-16, owing to steady economic (5.2% CAGR) and population (1.3% CAGR) growth over that time period. Under the BAU Scenario, energy demand continues to grow by 59% over the Outlook period (2016-50), from 18 Mtoe to 29 Mtoe, which is still robust but not as strong as historical energy demand growth (Figure 14.1).

Figure 14.1 • Peru: Final energy demand by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

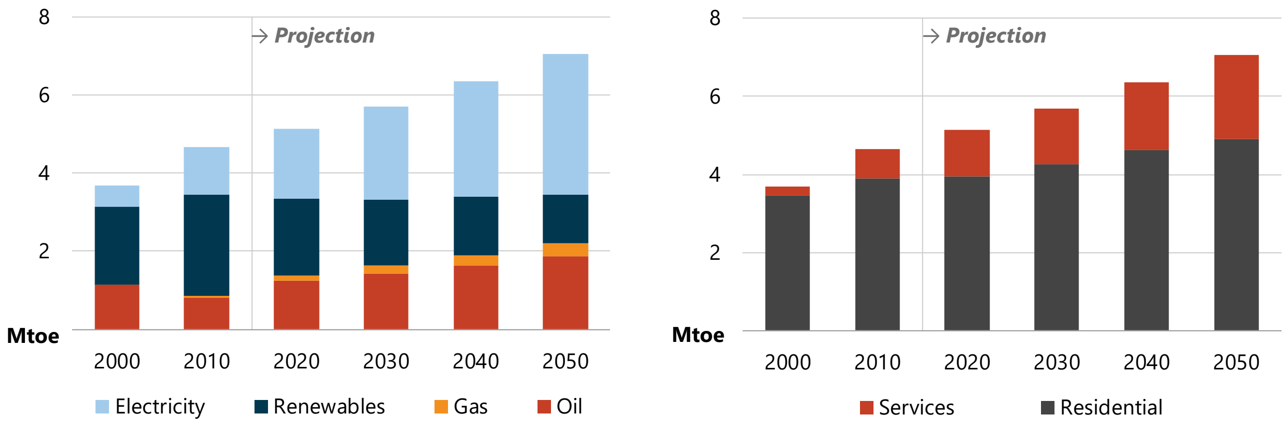
Transport energy demand, currently the largest end-use sector, remains dominant, as it almost doubles to 15 Mtoe by 2050, or 51% of Peru's FED. Industry and buildings energy demand was similar over the past decade; however, buildings grow 46% by 2050, while industry increases by 32%. Despite the agriculture sector having a modest share of FED, demand grows 32% by 2050. While energy demand for non-energy uses increases by 40%, it remains below 0.30 Mtoe.

[71] Osinergmin stands for Supervisory Body of Private Investment in Energy and Mines and is the main regulatory body for oil and gas, electricity and mining industries in Peru. In Spanish: *Organismo Supervisor de la Inversión en Energía y Minería*

BUILDINGS: BETTER LIVING CONDITIONS RAISE ENERGY DEMAND

Energy demand in Peru's buildings sector has grown 31% since 2000, mainly driven by a wider segment of the population having access to better living conditions. This is most evident in increased electricity demand, which has more than doubled since 2000 (Figure 14.2). The residential subsector accounted for 79% (3.8 Mtoe) of energy demand in 2016; the services subsector consumed the remainder. Under the BAU, buildings energy demand grows 46%, from 4.8 Mtoe in 2016 to 7.1 Mtoe in 2050.

Figure 14.2 • Peru: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Although Peru has significant natural gas reserves and a variety of renewable resources, the buildings energy fuel mix was still dominated by traditional biomass in 2016 (42%). Traditional biomass accounts for 98% of renewable energy demand in buildings (with over 90% in residential), reflecting the economy's significant income disparities (MEM, 2016). Non-commercialised fuelwood is the predominant source of traditional biomass, but charcoal and manure are also used. While traditional biomass consumption has decreased 21% since 2010, it remains the main source of energy for about 20% of households (Osinergmin, 2017b).

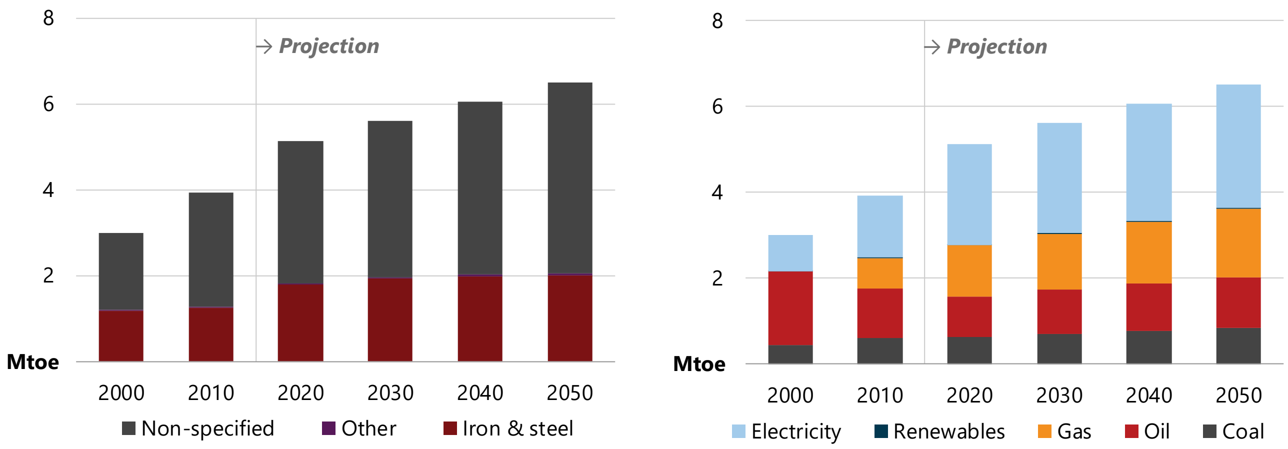
Under the BAU, traditional biomass use in both residential and services falls 44%, from 2.0 Mtoe in 2016 to 1.1 Mtoe in 2050. In contrast, electricity demand more than doubles, reaching 3.6 Mtoe and becoming the primary fuel in buildings by 2023. Similarly, oil use, mostly as liquefied petroleum gas (LPG), increases 64% over the Outlook period, with 72% of demand concentrated in the residential subsector. Natural gas is the fastest growing fuel but accounts for only 4.7% of total buildings demand in 2050, mostly concentrated in residential buildings.

These trends mainly result from economic growth and improved living conditions in the residential subsector, and increased energy access for suburban and rural inhabitants. Electricity, LPG and, to a lesser extent, natural gas and modern renewables replace traditional biomass for cooking, water heating and space heating during the Outlook period. This transition to phase out traditional biomass could be accelerated by government policy, such as continuing the *Cocina Peru* program, which provided LPG stoves to low-income households that used traditional biomass as their main fuel. In services (i.e. in urban areas), electricity, LPG and natural gas demand rise as activity increases with economic development during the Outlook period.

INDUSTRY: ENERGY DEMAND GROWTH DECELERATES AND THE FUEL MIX DIVERSIFIES

Energy demand in Peru's industry sector grew steadily in 2000-16 (64%) but grows more slowly from 2016 to 2050 under the BAU, rising 32% from 4.9 Mtoe to 6.5 Mtoe (Figure 14.3). Industry energy demand is mainly driven by the manufacturing, iron and steel, and mining subsectors.

Figure 14.3 • Peru: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Unfortunately, the poor quality of available data made it impossible to disaggregate mining and manufacturing from several other sectors, which are therefore grouped together as 'non-specified' in this Outlook. According to International Energy Agency (IEA) definitions, this category is meant to include only the rubber and plastic products, furniture and other manufacturing industries. Instead, it appears to be acting as a catch-all for energy use that cannot be disaggregated by subsector. This lack of disaggregation creates a significantly higher degree of uncertainty around these projections and represents an area of opportunity for Peru to expand data collection and enhance data quality to allow for more robust analysis.

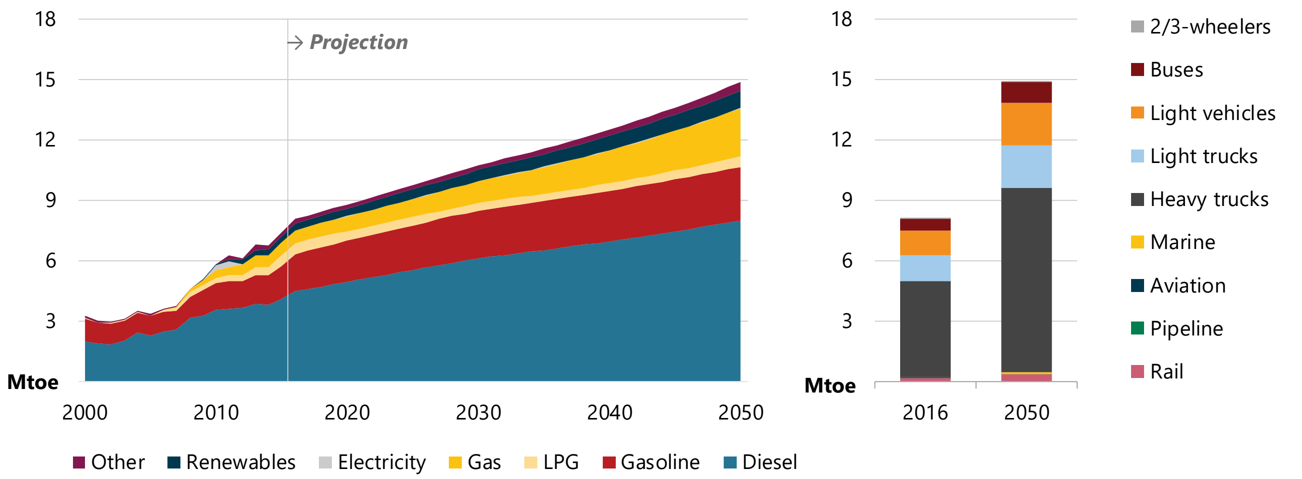
While industry energy demand has been growing, the fuel mix has become more diversified. Electricity was the dominant fuel in 2016 (46%), but it accounted for only 28% in 2000. Moreover, natural gas consumption in this sector was virtually non-existent in 2000, and in 2016, it amounted to 23%, following the development of the Camisea field. Conversely, the share of oil, mainly fuel oil, fell from 57% in 2000 to 18% in 2016 owing to its higher cost and air pollutant emissions compared with natural gas and electricity. However, lack of access to natural gas outside Lima and a handful of cities has impeded demand growth in other regions.

While industrial demand for all fuels increases though 2050, electricity use grows the most (0.61 Mtoe) over the projection period. Conversely, demand for renewables grows the most slowly, serving only 0.40% (0.02 Mtoe) of total industrial demand in 2050.

TRANSPORT: ROBUST ENERGY DEMAND GROWTH LED BY DIESEL-FUELLED ROAD TRANSPORT

Peru's domestic transport sector has had the highest and fastest-growing energy demand of all sectors since 2008, more than doubling between 2005 and 2016 (Figure 14.4). Road transport dominates demand at more than 95% of the sector's energy consumption and about 30% of FED since at least 2000. Most of the growth in transport energy demand between 2005 and 2016 resulted from a considerable surge in road transport stock: a 119% increase in the light-duty vehicle fleet, 164% increase in light-duty trucks, three times the number of heavy-duty trucks and double the buses. This is an indicator of both Peru's rapid economic growth in the past decade and the rise in personal income that has allowed a larger share of the population to own private vehicles. Moreover, the lack of an extensive, safe and efficient public transport network in most cities incentivises consumers to acquire private vehicles.

Figure 14.4 • Peru: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Under the BAU, domestic transport sector energy demand continues to grow quickly (1.8% CAGR), increasing from 8.1 Mtoe in 2016 to 15 Mtoe in 2050. This expansion results from continued economic growth (3.2% CAGR in 2016-50), which leads to greater personal wealth, with per-capita GDP more than doubling over the Outlook period.

Road continues to dominate transport energy demand, remaining at over 95% throughout the Outlook period. Although marine transport energy consumption increases (mainly for fishing activities and some freight transport), the share remains below 1.0% in 2050. Data limitations hinder analysis of the rail and air subsectors: no detailed public data are available for rail transport, but it is assumed that joint rail and air transport energy demand does not exceed 2.5% of total transport demand by 2050. Aviation data indicates energy consumption of 0.97 Mtoe for international aviation in 2016 but no fuel consumption for domestic aviation, which undoubtedly exists. Given this data limitation, domestic aviation fuel demand was estimated and projected to grow to 0.002 Mtoe while international aviation grows to 2.4 Mtoe by 2050.

Around 80% of energy demand by heavy-duty trucks and buses was diesel in 2016, accounting for 53% of domestic transport demand. Diesel continues to be Peru's main fuel throughout the projection period under the BAU, supplying 58% (8.7 Mtoe) of domestic transport demand in 2050 and 30% of FED overall. Gasoline is the second most-consumed fuel, satisfying 17% (2.5 Mtoe) of domestic transport demand in 2050, a smaller share than in 2016 (22%) owing to improved vehicle fuel efficiency, a shift to fuels such as compressed natural gas (CNG) and LPG, and wider use of public transport. Unlike other APEC economies, CNG has positioned itself already as a relevant fuel in Peru's transport sector, with about 8.1% of total transport demand. Natural gas demand in the transportation sector almost quadruples, representing about 16% of the total share (2.4 Mtoe) by 2050. In 2016, energy demand for advanced vehicles, including hybrid and plug-in hybrid vehicles, battery electric vehicles (EVs) and fuel cell EVs, was negligible. Even though energy demand for advanced fuels (electricity and hydrogen) increases four times by 2050, it still accounts for a marginal 0.0001% of road transport demand.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

In 2016, Peru's TPES was dominated by oil (43%) and natural gas (38%). Natural gas production is used primarily for electricity generation and LNG exports, while most oil is consumed in transport. Traditional biomass remains the main fuel in buildings, accounting for roughly 9.4% of TPES in 2016. Peru's crude oil production is unable to meet refining needs, while at the same time refining capacity is unable to meet domestic demand for oil products.

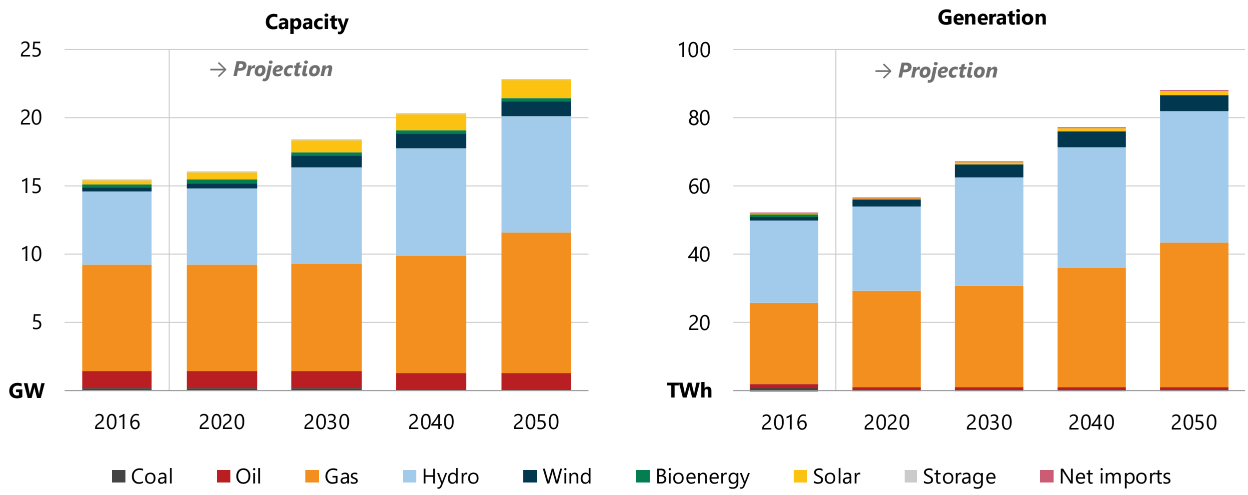
ENERGY TRANSFORMATION: REFINING CAPACITY UNABLE TO MEET GROWING DIESEL DEMAND

As domestic crude oil production is unable to keep up with demand, around 70% of refinery intake is imported (MEM, 2016). Additionally, the total capacity of Peru's seven refineries (200 000 barrels per day or 9.6 Mtoe per year) is not enough to meet demand, resulting in net imports of some oil products as well. Diesel is the most imported liquid fuel, with net imports growing more than five-fold from 2005 to 2016, driven predominately by rapid transport growth. Conversely, gasoline, jet fuel and fuel oil production exceed domestic demand, resulting in Peru being historically a net exporter of these oil products. Demand is projected to grow quickly (particularly in diesel-fuelled road freight transport and, to a lesser extent, gasoline-fuelled passenger light vehicles), in contrast to refining capacity, resulting in net diesel imports almost tripling throughout the Outlook period.

POWER SECTOR: ELECTRICITY GENERATION GROWS 69% WITH FEW CHANGES TO THE FUEL MIX

In Peru's National Integrated Electrical System (SEIN), which consists of more than 40 competing power generation companies, electricity rates are mostly based on marginal costs and free-market forces. The SEIN accounts for 96% of electricity generation in Peru, the remainder coming from isolated systems and own-energy consumption (MEM, 2016). Total power generation capacity was 15 GW in 2016, mainly gas-fired (51%) owing to the development of the Camisea gas field in 2004, but hydro power-based capacity also accounts for a large portion (35%) (Figure 14.5). Peru's power generation fuel mix is therefore not diverse, as it relies mainly on these two sources and only marginal amounts of oil, coal and non-hydro renewables. In 2016, hydro resources accounted for 47% of power generation and natural gas for 46%. The rest was divided almost evenly among oil, wind, coal, biomass and solar.

Figure 14.5 • Peru: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

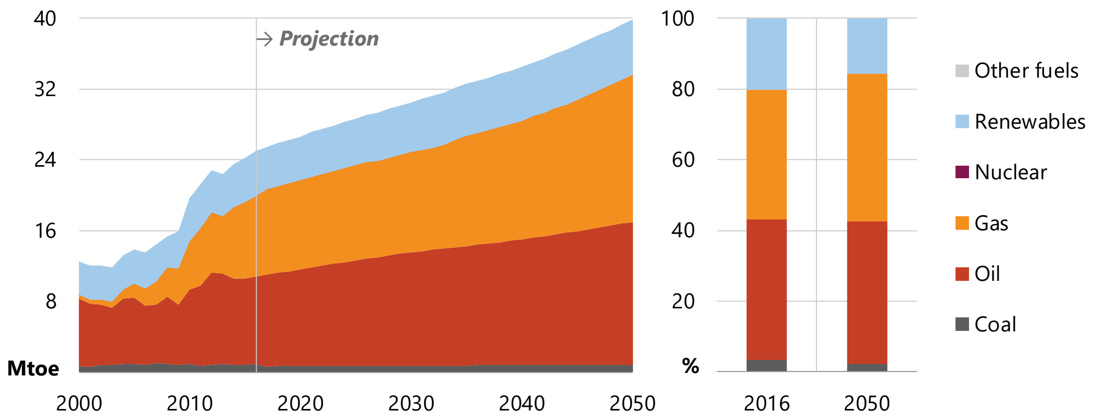
Power capacity expands 48% in the BAU (to 23 GW by 2050), reflecting rapid economic growth, but electricity generation grows even more quickly (69%). Hydro power generation, which grows 59% by 2050 (at a CAGR of 1.4%), remains along with natural gas, the pillars of electricity generation in Peru along the Outlook period. Likewise, the addition of 3.2 GW of hydro power capacity by 2050 accounts for most of Peru's capacity expansion. Gas-fired power generation grows the most, increasing by 78% over the Outlook period, due to higher utilisation rates. Wind power generation grows almost five-fold, but its share reaches only 5.5% of total generation in 2050. Similarly, solar power generation grows at 4.6% CAGR but makes up only 1.3% of total generation in 2050. Oil-fired generation is maintained only as backup or peaking technology, and coal-based generation ceases around 2020. No nuclear power plants are assumed to be built, as the government has not announced any concrete plans for the development of this technology.

While the electricity system has a significant amount of renewable energy by 2050, only 6.7% is generated from renewable sources other than hydro power (2.7 GW of installed capacity), despite the economy having non-hydro renewables potential of more than 35 GW (Osinergmin, 2017a). Peru has, however, enacted laws and regulations to promote renewable energy and set minimum renewables power shares every year (El Peruano, 2008). Moreover, the Osinergmin has successfully conducted four renewable energy auctions since 2015, which have resulted in wind, solar and modern biomass renewable projects. Nevertheless, much of the non-hydro renewable energy potential remains untapped.

TOTAL PRIMARY ENERGY SUPPLY: STEADY GROWTH BUT OIL AND NATURAL GAS STILL DOMINATE

Peru's TPES grows 65% in the BAU, from 24 Mtoe in 2016 to 40 Mtoe in 2050, driven by sustained economic growth (Figure 14.6). The fuel mix remains very similar, with fossil fuels (coal, oil and natural gas) continuing to account for around 82% of TPES through the Outlook. Renewable energy accounted for around 21% of total supply in 2016, of which roughly 51% came from traditional biomass and 41% from large hydro power generation, with modern forms of renewable energy, such as wind and solar, accounting for the remaining share.

Figure 14.6 • Peru: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

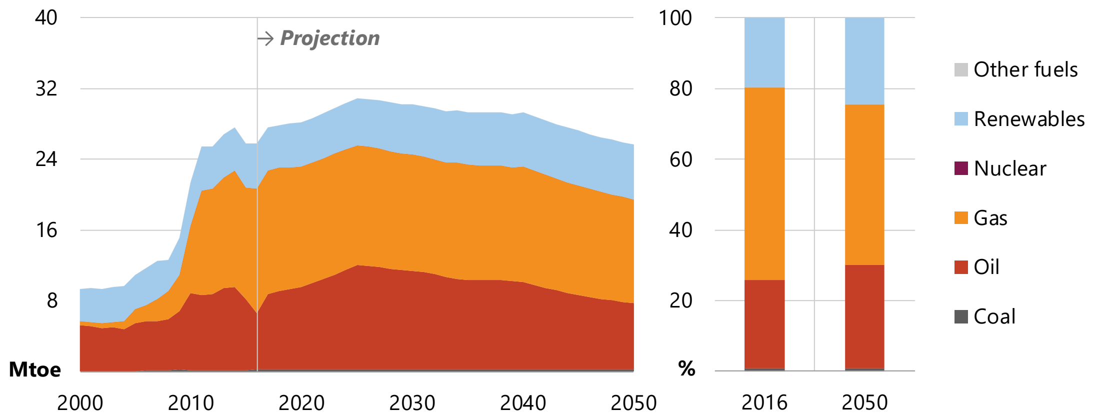
Oil grows by 63% and remains the dominant fuel in TPES until around 2045 when it is surpassed by natural gas, which has been increasing in importance since 2004, when major production in the Camisea field started. Natural gas supply grows 82% and its share in the supply mix increases from 38% (9.1 Mtoe) in 2016 to 42% (17 Mtoe) in 2050.

Renewable energy grows 23% to 6.3 Mtoe by 2050, but its share of TPES falls gradually, from 21% in 2016 to 16% by 2050, because a 35% drop in the use of traditional biomass (from 2.3 Mtoe in 2016 to 1.5 Mtoe in 2050) offsets growing consumption of other renewables, mainly hydro power. While solar energy production grows more than four-fold and wind energy grows almost five-fold by 2050, their combined share nevertheless remains less than 2.0% of TPES. Unlike in many other APEC economies, coal's share of TPES is marginal, further decreasing from 3.6% to 2.1% over the projection period.

ENERGY PRODUCTION AND TRADE: STAGNANT PRODUCTION LEADS TO HIGHER IMPORTS

Peru's energy production was relatively stable during the 1990s and early 2000s, with some crude oil and minimal natural gas production (Figure 14.7). Development of the Camisea natural gas field in 2004 revolutionised Peru's energy market, however, providing more than 98% of the economy's natural gas production and 60% of the natural gas liquids used for LPG production (Osinergmin, 2014). Primary energy production more than doubled from 2005 to 2016 (reaching 26 Mtoe) owing to the development of the Camisea field. Under the BAU, however, energy production grows more modestly, peaking around 31 Mtoe in 2025, and then declining slowly to 26 Mtoe in 2050. Overall energy production decreases by a marginal 0.25% during the Outlook period. This trend primarily results from continued natural gas and oil development in the near term before a marked decrease after 2025 due to asset depletion, assuming there are no major discoveries in the coming years.

Figure 14.7 • Peru: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Natural gas dominated energy production (55%) in 2016. Peru has been a net natural gas exporter (all of it via LNG) since 2010, with 41% of natural gas production designated for LNG exports in 2016 (mainly to Mexico and Spain) (MEM, 2016). Natural gas production grew dramatically in 2005-16 (more than eight-fold) but falls 17% over the Outlook period (to 12 Mtoe in 2050) with the depletion of the Camisea field. Peru begins importing natural gas by 2036, becoming a net natural gas importer around 2039, to meet quickly growing natural gas demand for power generation and industrial applications while production decreases.

Although crude oil production has been declining since the late 1990s, a greater output of natural gas liquids from the Camisea field has boosted overall oil production by 36% since 2004. Consequently, oil production follows a similar trend to natural gas production, growing 83% to 12 Mtoe by 2025 when it peaks, then dropping sharply to 7.5 Mtoe by 2050, despite modest shale oil production starting by 2030. As a result, Peru remains a net crude oil importer throughout the Outlook period.

In contrast with fossil fuels, overall renewable energy production grows 23% by 2050 as production from all renewable energy sources (except bioenergy) increases. Hydro, wind and solar electricity generation all expand quickly, but overall bioenergy (mostly traditional biomass) use shrinks as it is replaced with LPG and electricity, offsetting a marginal growth in modern biomass.

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Peru's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increased energy intensity and renewables deployment, and reduced CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050.

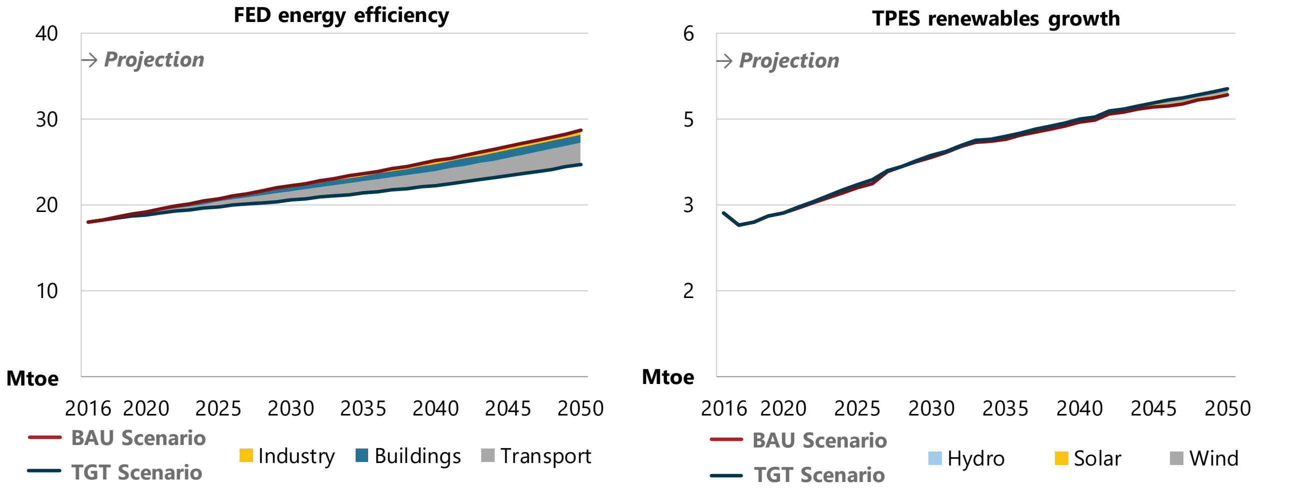
Relative to the BAU, both FED and CO_2 emissions are 14% lower under the TGT by 2050. Under the 2DC, Peru's FED is 27% lower and CO_2 emissions are 43% lower when compared to the BAU over the Outlook period. The share of renewables in TPES is considerably higher in the alternative scenarios, 16.3% in the TGT and 28% in the 2DC, compared to 15.7% in the BAU.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. In the TGT, FED increases by 37% over the Outlook period, compared to 59% under the BAU while the share of renewables in TPES is slightly higher (16.3%) than in the BAU (15.7%), despite a smaller absolute increase due to lower traditional biomass use in buildings and greater energy efficiency.

The most significant difference between the TGT and the BAU is much slower growth in transport, as energy demand grows 54% (12 Mtoe in 2050), compared to 85% (15 Mtoe in 2050) under the BAU, mainly owing to improved fuel efficiency, technological advances and higher standards for road vehicles, particularly heavy-duty trucks (Figure 14.8). Other sectors present more modest energy demand savings, such as the buildings sector (14% less than in the BAU, 1.0 Mtoe) and industry (7.5% less than in the BAU, 0.49 Mtoe).

Figure 14.8 • Peru: Energy efficiency and renewable development, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewable growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Transport energy demand reductions result from stronger fuel efficiency standards, wider deployment of new vehicles and more technologically advanced motors in the road transport subsector. Domestic freight transport shows the largest progress, particularly for heavy-duty trucks, as the gap between the BAU and the TGT amounted to 1.4 Mtoe or 14% less. As transport demand rises in tandem with steady economic growth, and heavy-duty trucks transport almost the totality of freight, better fuel efficiency in these vehicles strongly impacts energy demand. The share of EVs remains low, at less than 0.10% of road transport energy demand, despite being more than double its value in the BAU in 2050.

Energy demand in buildings grows 26% by 2050, compared to 46% in the BAU. Considering that population grows 32% and GDP almost triples (raising the standard of living) over the Outlook period, reducing energy demand requires aggressive actions and programs, with most curtailment achieved through more stringent energy efficiency standards, labelling programs and replacing traditional biomass with modern technologies. Renewable energy consumption (most of which was traditional biomass in 2016) decreases 32% over the Outlook period as LPG, electricity and modern renewables almost completely replace traditional biomass in the residential subsector.

Energy savings in industry demand are only moderate in the TGT: 0.49 Mtoe (7.5%) below the BAU. Most of the progress comes from extensive adoption of less energy-intensive technologies, such as electric arc furnaces, and from stricter efficiency standards in the iron and steel subsector.

Electricity generation in the TGT grows 57% by 2050, 7.3% less than in the BAU because energy demand grows at a slower pace. Renewable electricity generation almost doubles, similar to the BAU, and its share grows to 56% of total generation. Similarly to the BAU, natural gas-fired generation grows 47%, with solar and wind generation growing around 15% more than in the BAU, however, deployment is limited due to higher hydropower capacity additions.

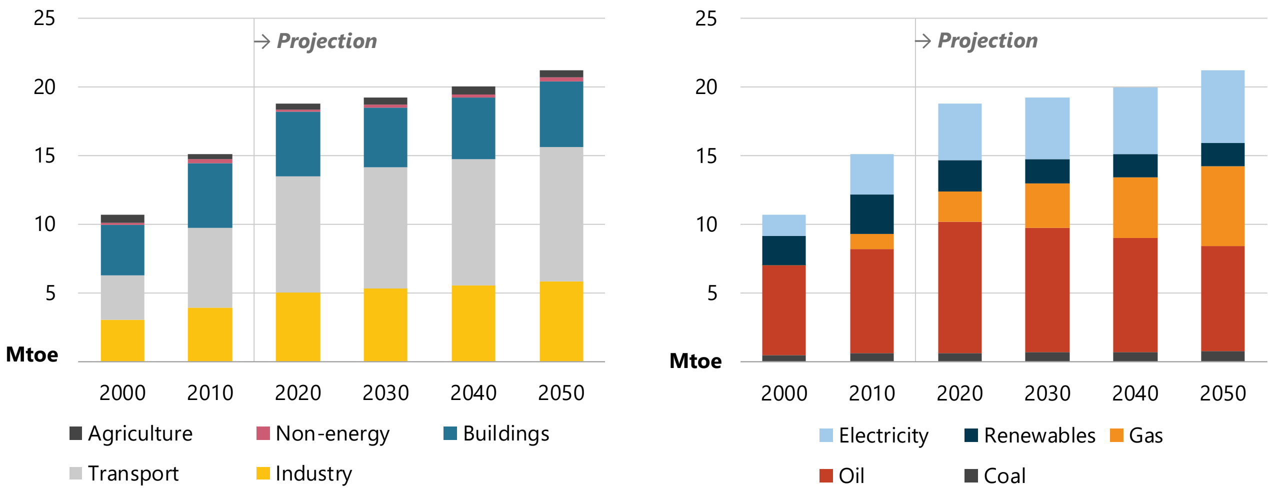
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Peru will have to undergo various levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the Energy Technology Perspectives publication by the IEA (2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Each key demand sector (buildings, industry and transport) consumes less energy in the 2DC than in the other scenarios owing to energy efficiency improvements and, in the case of transport and building services, behavioural change. Overall energy demand still grows in all sectors, except buildings. Under the 2DC, FED grows 15% over the Outlook period, mainly driven by transport demand (Figure 14.9).

Figure 14.9 • Peru: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Compared with the other scenarios, the largest savings occur in the transport sector, mainly owing to fuel efficiency improvements and stricter standards, particularly for heavy-duty trucks. Other factors contributing to more moderate growth include increased use of other transport modes, such as buses and rail, and behavioural change that involves better planning and logistics to reduce the amount of travel. Transport demand grows 21% in the 2DC, compared with 85% in the BAU and 54% in the TGT.

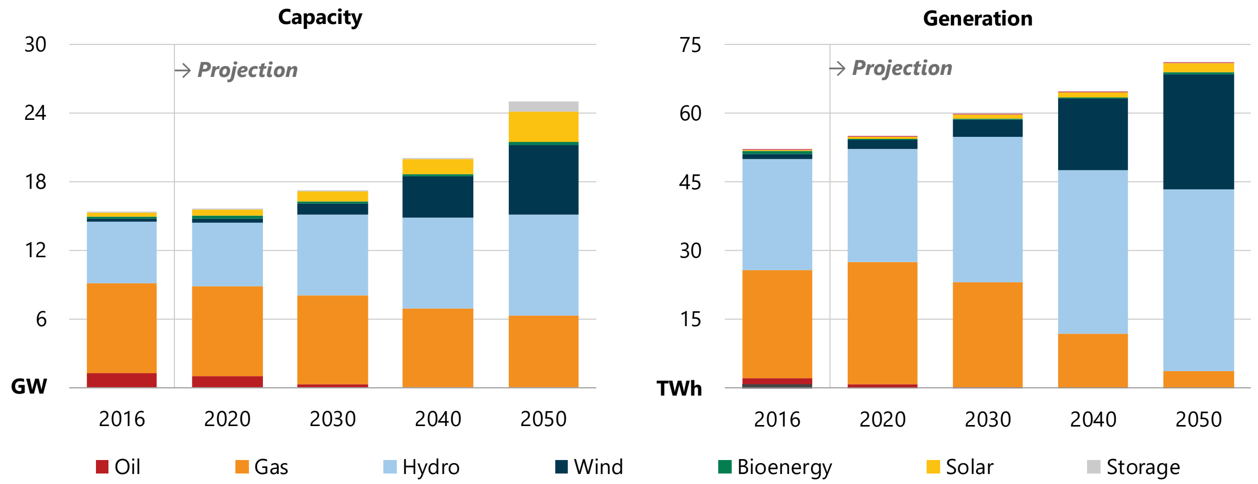
Industry energy demand increases 18% (compared to 32% and 22% under the BAU and TGT), despite GDP growing at a 3.2% CAGR throughout the Outlook. This highlights the relevance of stricter energy efficiency standards, the adoption of best available technologies (BATs), and the electrification of mining processes to reduce the use of fossil fuels, particularly coal, fuel oil and petroleum coke.

Buildings energy demand remains largely stagnant around 4.8 Mtoe over the Outlook period with a gentle 10% decrease towards 2030, and an almost equal increase afterwards. This is due mainly to higher energy efficiency standards for water heating and cooking. Additionally, behavioural changes, particularly through the more efficient use of lighting and comfort appliances, also contribute to energy savings in this scenario, more than offsetting the effects of growing GDP and appliance penetration. Services demand increases by 30% (0.31 Mtoe) through the Outlook period with greater business and economic activity, offset by an equivalent 8.1% decrease in residential demand.

TRANSFORMATION AND SUPPLY IN THE 2DC

In the 2DC, electricity generation grows 37% by 2050, compared with 69% in the BAU and 57% in the TGT. This owes to lower demand growth, particularly in buildings and industry, thanks to efficiency measures and behavioural changes. However, installed electricity capacity expands 62% to 25 GW in 2050 (more than 2.2 GW above the BAU) because most capacity additions are for non-hydro renewable energy (mostly wind but also solar), which operate at lower utilisation rates than hydro and gas-fired plants. Renewable sources account for 95% of electricity generation by 2050, with the remainder from natural gas (Figure 14.10). Hydro power dominates (56%), followed by wind (35%), solar (3.0%) and modern bioenergy (0.56%).

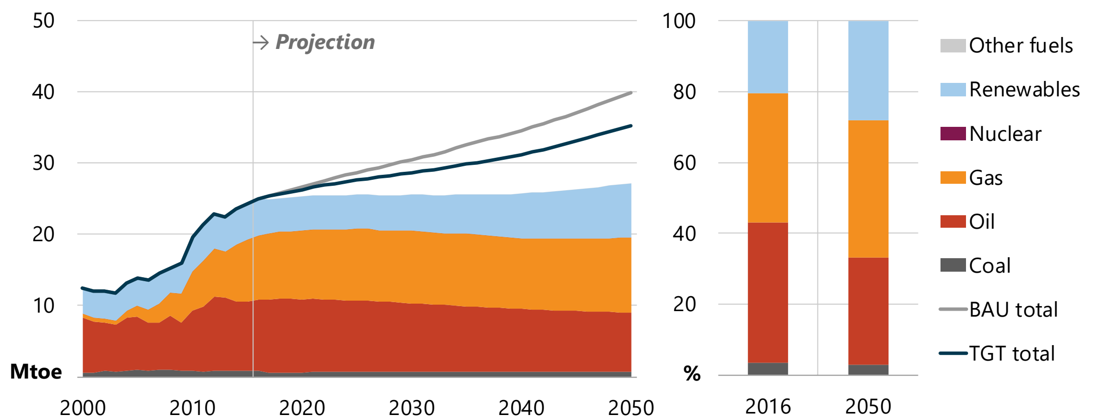
Figure 14.10 • Peru: Power capacity and electricity generation in the 2DC by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

TPES trends are similar across scenarios until 2020, when oil accounts for 40% of TPES, natural gas for 38% and renewables (mostly hydro power) for 19% (Figure 14.11). Thereafter, the fuel mix changes as a result of lower overall energy demand and growth in the share of renewables (which almost equals oil by 2050). This fuel switch happens predominantly in electricity generation, with natural gas getting almost completely replaced by renewable sources by 2050. Nevertheless, most oil demand is in transport, which has limited fuel substitution opportunities, especially for heavy-duty road transport—Peru's most energy-demanding sector. Still, TPES in the 2DC by 2050 is 32% lower than the BAU and 23% lower than the TGT.

Figure 14.11 • Peru: Total primary energy supply in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy production is nearly the same under the BAU and the TGT in both absolute and relative terms. The 2DC shows no major differences besides faster renewable growth, which begins in 2035 as more wind and solar are used for electricity generation and both combine to reach 5.6 Mtoe in 2050. Oil and natural gas production are the same across scenarios. However, in contrast to the other scenarios, Peru remains a natural gas exporter in the 2DC because of lower domestic use (37% less than under both the BAU and TGT in 2050). Peru remains a net importer for both crude oil and most oil products. However, diesel imports are more than three times lower by 2050 in the 2DC than in the BAU because of greater efficiency in transport (but demand still exceeds refining capacity). Coal imports remain minimal at around 0.50 Mtoe throughout the Outlook period owing to limited efficiency improvements, particularly in the cement industry.

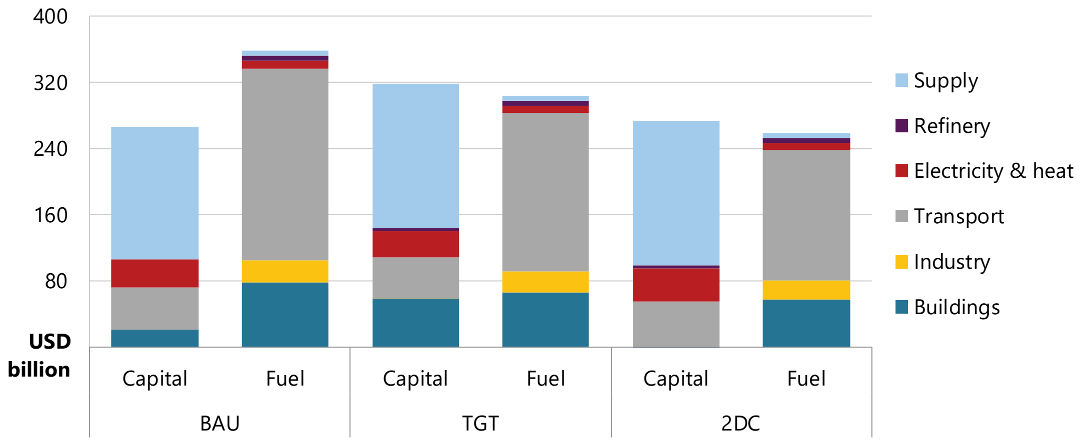
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC Outlook 7th Edition considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[72]

In the BAU, total cumulative investment in Peru's energy sector is around USD 625 billion (Figure 11.12). Energy investments in fuel costs represent about 57% of the total at USD 358 billion, while total capital investment is USD 266 billion. More than half of the capital investment is destined for the upstream oil and natural gas sector, resulting in a capital inflow of USD 160 billion. The electricity sector attracts a cumulative investment of USD 34 billion between 2016 and 2050, of which 34% is for renewable energy and 57% for strengthening transmission and distribution networks. The midstream natural gas sector attracts around USD 12 billion by 2050, between natural gas pipelines and LNG terminals. Demand-side investments (transport, buildings and industry) account for 27% of capital investment. Fuel cost investments account for 65% in transport, 22% in buildings, 7.3% in industry and about 6.0% in the electricity, refineries and supply sectors combined.

Figure 14.12 • Peru: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

[72] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Total investment decreases marginally to USD 623 billion in the TGT. While capital investment increases to USD 318 billion, fuel efficiency improvements help bring down fuel costs by 15% to USD 304 billion. Supply-side capital investment is 10% above the BAU. Capital investment in wind and solar energy increase by 15% compared to the BAU, totalling over USD 3.4 billion.

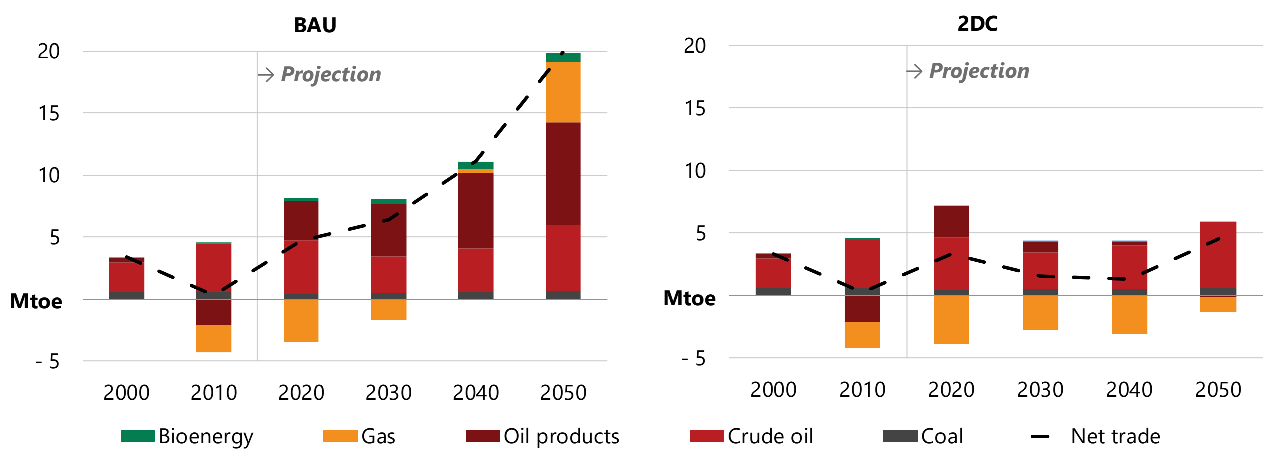
Capital investment and fuel costs in the 2DC decrease even further to USD 530 billion, mainly as a result of 28% lower fuel costs (USD 260 billion). Capital investment is 1.6% higher than in the BAU, reaching USD 271 billion. Investment in power increases from USD 34 billion in the BAU to USD 39 billion, as renewables-based power plants require more financing. Total demand-side investment decreases sharply, from USD 72 billion in the BAU to USD 53 billion in the 2DC, driven mainly by enhanced efficiency and behavioural change in the buildings sector.

ENERGY TRADE AND SECURITY

Peru was in 2016 a net energy importer, as coal, crude oil and some oil product imports exceeded natural gas exports (Figure 14.13). Over the Outlook period, however, oil product imports continue to grow and the economy transitions from net natural gas exporter to net importer around 2039, reflecting a slow but sustained decrease in natural gas production and rapidly growing domestic demand from power generation and industry.

Peru became a natural gas exporter in 2010 when the Pampa Melchorita LNG facility became operational. All natural gas exports (5.8 Mtoe in 2016) are in the form of LNG, as there are no natural gas pipeline connections with neighbouring economies. Under the BAU, natural gas exports decrease steadily until halting around 2038, when Peru's main source, the Camisea field, is projected to be depleted. Thereafter, as domestic demand continues to grow, the economy becomes a net natural gas importer and imports grow strongly to 4.9 Mtoe in 2050—roughly equivalent to Peru's LNG exports in 2015.

Figure 14.13 • Peru: Net energy trade, BAU and 2DC



Sources: APERC analysis and IEA (2018a).

Peru currently imports 70% of the crude oil used for refining: 50% from Ecuador and smaller shares from Colombia, Trinidad and Tobago, and other economies (MEM, 2016). Under the BAU, crude oil imports fall from 5.3 Mtoe in 2016 to 3.2 Mtoe in 2025 before growing to 5.6 Mtoe by 2050, for a 4.4% overall increase through the Outlook period. Historically, Peru's seven refineries (9.6 Mtoe combined capacity) have not been able to meet demand. Diesel is the most-consumed oil product and imports of it increased more than four-fold to 3.6 Mtoe from 2005 to 2016, with the rapidly expanding road transport subsector predominantly driving demand.

The United States provides 80% of diesel imports, which more than double to 9.6 Mtoe by 2050. Peru remains an overall net exporter of gasoline, jet fuel and fuel oil over the Outlook period.

Peru's heavy reliance on crude oil and oil product imports, lack of strategic diversification, heavy dependence on the Camisea gas and lack of redundancy of its transportation system are the main threats to energy security. Peru's widening crude oil reserve gap also highlights an opportunity to incentivise investments on the oil and gas upstream sector (Table 1.4). Over half of domestic refining capacity is concentrated in the La Pampilla complex, while almost all other refineries and import terminals are located on the coast, where earthquakes and floods are common. In the natural gas sector, the Camisea field is responsible for 95% of natural gas production and 60% of LPG production. A limited network of pipelines transport both natural gas and LPG, which provide around 45% of Peru's electricity. These sectors are therefore severely exposed to disruption risks, particularly in the Amazon region, where there are no other transport alternatives and access is extremely challenging.

Table 1.4 • Peru: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	86	93	98	100	65	71	95
Coal self-sufficiency (%)	20	25	26	26	21	22	23
Gas self-sufficiency (%)	100	100	100	100	71	71	100
Crude oil self-sufficiency (%)	55	94	94	94	73	73	73
Primary energy supply diversity (HHI)	0.34	0.33	0.33	0.33	0.34	0.36	0.29
Coal reserve gap (%)	2.6	40	40	40	94	94	94
Gas reserve gap (%)	3.5	57	57	57	127	127	127
Crude oil reserve gap (%)	7.9	149	149	149	338	338	338

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

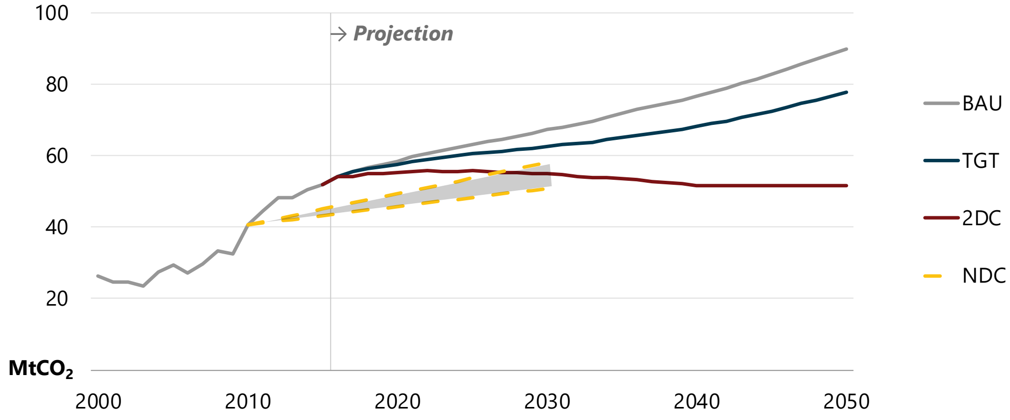
According to the final report recommendations of the APEC Oil and Gas Security Exercise in Peru held in November 2017, the MEM and Peru's other relevant energy security institutions should work cooperatively to enhance energy security (APEC EWG, 2018). Recommendations also include enhancing data quality collection, diversifying crude oil and refined product import sources, and fully implementing and updating the Law to ensure energy security and to promote the development of the petrochemical industry (El Peruano, 2012).

SUSTAINABLE ENERGY PATHWAY

Peru's GHG emissions account for 0.11% of the world's total (CAIT, 2018) and its nationally determined contribution (NDC)[73] targets a 30% reduction in GHG emissions below a 2030 projection using 2010 emissions levels as the base year, 10% of which is conditional on receiving international financing (UNFCCC, 2015) (Figure 14.14). This translates into a GHG emissions reduction of 90 million tonnes of carbon dioxide ($MtCO_2$), 53% of which comes from the forestry sector, including land use, land use change and forestry (LULUCF) activities. Peru's increases in energy demand have meant a 35% increase in energy-related CO_2 emissions from 2005 to 2016.

[73] The Nationally Determined Contributions (NDCs) reflect policy action to support the agreement reached during the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change, or 'COP21 Paris Agreement'.

Figure 14.14 • Peru: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, where applicable. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex II for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

Under the BAU, energy-related CO_2 emissions grow 67%, from 54 $MtCO_2$ in 2016 to 90 $MtCO_2$ in 2050. They increase more slowly (by 44%) in the TGT owing mainly to efficiency measures in the transport sector. In the 2DC, they peak in 2024, then slowly decline to 52 Mtoe in 2050 (4.3% overall decrease compared to 2016), mainly because gas-fired generation is nearly eliminated in the electricity sector and transport CO_2 emissions fall to almost 50% below BAU levels.

Peru falls short of achieving its NDC and international commitment both under the BAU and the TGT scenarios, as CO_2 emissions keep growing along the Outlook period. Under the 2DC scenario, however, Peru's energy-related CO_2 emissions do fall between the conditional NDC range as efficiency gains reduce energy demand and much gas-fired electricity generation is substituted with renewables-based (mostly hydro and wind) generation. Transport remains the largest source of CO_2 emissions across all scenarios, caused by quickly growing energy demand for road transport (particularly for transporting freight).

OPPORTUNITIES FOR POLICY ACTION

As transport remains the largest final energy demand sector throughout the Outlook, it is essential to implement active and innovative measures to ensure more affordable, efficient and cleaner use of energy. Peru should enact energy efficiency measures, such as enhancing fuel economy standards, providing opportunities for intermodal transportation (particularly in public transport) and promoting the development of alternative-fuel vehicles. The construction of Lima's metro line 2 and the system's expansion represent important steps in the right direction but more is needed to achieve a more affordable, energy-efficient, and less-polluting transport sector.

Peru has over 100 GW of untapped renewable resource potential, 70% of which is in hydro power. However, hydro power plants require substantial investment and have generated public opposition and environmental concerns in recent years: the Inambari and Tam 40 projects had to be cancelled (La Republica, 2012). Wind, solar and geothermal resource potential amounts to 30 GW, but current installed capacity of all three combined accounts for barely 0.50 GW. Peru must actively promote the development of such technologies through legislative change, attractive investment schemes and auctions, such as those recently carried out in Mexico and Chile (CENACE, 2018; Empresas Electricas, 2018).

Natural gas demand has boomed since production began at the Camisea field in 2004. However, power generation dominates natural gas demand, and FED accounts for only 22% of the total natural gas supply. Moreover, industry claims over half the FED share of gas, while buildings uses barely one-tenth of FED gas and only 2.0% of total natural gas total supply. This clearly shows that most Peruvians do not have access to natural gas for residential and services activities, despite rising production. Lack of access to natural gas mostly owes to the lack of an extensive and redundant transmission pipeline network across Peru. While the *Gasoducto Sur Peruano* pipeline could increase natural gas access in other regions, its unclear future could set a negative precedent for future natural gas infrastructure projects. Therefore, the Peruvian government should reactivate, as soon as possible, the construction of this important piece of infrastructure as it will boost economic growth, the consumption of natural gas and enhance energy security.

Finally, data quality is a crucial element for energy analysis, investment decisions and public policy. While there is already a solid foundation with data available for most fuels and sectors, there are still opportunities to improve data in key sectors such as transport, particularly rail, aviation and marine modes. Moreover, data on energy use by the industrial sector presents a big opportunity as over 60% of industrial energy demand is simply labelled as non-specified, hindering deeper and more detailed analysis. Investing in capacity building and personnel for data collection and statistics is a relatively inexpensive way of substantially contributing to a more robust and accurate analysis that would ultimately result in better policies for the Peruvian energy sector.

15. THE PHILIPPINES

KEY FINDINGS

- **FED grows at a CAGR of 2.0% in the BAU Scenario,** mainly in the buildings and transport sectors, driven largely by economic growth (CAGR 4.7%).

- **The share of coal in TPES increases significantly in the BAU, from 26% in 2016 to 39% in 2050, to meet surging electricity demand with domestic resources.** The Philippines will need to adopt additional policy actions to mitigate environmental concerns associated with coal use.

- **The share of renewable energy in power generation decreases in the BAU, from 24% in 2016 to 20% in 2050, but more than doubles in the 2DC, reaching 71% by 2050.** Large increases in fossil fuel generation, particularly coal, which triples, overshadows a more than doubling of renewable generation in the BAU.

- **Energy security becomes increasingly vulnerable as net energy imports more than double under the BAU.** Promoting renewables and diversifying trade will be important for maintaining energy security.

- **CO_2 emissions grow steadily in the BAU but decline in the TGT and 2DC.** The conditional NDC, while highly ambitious, is not achieved on schedule in any scenario.

ECONOMY AND ENERGY OVERVIEW

The Philippines is an archipelago in south-east Asia comprising over 7 000 islands. Gross domestic product (GDP) increased at a compound annual growth rate (CAGR) of 5.3% in 2000-16 (and by around 6.9% in 2016), compared with an Asia-Pacific Economic Cooperation (APEC) CAGR of 4.0% over the same period. In 2016, GDP reached USD 797 billion, up from USD 352 billion in 2000 (Table 15.1). Per-capita GDP was USD 7 718 in 2016, 1.7 times higher than in 2000 but less than one-third of the APEC average of USD 22 536.

Over the Outlook period (2016-50), the Philippines is projected to continue growing rapidly (4.7% CAGR), with GDP increasing almost five-fold to USD 3 861 billion in 2050. The services sector is the major contributor, accounting for nearly 60% of GDP in 2016 (World Bank, 2019a). The Philippines is currently the 12th most-populated economy in the world, with 103 million people and a population density of 347 people per square kilometre (km^2) (World Bank, 2016). Population growth slows from a CAGR of 1.8% in 2000-16 to 1.1% over the Outlook period. At this slower growth rate, the population reaches 151 million in 2050.

Table 15.1 • The Philippines: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	352	560	797	992	1 671	2 638	3 861
Population (million)	78	94	103	110	125	139	151
GDP per capita (2016 USD PPP)	4 507	5 972	7 718	9 041	13 328	18 918	25 520
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	41	41	55	64	78	96	117
TPES per capita (toe)	0.52	0.43	0.53	0.58	0.62	0.69	0.77
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3	3.2
TPES per GDP (toe per 2016 USD million PPP)	115.98	72.52	68.41	64.12	46.64	36.47	30.24
APEC TPES per GDP (toe per 2016 USD million PPP)	167.53	146.67	123.3	110.52	84.98	67.18	56.08
Final energy demand (Mtoe)	24	24	32	35	43	52	61
FED per capita (toe)	0.31	0.25	0.31	0.32	0.34	0.37	0.41
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2	2.1
FED per GDP (toe per 2016 USD million PPP)	68	42	40	35	26	20	16
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	74	82	120	150	184	232	289
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	74	85	89	90	90	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

The Philippines has modest hydrocarbon resources, with estimated reserves of 42 million barrels (Mbbl) of oil, 38 Mbbl of condensate, 3.4 trillion cubic metres of natural gas and 491 million tonnes of coal (DOE, 2017a). Oil production has been falling in recent years, reflecting natural depletion. The main natural gas-producing field at Malampaya is also expected to run out in 2022-25 (DOE, 2018a).

Renewable energy potential in the Philippines is vast. Renewables contributed 23% of total power generation in 2017 and 31% of generating capacity, with hydropower providing the largest share (DOE, 2017b and 2017c). A significant amount of the economy's total primary energy supply (TPES) is from renewables, specifically from geothermal (17%) and biomass (15%). The government estimates that 17 gigawatts (GW) of renewable electricity potential remains to be developed (DOE, 2016a).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Launched in 2018, *AmBisyon Natin 2040* (Our Ambition 2040) envisages a "strong-rooted, comfortable, and secure life for all by the year 2040" in the Philippines (Box 15.1). The Department of Energy has strengthened its policy on Energy Sector Strategic Directions in support of *AmBisyon Natin 2040* to promote a technology-neutral approach to meeting operational requirements. This strategic direction aims to address the high cost of electricity, sporadic power interruptions and electrification gaps in off-grid areas (DOE, 2016b). A possible policy shift to 50% baseload and 50% flexible power plants is being considered but requires extensive research (Business Mirror, 2018).

The Philippines is currently implementing renewable energy feed-in tariffs (FiTs). An on-grid renewable portfolio standard (RPS) has already been finalised and approved and will require power generation companies, distribution utilities and suppliers to source or produce a portion of their electricity from eligible renewable resources. Through the RPS, the economy intends to increase the share of renewables in power generation to 35% in 2030-40 (from 24% in 2016) and has already drafted an off-grid RPS for adoption in the short-term. Other policy mechanisms stipulated in the Renewable Energy Act, such as net metering and a Green Energy Option (GEOP), are also underway. The GEOP empowers end-users to choose renewable generation for their energy requirements through their distribution utilities (DOE, 2017d). In the updated National Renewable Energy Program, the Philippines aims to increase renewable energy capacity to 20 GW by 2040 (DOE, 2018c).

The Nuclear Energy Program Implementing Organization (NEPIO) was created in October 2016 after the Philippines hosted the 2016 International Atomic Energy Agency (IAEA) Conference on the Prospects of Nuclear Power in the Asia-Pacific Region. NEPIO carries out technical cooperation projects and programs on nuclear energy. Once the Philippines has established a position on nuclear energy as recommended by NEPIO, nuclear energy will be included in the energy plan as an option for power generation. The government signed a Memorandum of Cooperation with the Russian Federation State Atomic Energy Corporation in November 2017 to assess the possible rehabilitation of the mothballed Bataan Nuclear Power Plant. Technical cooperation with the IAEA for the development of nuclear infrastructure in the Philippines in 2019 is ongoing (DOE, 2018d).

To streamline regulatory processes and procedures for energy projects deemed of economic and strategic significance, and to ensure their efficient and effective implementation, the government issued an executive order in June 2017 creating the Energy Investment Coordinating Council. The executive order established a simplified approval process and harmonised rules and regulations for all government agencies involved in issuing permits and regulatory approvals for high-cost energy projects (DOE, 2019a).

Box 15.1 • The Philippines: *AmBisyon Natin 2040* and the new energy plan

In embarking on *AmBisyon Natin 2040* (Our Ambition 2040), the new government has strengthened its Energy Sector Strategic Directions to serve as guidelines for energy policy over the next 22 years. They include ensuring energy security, expanding access to energy and promoting a low-carbon future (DOE, 2018b).

The government has set out modified and indicative targets for its energy agenda):

- Ensure access to basic electricity for all by 2022.
- Adopt a technology-neutral approach to achieve an optimal energy mix.
- Improve power supply reliability to meet demand by 2040.
- Develop liquefied natural gas (LNG) capacities in anticipation of Malampaya gas field depletion.
- Complete transmission projects by 2020, specifically those connecting the two major islands (Visayas and Mindanao) to establish a one-economy, one-grid system.
- Create a pro-consumer distribution framework for affordability, choice and transparency.
- Streamline domestic policies to fast-track energy project implementation.
- Promote efficient energy use.

Power generation policy is technology-neutral and comprises three broad generation types:

- 70% baseload capacity from coal, geothermal, large-scale hydro, natural gas, nuclear and biomass.
- 20% mid-merit capacity from natural gas.
- 10% peaking capacity from oil-based power plants and variable renewable energy, such as solar photovoltaic (PV) and wind.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for the Philippines under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 15.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere. Government targets and projections, such as those in *AmBisyon Natin 2040*, are not necessarily achieved.

Table 15.2 • The Philippines: Key assumptions and policy drivers under the BAU

Buildings	MEPS and labelling remain at current levels for household air conditioners, refrigerators and lamps.
Transport	Limited deployment of hybrid, compressed natural gas and EVs. Biofuel blend maintained at the current levels of 10% bioethanol and 2% biodiesel.
Energy supply mix	No new major natural gas fields identified.
Power mix	Least-cost options for power generation implemented. Plans to develop nuclear generation not confirmed.
Renewables	Target of 30% share of renewables in total generation capacity considered.
Energy security	Continued policy of harnessing domestic energy resources improved, energy self-sufficiency maintained and import dependency reduced.
Climate change	Policies insufficient to achieve the target of reducing GHG emissions 70% by 2030 compared with its official business-as-usual projections.

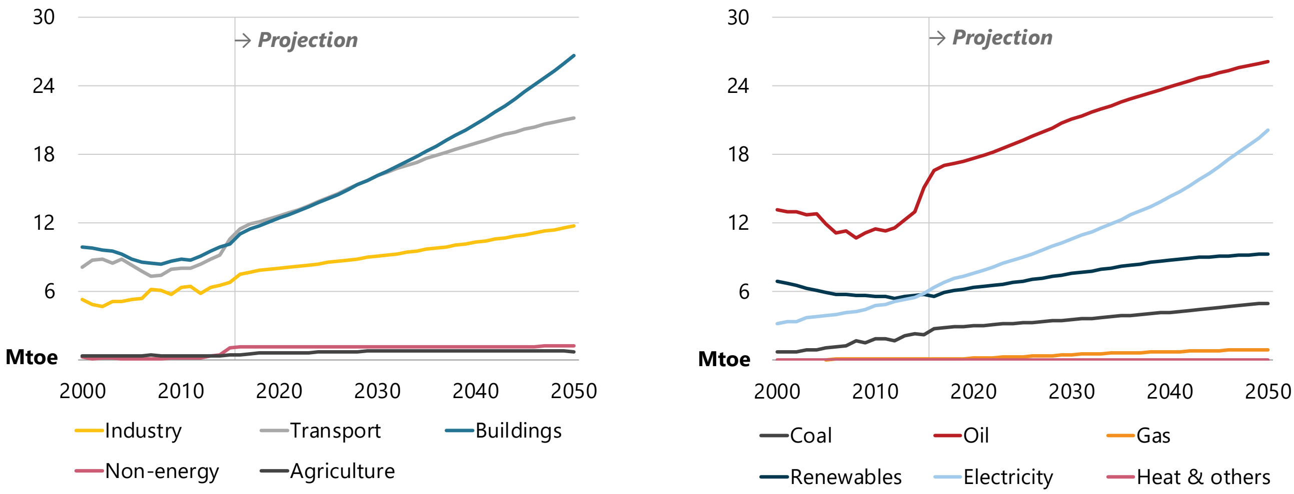
Notes: EVs = electric vehicles. MEPS = minimum energy performance standards. GHG = greenhouse gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

The Philippines is one of the fastest-growing economies in APEC, with a CAGR of 5.6% over the past decade and a projected CAGR of 4.7% over the Outlook period. To support economic growth, final energy demand (FED) reached a CAGR of 3.7% in 2006-16 and is projected to double, from 32 Mtoe in 2016 to 61 Mtoe in 2050. FED growth is, however, significantly smaller than economic growth, which expands almost five times, from USD 797 billion to USD 3 861 billion between 2016 and 2050.

Buildings sector energy demand increases at a CAGR of 2.6% to become the largest FED sector (43%) in 2050 under the BAU (Figure 15.1). This growth is reflected in the overall fuel mix, in which the oil share decreases (from 53% in 2016 to 43% by 2050) but remains the largest over the projection period, while electricity demand increases to 33% of FED in 2050, up from 20% in 2016, largely due to its increased use in the buildings sector. The renewables share falls from 18% in 2016 to 15% in 2050, despite growing 70% in absolute terms due to rising use in the transport and buildings sectors.

Figure 15.1 • The Philippines: Final energy demand by sector and fuel, 2000-50



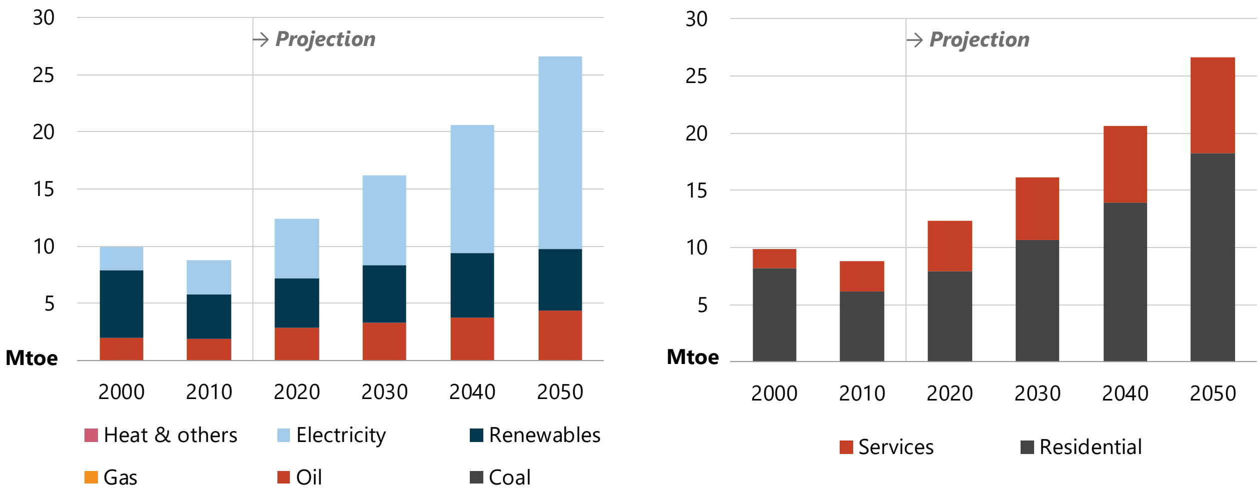
Sources: APERC analysis and IEA (2018a).

To check rapidly increasing energy demand, the government implemented the National Energy Efficiency and Conservation Program in 2004. Initiatives include an energy efficiency standards and labelling program; fuel conservation and efficiency in road transport; energy management services and energy audits; power conservation and demand management; and the Philippine Industrial Energy Efficiency Project.

BUILDINGS: RAPID INCREASE IN ELECTRICITY AND MODEST DECREASE IN RENEWABLES

Following a drop in the early 2000s, energy use in the buildings sector reached 11 Mtoe in 2016 as liquefied petroleum gas (LPG) and electricity replaced traditional biofuels in the residential subsector. Buildings FED doubles over the Outlook period under the BAU, reaching 27 Mtoe by 2050 (Figure 15.2). Electricity use expands rapidly (at a CAGR of 4.3%) and accounts for the largest share (63%) of the energy mix in 2050, up from 37% in 2016, to keep pace with growing energy demand for space cooling and electrical appliances. Renewables and oil use also increase because of higher demand for water heating and cooking in the residential subsector, although their shares in the energy mix decline overall between 2016 and 2050: from 36% to 20% for renewables and from 25% to 17% for oil.

Figure 15.2 • The Philippines: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Strong energy demand growth in the residential subsector results from a tripling in residential floor area and a doubling in the number of households as economic and population growth lead to more and larger houses having fewer people in them by the end of the Outlook period. The government's program to expand access to energy contributes to rapid residential electricity demand growth (4.6% CAGR), raising the share of electricity from 31% in 2016 to 55% in 2050.

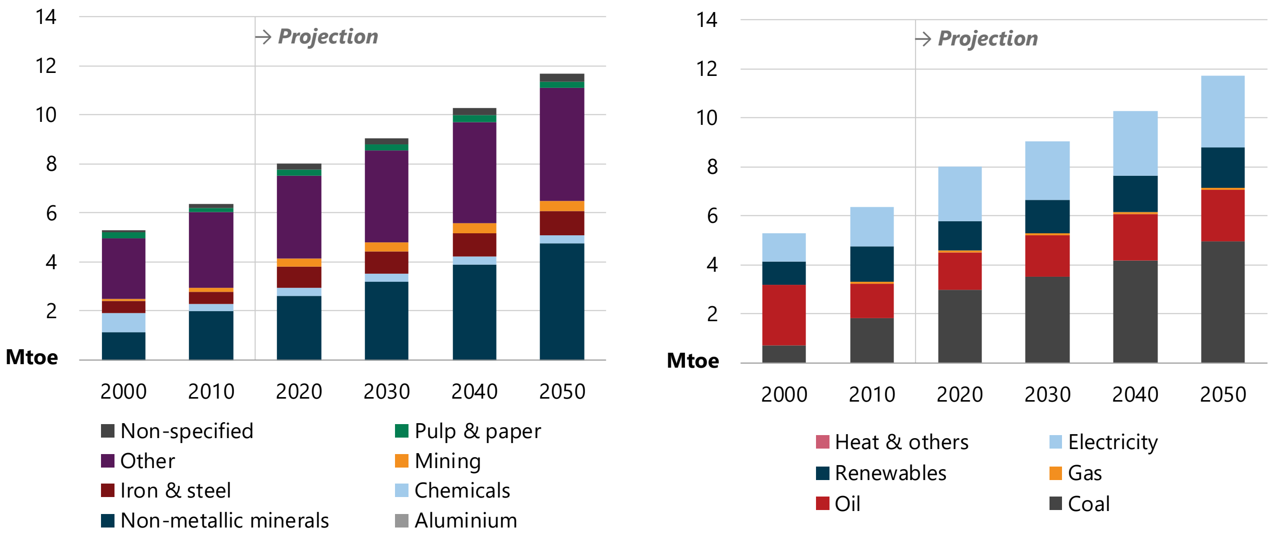
Electricity also comes to dominate the services subsector, with the share increasing from 48% in 2016 to 80% in 2050, mostly owing to greater demand for space cooling, lighting and other end-uses as floor area more than doubles. The largest increase is in the 'other' subsector, as it includes the appliances and electronics (such as computers) that pervade the services subsector during the projection period.

The Philippine Energy Efficiency Project, funded by the Asian Development Bank, was introduced to promote energy-efficient lighting systems in buildings (ADB, 2019). The revised Energy Efficiency and Conservation Roadmap addresses energy demand in services, including energy efficiency measures in the building code and 'green building' ratings (DOE, 2019b). These measures are projected to curtail demand growth and improve energy use per square metre in residential and services buildings over the Outlook.

INDUSTRY: COAL USE IN NON-FERROUS METALS PUSHES UP DEMAND

Industry has been a key driver of economic growth in the Philippines, contributing about one-third of GDP in 2016 (World Bank, 2019b). Energy demand has also been growing quickly, from 5.3 Mtoe in 2005 to 7.5 Mtoe in 2016 (3.3% CAGR), and it continues to increase to 12 Mtoe by 2050 (1.3% CAGR) under the BAU. Coal use expands the most (1.8% CAGR), its share of industry energy use rising from 37% in 2016 to 43% in 2050 (Figure 15.3). It is used mostly in the non-metallic minerals and the iron and steel subsectors, which grow rapidly in pace with economic development. Electricity and oil use also increase (electricity 40% and oil 42%), but their shares drop slightly between 2016 and 2050: from 28% to 25% for electricity and from 19% to 18% for oil.

Figure 15.3 • The Philippines: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

The non-metallic subsector accounts for 56% of the increase in industrial energy demand over the Outlook period, mostly driven by domestic infrastructure development, and buildings construction. Non-metallic industry energy demand, therefore, more than doubles, from 2.4 Mtoe in 2016 to 4.8 Mtoe in 2050 (2.0% CAGR). Energy demand from other subsectors, such as chemicals and petrochemicals, iron and steel and pulp and paper, grow more modestly at CAGRs of less than 1.0%.

The government recently launched the Philippine Industrial Energy Efficiency Project, funded under the Global Environment Fund in partnership with the United Nations Industrial Development Organization. It aims to introduce and provide tools and capacity-building for applying the ISO 50001 Energy Management Standard and System Optimization Frameworks in the chemical, food and beverages, iron and steel, and pulp and paper subsectors (DOE, 2019c).

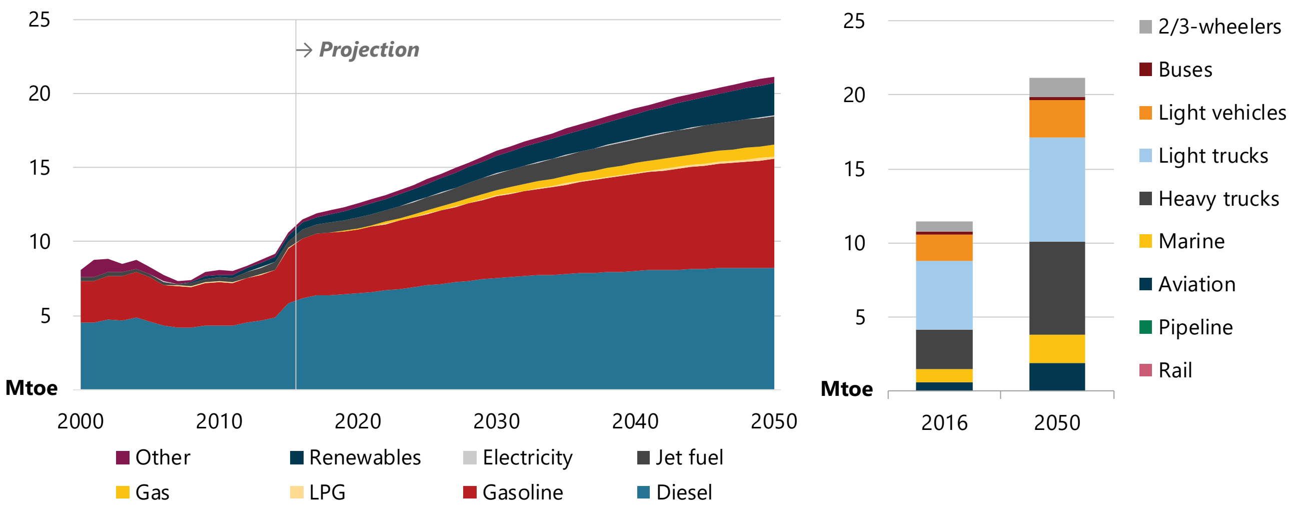
TRANSPORT: GASOLINE AND DIESEL USE CONTINUE TO INCREASE

Domestic transport energy use stagnated in the early 2000s but then grew at a CAGR of 6.1% from 2010 to reach 12 Mtoe in 2016. Although growth moderates under the BAU (2.1% CAGR), demand still doubles from 13 Mtoe in 2016 to 26 Mtoe in 2050. Most domestic transport energy is used for road transport (87% in 2016 and 82% in 2050)—mainly in the form of gasoline and diesel for light-duty vehicles (LDVs) and heavy-duty trucks (HDTs) (Figure 15.4).

Energy demand in air transport increases from 0.59 Mtoe in 2016 to 1.9 Mtoe in 2050 as per-capita GDP growth leads to a three-fold increase in passenger-kilometres (pkm) travelled. The amount of energy used for maritime transport connecting the 7 000 islands of the Philippines likewise increases, from 0.85 Mtoe to 1.9 Mtoe over the Outlook, as pkm travelled doubles (although from a higher base than for air transport).

As part of the Energy Efficiency and Conservation Roadmap, the government introduced a vehicle labelling program and fuel efficiency standards to reduce road transport energy use. To further enhance transport efficiency, the government plans to devise a long-term master plan for transport and urban planning (DOE, 2019c). This program helps to moderate demand growth in the transport sector, as improving the efficiency of LDVs (from 4.2 megajoules [MJ] per km to 2.7 MJ per km) and HDTs (from 12 MJ per km to 8.9 MJ per km) partially offsets a doubling in the stock of both vehicle types over the Outlook.

Figure 15.4 • The Philippines: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

TPES was 55 Mtoe in 2016, with renewables and oil contributing about one-third each and coal contributing one-quarter. Half of the energy supply came from domestic resources in 2016, with energy production at 29 Mtoe. However, the energy supply of the Philippines becomes more import-dependent in the BAU as TPES doubles over the Outlook period and energy production increases at a much lower rate.

ENERGY TRANSFORMATION: REFINERY SECTOR EXPANDS IN THE NEAR TERM

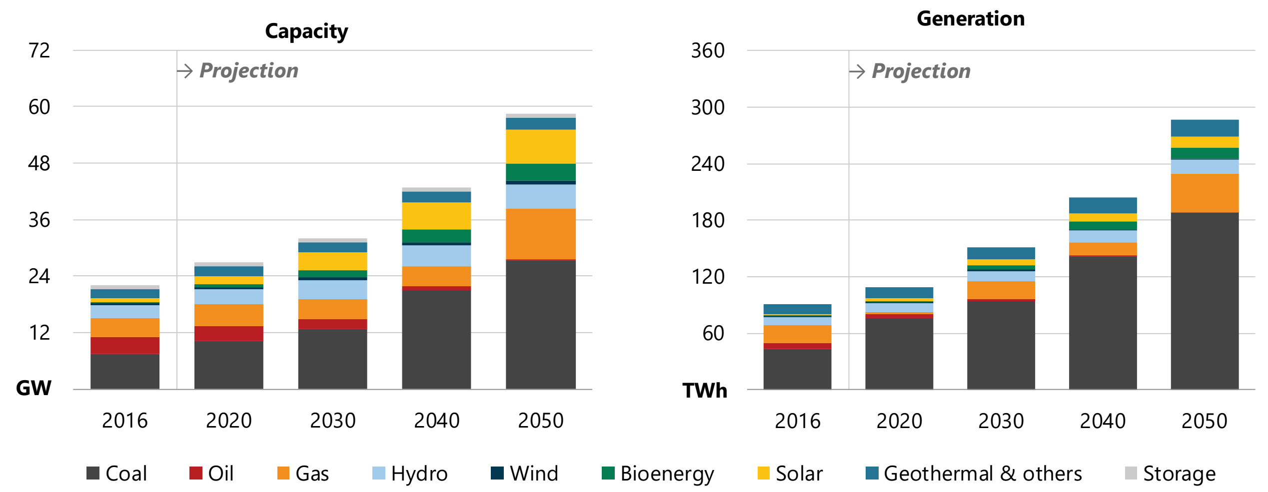
The refinery sector expands in the upcoming decade as Petron, the largest oil refiner and one of the two companies with facilities in the Philippines, plans to expand its refinery capacity from 180 000 barrels (bbl) of oil per day (9.0 Mtoe) to 270 000 bbl per day (13 Mtoe). Investment for this additional capacity is estimated at USD 3.5 billion and operations are expected to start by 2022. Refinery industry energy own-use grows even more strongly than capacity (from 0.24 Mtoe in 2016 to 1.3 Mtoe in 2050) as refinery utilisation rates continue to rebound from their recent and historical lows over the Outlook period.

POWER SECTOR: COAL AND RENEWABLES INCREASE

Electricity generation in the Philippines has more than doubled since the turn of the century, from 45 terawatt-hours (TWh) in 2000 to 91 TWh in 2016. Coal accounted for 48% of electricity generation in 2016, followed by renewables (24%) and natural gas (22%). Coal and renewables have long been integral to the Philippines' generation mix, but natural gas has largely replaced oil since 2000.

Electricity demand more than triples over the Outlook period, from 91 TWh in 2016 to 287 TWh in 2050, driven by rapid economic growth. This demand increase prompts a more than doubling of generation capacity over the Outlook, from 22 GW to 59 GW (Figure 15.5). Coal (20 GW) and renewables (13 GW) lead the capacity expansion, while oil continues to decline and is practically phased out as an input fuel for power generation by 2050.

Figure 15.5 • The Philippines: Power capacity and electricity generation by fuel, 2016-50



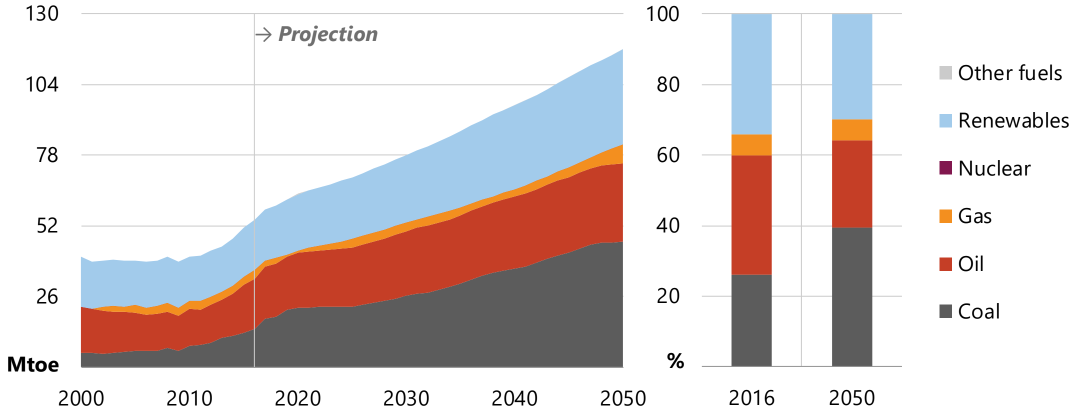
Sources: APERC analysis and IEA (2018a).

Despite negative environmental and social impacts, coal is an attractive resource for power generation because of its low cost compared with natural gas and oil. In terms of power capacity, coal expands almost four-fold and accounts for 47% of total capacity in 2050. In total power generation, the coal share is even higher, reaching 66% in 2050, followed by renewables (20%) and natural gas (15%). Renewables capacity expands at a CAGR of 3.4%, rising from 6.2 GW in 2016 to 19 GW in 2050 and expanding its share in total generation capacity from 28% to 33%. Solar power (6.9% CAGR) and bioenergy (8.5% CAGR) expand sharply, while the CAGRs of hydropower (1.7%) and wind power (2.0%) are more modest. Oil capacity shrinks from 3.6 GW in 2016 to 0.14 GW in 2050 as existing power plants are retired and peaking capacity is met by hydro and natural gas.

TOTAL PRIMARY ENERGY SUPPLY: COAL SHARE EXPANDS

TPES of the Philippines doubles in the BAU, from 55 Mtoe in 2016 to 118 Mtoe in 2050, as increasing energy supplies are needed to meet economic growth. Coal leads the increase, overtaking renewables for the largest share of TPES in 2040 and reaching 39% by 2050—up from 26% in 2016 (Figure 15.6). Increased use in power generation drives 94% of this growth. To reduce dependency on imported coal, the government will formulate and implement a policy to expand the use of domestically produced lignite and locally adopt technology upgrades, such as coal washing, preparation and blending, to comply with environmental standards. The government has also explored alternative uses of coal through a project assessing the coal-bed methane potential of selected coalfields (DOE, 2017a).

Figure 15.6 • The Philippines: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

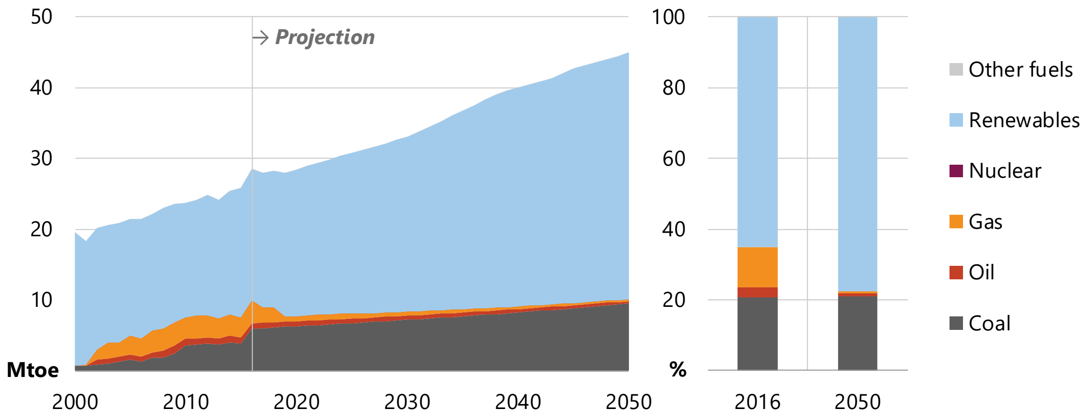
Renewables account for 31% of TPES in 2050, down from 34% in 2016 as a result of higher coal use in the power sector. Bioenergy and geothermal account for more than 90% of renewable resources, whereas wind and solar contribute only 3.1% of the renewable energy supply. Geothermal was the largest renewable energy resource in 2016, while bioenergy is the largest in 2050. Bioenergy, mostly solid biomass, is widely used for cooking and heating in residential buildings and is also used in industry and services. Bioenergy use doubles over the projection period, reaching 18 Mtoe (a 15% share of TPES) in 2050.

The share of oil in TPES drops from 34% in 2016 to 24% in 2050 because its use expands more slowly than that of coal. Fuel efficiency improvements in transport, together with the introduction of more biofuels and reduced demand for oil-based electricity generation, constrain growth. The share of natural gas is volatile, driven by power generation, but ends the Outlook as it started, around a share of 6.0%.

ENERGY PRODUCTION AND TRADE: COAL AND OIL IMPORTS CONTINUE TO EXPAND

As the economy expands and domestic energy production struggles to meet increased energy demand, the Philippines increases energy imports significantly under the BAU. While TPES increases by 116% over the Outlook period, domestic energy production rises only 62%, from 29 Mtoe in 2016 to 46 Mtoe in 2050 (Figure 15.7). Due to the Philippines having only modest fossil fuel reserves, renewable energy remains the largest source of primary energy production, increasing from 65% in 2016 to 78% in 2050. Most of this production growth is in bioenergy and geothermal, which are used mainly in the buildings, industry and power sectors.

Figure 15.7 • The Philippines: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Net energy imports increase at a CAGR of 3.0%, reaching 75 Mtoe in 2050 (from 28 Mtoe in 2016). Net coal imports quadruple from 8.2 Mtoe in 2016 to 37 Mtoe in 2050 to meet growing power sector demand, as domestic coal production increases only 3.5 Mtoe over the projection period. Net crude oil imports also expand rapidly, tripling from 9.8 Mtoe in 2016 to 33 Mtoe in 2050 as refining capacity increases almost three times to meet domestic oil demand growth. Conversely, net oil product imports decrease rapidly (from 9.6 Mtoe in 2016) and shift to net export status in 2020.

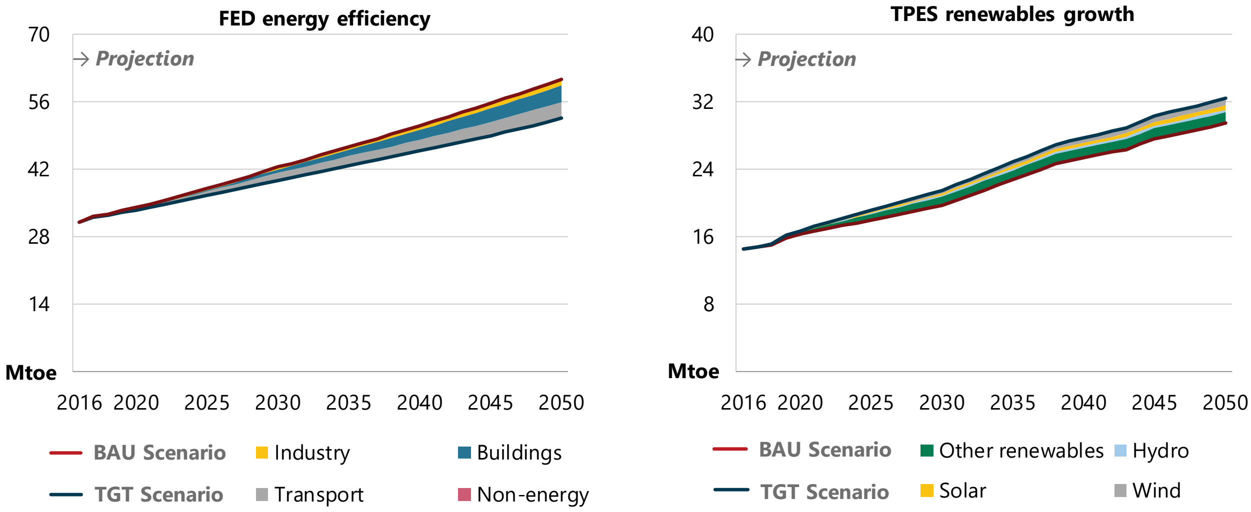
ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of current energy demand and supply trends as well as policy commitments in the Philippines, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 13% lower while carbon dioxide (CO_2) emissions are 14% lower under the TGT in 2050. Under the 2DC, the Philippines' FED is 29% lower and CO_2 emissions are 71% lower. The share of renewables in TPES is 4% higher in the TGT and 27% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. Energy intensity (measured as final energy in tonnes of oil equivalent [toe] per unit of GDP) in the Philippines drops significantly through the Outlook (60%), from 41 toe per USD million in 2016 to 16 toe per USD million in 2050. Achieving the TGT assumptions requires numerous policy changes, such as more stringent fuel efficiency regulations in the transport sector, more and stricter building and appliance standards, and stronger government support for renewables. Under the TGT, FED increases 69% to 53 Mtoe in 2050, compared with 61 Mtoe in the BAU (Figure 15.8). The largest energy demand comes from buildings (42% in 2050), followed by transport (35%). Total renewables use shrinks compared with the BAU because FED is much lower.

Figure 15.8 • The Philippines: Energy efficiency and renewables, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by fuel type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Buildings energy demand grows from 11 Mtoe in 2016 to 23 Mtoe in 2050—3.5 Mtoe below the BAU. Improved efficiency resulting from stronger building and electric appliance regulations is the main source of reduced demand in both the residential (3.0 Mtoe lower in 2050 than in the BAU) and services (0.46 Mtoe lower) subsectors.

Domestic transport energy demand increases from 11 Mtoe in 2016 to 18 Mtoe in 2050, remaining 3.3 Mtoe below the BAU projection. Most of the demand reduction comes from road transport, which has the largest share in all scenarios. Although the vehicle stock doubles, oil use in road transport remains flat (9.6 Mtoe in 2016 and 11 Mtoe in 2050), reflecting more stringent fuel standards and the transition to a more efficient fleet.

In industry, energy demand reaches 11 Mtoe in 2050 (from 7.5 Mtoe in 2016), which is 1.2 Mtoe below the BAU. The reduction comes mainly from the non-metallic subsector, which uses less coal in the TGT as more energy-efficient technologies are applied through increased deployment of best available technologies (which improves the clinker-to-cement ratio).

Renewables use in FED increases 37%, from 5.8 Mtoe in 2016 to 7.9 Mtoe in 2050, although increased energy efficiency and more aggressive fuel switching (from biomass to electricity in the residential sector) result in 15% lower renewable energy demand in 2050 than in the BAU. This is marginally offset by stronger growth in renewables use in other sectors. In road transport, higher biofuel mandates boost renewables across the sector, from 0.42 Mtoe in 2016 to 2.5 Mtoe in 2050 (16% higher than in the BAU). In industry, fuel switching from coal to modern biomass causes renewable energy demand to grow from 1.2 Mtoe in 2016 to 1.8 Mtoe in 2050 (11% above the BAU). In the electricity generation sector, renewable capacity increases more than four-fold, from 6.2 GW in 2016 to 29 GW in 2050 (9.8 GW above the BAU). This additional renewable capacity mainly offsets coal and natural gas, which each fall around 2.0 GW below their levels in the BAU.

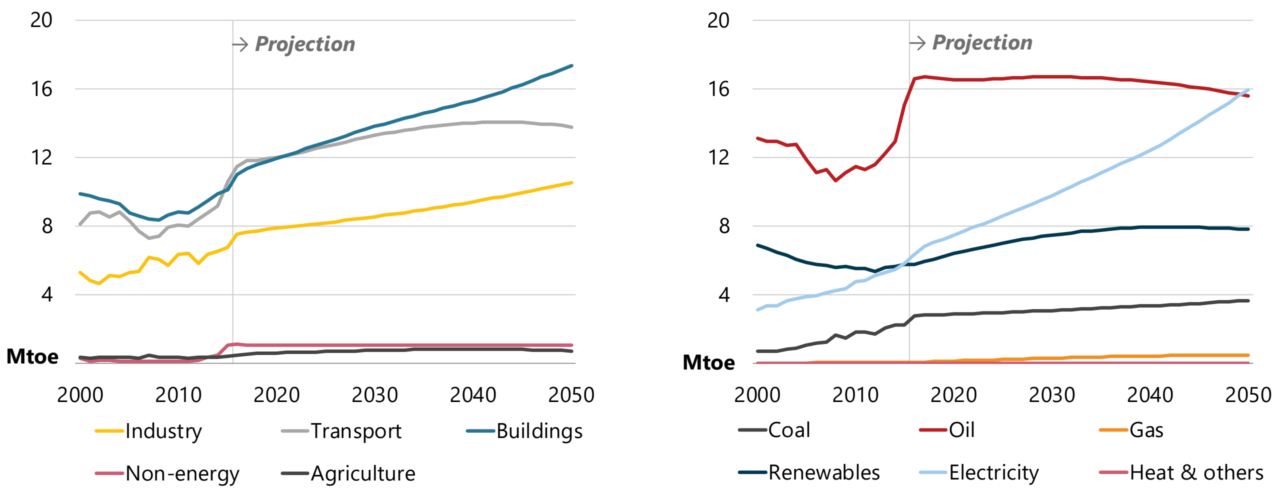
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in the Philippines will have to undergo various levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Reducing CO_2 emissions to put the Philippines on the 2DC pathway is most effectively achieved in FED sectors through improved efficiency since opportunities for additional renewable energy deployment are limited. Total FED under the 2DC is therefore 43 Mtoe in 2050—29% below the BAU and 19% below the TGT—owing to demand reductions, mainly in buildings and transport (Figure 15.9).

Figure 15.9 • The Philippines: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Buildings energy demand under the 2DC increases by 58%, from 11 Mtoe in 2016 to 17 Mtoe in 2050 (9.3 Mtoe lower than in the BAU). Residential energy demand increases 71% over the projection period, mainly due to increased deployment of space cooling and electrical appliances, which reflects income growth. Services energy demand increases by 34%, from 3.9 Mtoe in 2016 to 5.2 Mtoe in 2050. Total buildings electricity demand increases strongly, from 4.1 Mtoe in 2016 to 12 Mtoe in 2050, as electrification, fuel switching and appliance use expand in both subsectors. Reduced energy demand compared with the BAU and TGT scenarios is the result of improved building standards and enhanced minimum energy performance standards (MEPS) for appliances. Renewables use in buildings falls from 4.2 Mtoe to 3.2 Mtoe as consumers switch from traditional biomass to electricity more aggressively than in the other scenarios to improve air quality.

Domestic transport energy demand rises only marginally, to 14 Mtoe in 2050 from 12 Mtoe in 2016. Electricity demand increases at a CAGR of 15% over the projection period, reflecting greater deployment of electric vehicles in response to environmental concerns. Renewables expand at a 5.2% CAGR as biofuel use increases in road transport. Oil use shrinks slightly, from 11 Mtoe in 2016 to 10 Mtoe in 2050, as the shares of electricity and renewables increase strongly.

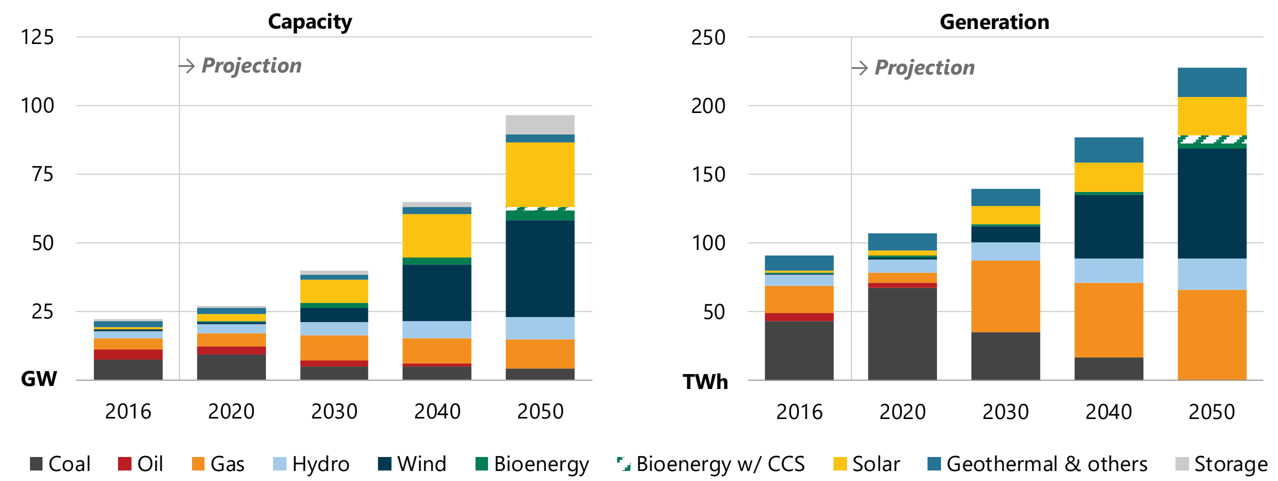
Industry FED grows 40%, from 7.5 Mtoe in 2016 to 11 Mtoe in 2050 (1.2 Mtoe below the BAU). Almost 50% of this growth can be attributed to the non-metallic minerals subsector, which supports buildings' floor area expansions but also accounts for most of the energy demand reduction compared with the BAU. The iron and steel and the mining subsectors make up the rest.

TRANSFORMATION AND SUPPLY IN THE 2DC

The electricity generation sector undergoes profound changes under the 2DC, despite still expanding strongly. Generation increases from 91 TWh in 2016 to 228 TWh in 2050, and power capacity expands four-fold, from 22 GW to 97 GW (Figure 15.10). In contrast to the BAU and TGT, however, coal-based generation drops drastically from 43 TWh in 2016 to 1.8 TWh in 2046 and then is phased out completely. As natural gas and renewables replace the lost coal, natural gas generation capacity increases almost three-fold, from 4.0 GW in 2016 to 11 GW in 2050.

Renewables also expand rapidly with a twelve-fold expansion in capacity—from 6.2 GW in 2016 to 75 GW in 2050—and a seven-fold increase in power generation, from 22 TWh in 2016 to 162 TWh in 2050. Significant new solar capacity (24 GW) and wind capacity (35 GW) is installed over the Outlook period. Bioenergy use also rises dramatically, from 0.22 GW of capacity (and 0.72 TWh of generation) in 2016 to 4.7 GW (9.3 TWh) in 2050. Hydro generation increases almost three times, from 8.1 TWh in 2016 to 22 TWh in 2050, and geothermal doubles from 11 TWh in 2016 to 22 TWh in 2050.

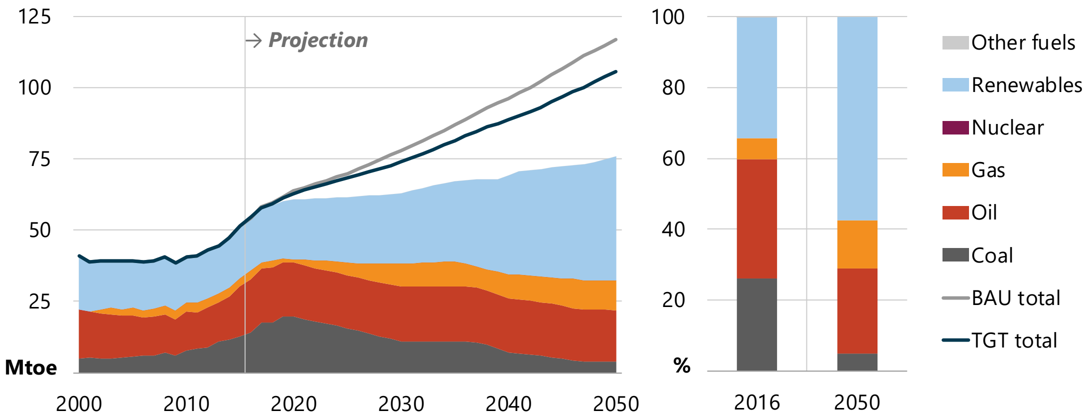
Figure 15.10 • The Philippines: Power and electricity in the 2DC by fuel, 2016-50



Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

TPES in the 2DC grows 40%, from 55 Mtoe in 2016 to 76 Mtoe in 2050, 35% lower than the BAU (Figure 15.11). The share of coal falls from 26% in 2016 to 5.0% in 2050 as the coal supply shrinks from 14 Mtoe in 2016 to 3.8 Mtoe in 2050. This drop is mainly driven by decarbonisation efforts in the electricity sector, which eliminate coal from its fuel mix in 2047. The renewables share is also drastically different in the 2DC, with a strong increase from 34% in 2016 to 58% in 2050, mostly owing to the greater use of bioenergy, geothermal and wind resources in electricity generation. Oil (0.29 Mtoe lower in 2050 than in 2016) and natural gas (7.1 Mtoe higher) are less affected than renewables in the 2DC because demand for oil shrinks slightly as efficiency in transport, and for natural gas enlarges somewhat in response to higher demand in the power sector.

Figure 15.11 • The Philippines: TPES in the 2DC compared with the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Energy production in the 2DC rises to 47 Mtoe (0.40 Mtoe below the TGT and 0.35 Mtoe above the BAU) as a result of increased renewables demand. Production of renewables expands to 44 Mtoe in 2050, compared with 36 Mtoe in the BAU, for use in electricity generation and to meet biodiesel and bioethanol demand for transport and biomass demand in industry. Oil production remains unchanged across all three scenarios, as the Philippines produces at maximum economic quantity. Coal production, however, is much lower in the 2DC (at 1.3 Mtoe in 2050 compared with 9.5 Mtoe in the BAU) due to significantly lower demand.

Energy imports rise only slightly—from 33 Mtoe in 2016 to 34 Mtoe in 2050—in comparison with strong growth in the TGT (68 Mtoe) and BAU (80 Mtoe). Coal imports are significantly diminished to 2.9 Mtoe by 2050, compared with 39 Mtoe in the BAU, because of reduced power demand. Natural gas imports are significantly larger in the 2DC (9.9 Mtoe in 2050, compared with 6.9 Mtoe in the BAU) to support higher gas-fired power generation. Crude oil and petroleum products account for the majority of energy imports across all scenarios due to consistently robust transport demand.

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[74]

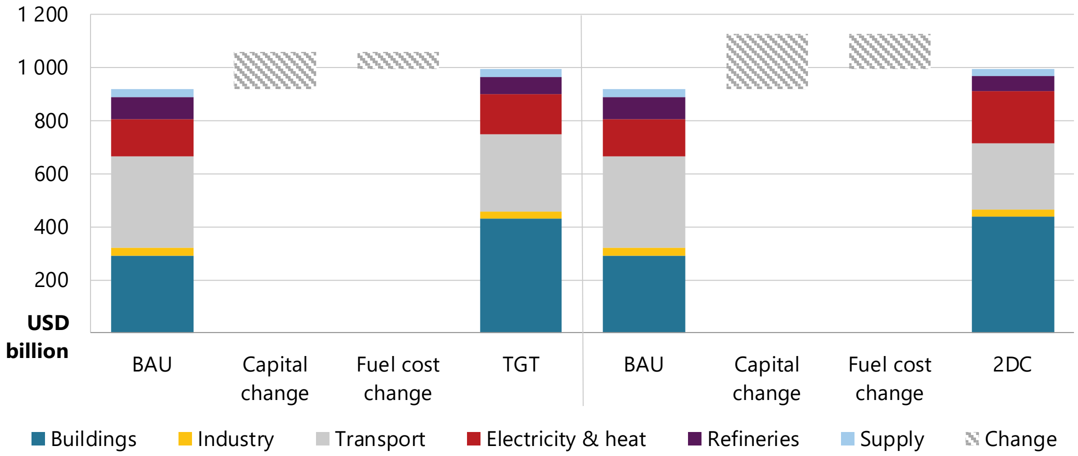
Total cumulative energy investment under the BAU is USD 918 billion over the Outlook period (Figure 15.12). Energy capital investments amount to USD 330 billion, with electricity and heat accounting for 37% (reflecting the huge expansion in electricity capacity), followed by buildings (25%), refineries (18%), transport (11%), supply (8.1%), and industry (0.06%). Fuel costs are USD 588 billion, dominated by transport (52%) and buildings (35%).

Total energy investments increase to USD 993 billion in the TGT and USD 996 billion in the 2DC. Unlike in the BAU, however, the buildings sector attracts most of the investment in the TGT and 2DC: cumulative buildings

[74] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

capital investment is USD 244 billion in the TGT and USD 280 billion in the 2DC, compared with USD 84 billion in the BAU. The additional investment is mainly for the residential subsector and can be attributed to increased electrification and fossil fuels replacing traditional bioenergy. In the 2DC, one-third of the capital investment is earmarked for electricity and heat, compared with 28% of the total investment in the TGT. Greater deployment of solar PV, coal and bioenergy with carbon capture and storage (CCS), combined with faster retirement of coal-fired power plants, results in USD 181 billion worth of investments and a significant reduction in CO_2 emissions. Higher capital costs in the two alternative scenarios are offset by lower fuel costs: USD 521 billion in the TGT and USD 455 billion in the 2DC (compared with USD 588 billion in the BAU). These lower costs, which result from energy efficiency improvements, are not greater in the 2DC than the TGT and the BAU because of the behavioural changes assumed under the 2DC (such as lower pkm travelled in transport and lower floor area as a result of teleworking in services).

Figure 15.12 • The Philippines: Energy sector capital and fuel costs, 2016-50



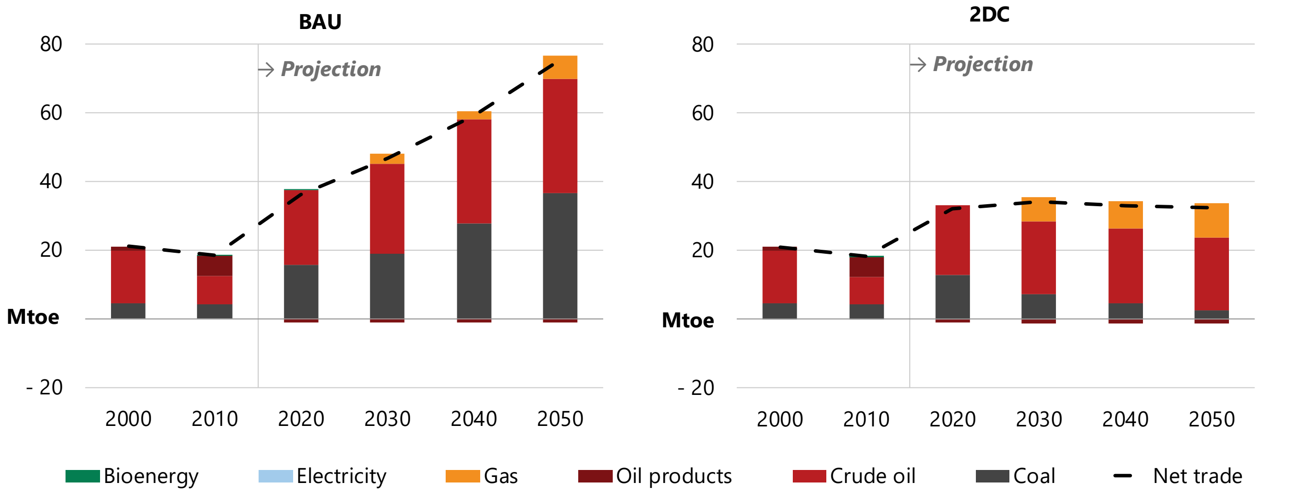
Sources: APERC analysis and IEA (2018a)

ENERGY TRADE AND SECURITY

The Philippines is a net fossil fuel importer, as its domestic resources are limited to a natural gas field nearing depletion and low-quality coal. Crude oil imports, mostly from the Middle East, amounted to 11 Mtoe in 2016 (Figure 15.13). In the BAU, they rise to 34 Mtoe in 2050 as refinery capacity expands to meet increasing domestic demand for petroleum products. With lower transport demand in the 2DC, crude oil imports reach only 22 Mtoe in 2050. Expanding intra-APEC crude trade could make the Philippines less dependent on Middle Eastern crude in all scenarios.

Natural gas imports begin before 2025, as depletion of the Malampaya natural gas field is expected during 2022-24; by 2050, net imports reach 6.9 Mtoe in the BAU and 9.9 Mtoe in the 2DC. The government is considering constructing liquefied natural gas (LNG) import terminals and floating storage regasification units to receive LNG from other economies. Net coal imports expand four-fold in the BAU (to 37 Mtoe in 2050) due to strong demand growth in the electricity sector and more stringent requirements for power generation plants to use high-quality imported coal blended with a small portion of domestic coal. In the 2DC, net imports fall to 2.5 Mtoe in 2050 as demand for electricity generation drops sharply. Net coal imports in 2016 were 8.2 Mtoe, mostly from Indonesia, with the rest coming from Australia and Viet Nam.

Figure 15.13 • The Philippines: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

As energy security is an important concern, the government prioritises the development and use of domestic energy resources to improve energy self-sufficiency and reduce import reliance; it also regularly conducts the Philippine Conventional Energy Contracting Program[75] for petroleum and coal. Meanwhile, as set out in the Renewable Energy Act of 2008, renewables development raises energy supply security (reflected in the higher primary energy self-sufficiency rates in the TGT and the 2DC) while providing access to clean, sustainable energy (Table 15.3).

Table 15.3 • The Philippines: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	43	32	35	37	28	32	37
Coal self-sufficiency (%)	50	37	43	49	24	31	23
Gas self-sufficiency (%)	91	14	8.1	13	8.9	3.6	4.9
Crude oil self-sufficiency (%)	7.3	2.2	2.4	2.6	1.1	1.3	1.7
Primary energy supply diversity (HHI)	0.29	0.29	0.27	0.24	0.29	0.26	0.21
Coal reserve gap (%)	1.3	31	31	27	84	84	45
Gas reserve gap (%)	6.0	38	32	49	54	43	77
Crude oil reserve gap (%)	4.0	54	54	54	104	104	104

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

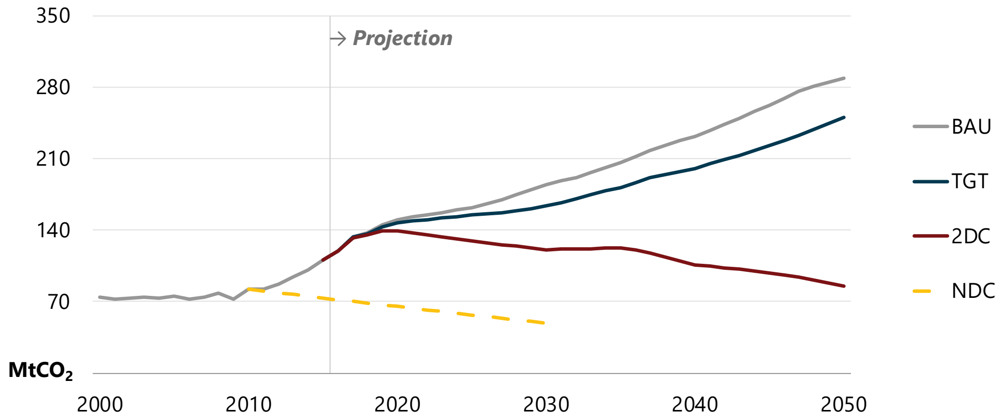
[75] Program to promote exploration and development of oil and gas by introducing a nomination-based application and challenge process available year-round, and access to marginal fields.

SUSTAINABLE ENERGY PATHWAY

As an archipelago with a population of more than 100 million, the Philippines is highly vulnerable to the impacts of climate change and natural hazards. It was the fifth most-affected economy in the world in 1997-2016, according to the long-term Climate Risk Index (Germanwatch, 2018). In this context, in 2015 the Philippines announced its conditional Nationally Determined Contribution (NDC)[76] to reduce CO_2 emissions 70% by 2030, compared with the economy's official 2000-30 business-as-usual projections. The NDC establishes that pursuing mitigation actions is contingent on receiving international financing, technology transfer and capacity-building support. The NDC also highlights the Philippines' need for technical inputs and assistance to reduce energy sector CO_2 emissions through grid efficiency improvements, the development of energy efficiency standards, the increased uptake of cost-effective renewable energy, and the adoption of alternative or high-efficiency technology for conventional power generation.

In the BAU, energy sector CO_2 emissions double, increasing more quickly than in the TPES as the share of coal in the energy mix expands, mainly at the expense of renewables. Although the TGT results in 14% lower CO_2 emissions in 2050, total energy-related CO_2 emissions increase in both scenarios, from 120 million tonnes of carbon dioxide ($MtCO_2$) in 2016 to 288 $MtCO_2$ in the BAU and 249 $MtCO_2$ in the TGT (Figure 15.13). In the 2DC, energy emissions are projected to decrease to 83 $MtCO_2$ in 2050—71% below the BAU. Coal emissions drop 81% and oil emissions decrease 14% in 2016-50, while natural gas emissions increase from 7.7 $MtCO_2$ in 2016 to 24 $MtCO_2$ in 2050. Most of these changes in the 2DC stem from the electricity generation sector, in which coal disappears by 2050 while renewables and natural gas use both expand.

Figure 15.13 • The Philippines: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

[76] NDCs reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), referred to as the 'COP21 Paris Agreement'.

OPPORTUNITIES FOR POLICY ACTION

Despite government efforts to implement policies promoting renewable energy, coal use in power generation accelerates in the BAU Scenario. As its economy grows rapidly, the Philippines requires more affordable energy to maintain economic competitiveness. Although no policy facilitating coal use exists, the coal share in electricity generation expands because it is a relatively inexpensive resource compared with other fuels. The government should, therefore, develop policies to construct more advanced coal-based power plants that employ ultra-supercritical (USC) or advanced USC technology, and should also explore the feasibility of CCS development for both fossil fuels and bioenergy.

Expanding the deployment of renewables—particularly in power generation—should also be prioritised to help curtail costly imports, improve energy security and meet the Philippines' NDC commitment. A detailed renewable energy technology and resource assessment to determine realistic potential and to address grid integration issues should be undertaken as soon as possible.

The NDC emissions reduction target is not achieved on schedule in any of the three scenarios, indicating that additional policy measures beyond even the 2DC are required. As the economy grows, fossil fuel dependency (and hence emissions) will increase unless renewable technology installation costs fall sufficiently to ensure that renewables are the main energy resource deployed to meet increasing demand. Balancing strong economic growth with CO_2 emissions reductions is therefore expected to be a challenge.

To strengthen energy efficiency and conservation, the Energy Efficiency and Conservation (EE&C) Act was passed by the two houses of the Philippines' congress in January 2019. Once the legislation is implemented, the energy efficiency regulations identified in the Energy Efficiency and Conservation Roadmap will become mandatory in all sectors. Among the important provisions of the EE&C Act is the establishment of MEPS to identify the minimum energy performance that appliances, lighting, electrical equipment and machinery must meet or exceed before they can be imported, offered for sale or used in the economy. It is important that these standards be set at a level that makes significant energy efficiency progress achievable without placing undue compliance or cost burdens on both retailers and consumers.

16. RUSSIA

KEY FINDINGS

- **Russia's energy and emissions intensities improve over the Outlook period in all three scenarios.** Structural economic changes, lower reliance on energy exports for budget revenue and domestic market liberalisation are contributory factors.

- **Russia's economic growth of 82%, supported by industrial development, drives energy demand by 20% over the Outlook period.** Industrial energy demand increases by 31% in the BAU, driven by production output increases from non-metallic minerals (65%), aluminium (35%), paper and pulp (25%), steel (25%) and chemicals and petrochemicals (23%).

- **Under the TGT, cumulative energy demand is reduced 1 508 Mtoe below BAU levels,** driven largely by declines in industry (36%) and buildings (28%). The share of renewables in power generation reaches 18% in 2030 and 22% in 2050, driven by large-scale hydro.

- **Under the 2DC, cumulative energy demand is reduced 2 893 Mtoe below BAU levels.** The largest reduction occurs in buildings (34%), in which emissions are reduced by 62%. Energy exports also decline (13% below BAU), indicating that relying on an export-oriented energy sector to drive economic growth may not be sustainable in the 2DC.

- **Russia achieves its INDC commitments under all scenarios by gradually decoupling economic growth from energy-related CO_2 emissions.** This is achieved through the adoption of best available technologies, and addressing key polluting sub-sectors.

ECONOMY AND ENERGY OVERVIEW

Russia has the largest land area in the Asia-Pacific Economic Cooperation (APEC) region and the world. Population stood at 144 million in 2016. Gross domestic product (GDP) grew from USD 2 198 billion PPP in 2000 to USD 3 821 billion PPP in 2016 at a compound annual growth rate (CAGR) of 3.5%, whereas GDP per capita grew at a CAGR of 3.6% to reach USD 26 543. Key macroeconomic indicators are summarised in Table 16.1.

While goods manufacturing, trade and transportation are the main drivers of Russia's economic development, accounting for 45% of GDP (GKS, 2018a), the energy sector is also a large contributor, accounting for 23% of GDP in 2016 (MoE, 2017a). Russia is a large energy exporter. In 2016, it exported over 600 million tonnes of oil equivalent (Mtoe) worth USD 269 billion, which was 57% of total exports (IEA, 2018a; MoE, 2017b).

Table 16.1 • Russia: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	2 198	3 522	3 821	4 280	5 622	6 616	6 939
Population (million)	146	143	144	144	141	136	133
GDP per capita (2016 USD PPP)	15 013	24 603	26 543	29 769	40 005	48 703	52 282
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	625	698	731	760	819	859	877
TPES per capita (toe)	4.3	4.9	5.1	5.3	5.8	6.3	6.6
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	284	198	191	177	146	130	126
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	418	449	472	494	531	554	566
FED per capita (toe)	2.9	3.1	3.3	3.4	3.8	4.1	4.3
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	190	128	124	116	94	84	82
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	1 508	1 557	1 603	1 613	1 716	1 777	1 793
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

Mineral resources are mined in various climate zones and regions of Russia. Most natural gas is produced in the Khanty-Mansi Autonomous region and most crude oil comes from the Tyumen Oblast; both are located in Western Siberia. The Arctic is estimated to contain between 26 000 Mtoe and 97 000 Mtoe of oil and natural gas reserves, with 70% of natural gas and 30% of oil in the Russian territory (Moore, 2017). Russia's average annual temperature varies from -2 degrees Celsius (°C) to +14 °C in the European part and from -16 °C to +4 °C in other regions. This makes Russia the coldest economy in APEC, which contributes to its high energy intensity. In 2016, total primary energy supply (TPES) per capita was 5.1 tonnes of oil equivalent (toe) per person, compared with 2.8 toe per person for APEC. Total final energy demand (FED) per capita was 3.3 toe, higher than the APEC average of 1.9 toe.

Despite a drop in revenues from oil and natural gas, from 53% in 2014 to 38% in 2016, these fuels still contribute greatly to Russia's state budget and remain important for its economic development (MoE, 2017c). A mineral resource tax (NDPI) is applied to all crude oil production and an oil export duty is applied to volumes exported overseas. A new oil excess profit tax (NDD) was introduced in 2017 to help sustain existing, and attract new, investment in oil production. This is especially important for the main oil-producing province of Western Siberia, where production decreased from 308 Mtoe in 2010 to 286 Mtoe in 2016 (MoE, 2017c).

ENERGY RESOURCES

Russia is the third-largest energy producer in both APEC and the world. As of 2017, Russia holds 6.3% of global proved crude oil reserves, 18% of proved natural gas reserves and 15% of coal reserves (Table 16.2). Currently, 25 oil and natural gas bearing provinces have been identified, of which four are labelled as prospective (Kalamkarov, 2005). Key provinces in the European part are Volgo-Ural'skaya, Prikaspijskaya, and Timano-Pechyorskaya; in central and eastern Russia they are Leno-Tungusskaya, Enisejsko-Anbarskaya, Leno-Viljujskaya and Zapadno-Sibirskaya, with total reserves of nearly 58 000 Mtoe of crude oil and 90 000 Mtoe of natural gas. The province of Zapadno-Sibirskaya, in Western Siberia, currently produces nearly 70% of crude oil and 90% of natural gas.

Table 16.2 • Russia: Energy reserves and production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	160 364	391	15	2	2
Oil (billion bbl) [a]	106	26	6.3	6	2
Natural gas (tcm) [a]	35	55	18	1	1
Uranium (tU) [b]	214 500	74	5.5	7	3

Notes: a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kilogram of uranium (kgU). Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. tU = tonnes of uranium.
Sources: for coal, oil and natural gas, BP (2018); for uranium, NEA (2018).

In addition to fossil fuel resources, Russia has significant potential for renewable energy, including 27 000 Mtoe of solar, mainly in the Rostov region and Krasnodar territory (in the south-west); 5 400 Mtoe of wind, mainly in Kalmykia Republic and the Stavropol region (near the Caucasus); 800 Mtoe of forest biomass, mainly in the Irkutsk region and southern Krasnoyarsk territory (in Eastern Russia); 77 000 Mtoe of geothermal in Kamchatka; and 200 Mtoe of small-scale hydro in Siberia and the Russian Far East (HSE, 2017). Using this potential is, however, restricted by the vast distances over which energy needs to be transported to reach consumers.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

The key objectives of Russia's energy policy include attracting investment into infrastructure renovation; stimulating innovation; maximising the benefits of energy resources to the economy; maximising Russia's integration into global energy markets; and continue being a reliable energy supplier (MoE, 2017d).

The government recently launched a new pricing mechanism to boost profitability and attract infrastructure investment in the heat supply industry, which is an essential asset in Russia's very cold climate. Russia is the largest heat producer and consumer in APEC, making up over 50% of APEC heat demand in 2016, and new 'Alternative Boiler House' guidelines are expected to establish a heat market (MoE, 2018a).

To support domestic natural gas demand, the government is increasing support for compressed natural gas (CNG) vehicles including the development of refuelling infrastructure and subsidising equipment installations (MoE, 2019). Despite acknowledging the potential of battery electric vehicles (BEV), support for them is currently limited given the expectations that battery technology will improve, lowering their costs over time (MoE, 2017e).

Russia signed the first ever agreement with the Organization of the Petroleum Exporting Countries (OPEC) and 11 non-OPEC crude oil exporters, in December 2016. The agreement was designed to remove surplus oil from the market by cutting production and has brought moderate results, raising global crude oil prices back to over USD 70 per barrel (bbl) (IEA, 2018b). The agreement also assumes that key crude oil producers will limit their production to the negotiated level referenced at a five-year average of global crude stockpiles. For Russia this means voluntarily reducing oil production to roughly 11.2 million bbl per day (550 Mtoe per year), the same level as in 2016 (MoE, 2018b).

Russia signed the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement', held in Paris, France in 2015. 'Subject to the maximum possible account of the absorbing capacity of forests' (UNFCCC, 2015), Russia approved legislation to work towards its Intended Nationally Determined Contributions (INDC), which support the COP21 Paris Agreement. Although current INDC targets to reach between 70% and 75% of the 1990 level by 2030 might not sound so ambitious, Russia relies heavily on energy- and greenhouse gas (GHG) emission-intensive industries for economic growth. Nevertheless, government's long-term plans to attract significant investment to upgrade aging infrastructure and promote the wider adoption of energy efficient and best available technologies (BATs) (Consultant, 2018) make INDC target feasible.

Several cities and regions such as Krasnoyarsk (AdmKrsk, 2011), Ufa (UfaCity, 2014), Ekaterinburg (Ekburg, 2018) and Kazan (Kzn, 2016) have either already adopted or are working on their own emissions reduction and green development strategies. These documents are interlinked with urban development plans for these cities through 2025 and beyond, strongly affecting urban infrastructure development and promoting human-centred design.

A number of measures to address environmental impact are outlined in both the Climate Doctrine (Kremlin, 2009) and the Environmental Policy until 2030 (Kremlin, 2012). They mainly address harmful pollutant emissions, such as toxic waste, non-recyclable materials, or pollution occurring in dense urban environments. Although international efforts to reduce GHG emissions are recognised, these are not addressed directly in the policy. The framework includes policies aimed at reducing administrative barriers and addressing educational, technological and economical components to grow the economy and preserve the environment.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Russia under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 16.3). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 16.3 • Russia: Key assumptions and policy drivers under the BAU

Buildings	Energy performance and labelling programs remain at current levels. Share of low quality and ramshackle buildings reduced to 0% by 2030.
Industry	Federal Law on BAT adoption.
Transport	Support for locally manufactured CNG, especially municipal and freight, vehicles. No regulation for vehicle fuel economy, except for government procurement.
Energy supply mix	Energy Efficiency Federal Law target of a 44% reduction in energy intensity in the 2005-30 period.
Power mix	Implementing the Energy System Development Plan 2018-24 (MoE, 2018c).
Renewables	Government support for 5.5 GW by 2024, excluding large-scale hydro. First steps in liquid biofuels regulations. Support for bioenergy development in limited areas.[77]
Energy efficiency	An array of policies and programs: insulation requirements for new buildings and funding for existing ones; building rating program; lighting programme; EVs and natural gas vehicle support programme; and energy service companies.
Energy security	100% self-sufficiency for energy resources. Maintain stable production and exports by stimulating new field development. Maintaining a reliable energy supply for remote regions of the economy.
Climate change	Work towards the INDC limiting anthropogenic GHGs to between 70% and 75% of the 1990 level by 2030, subject to the maximum possible account of the absorbing capacity of forests.

Notes: CNG = compressed natural gas. EVs = electric vehicles. GW = gigawatts. GHG = greenhouse gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

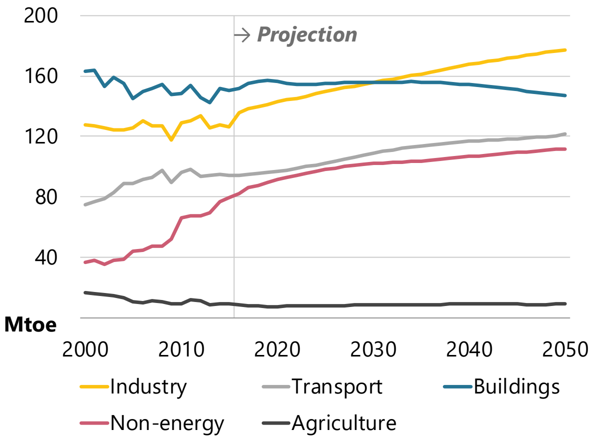
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

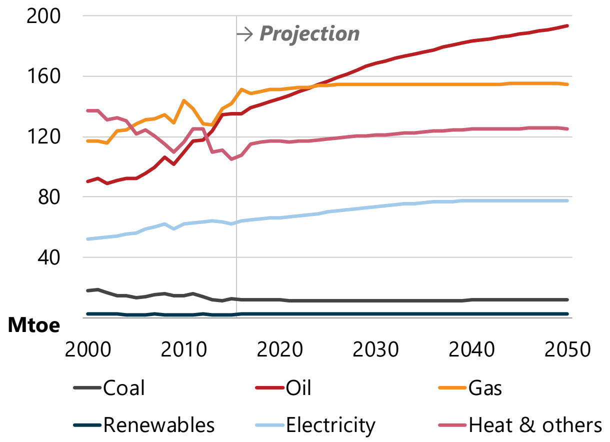
Following the dissolution of the Soviet Union in 1991, Russian GDP and energy demand continued to fall until 1998, when default was declared and a gradual economic recovery began. This drop in demand and GDP happened as economic ties with other members of the Soviet Union were broken and the integrated technological chains and markets inherent to the economy were damaged. In 2000-16, GDP grew at a CAGR of 3.5% and FED at a CAGR of 0.77%.

Under the BAU, Russia's FED increases by 20% (from 472 Mtoe to 566 Mtoe) in the Outlook period (2016-50). The buildings sector remains the largest energy consumer until 2030 when it is overtaken by industry, which accounts for 31% of FED in 2050, compared to 26% for buildings (Figure 16.1). Domestic transport FED gradually increases from 94 Mtoe in 2016 to 121 Mtoe in 2050 when it accounts for 20% of the total.

[77] For municipal solid waste, local waste to energy in remote areas (to limit expensive fuel transport), areas with abundant feedstock (farms, crop fields) and areas where waste products (potential bioenergy feedstock) could have a negative impact on the environment.

Figure 16.1 • Russia: Final energy demand, by sector and fuel, 2000-50





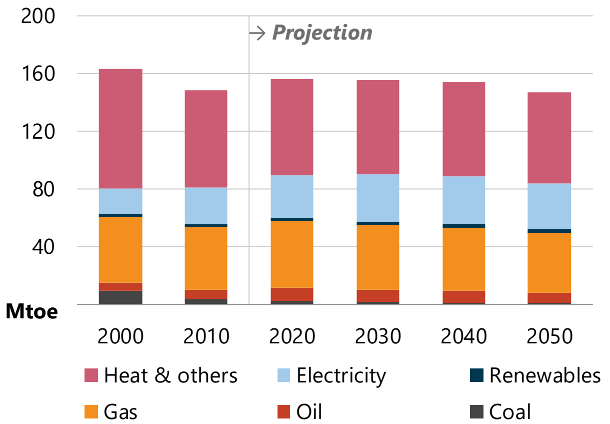
Sources: APERC analysis and IEA (2018a).

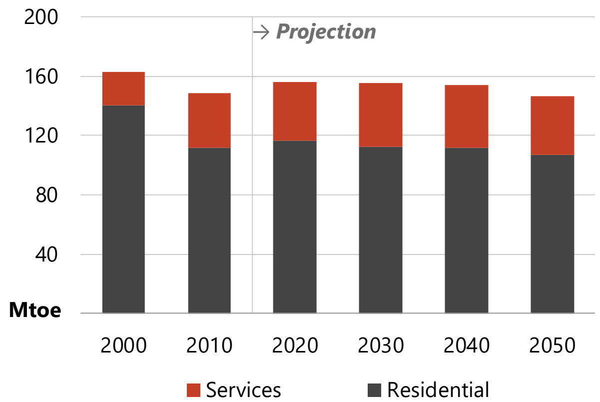
BUILDINGS: ENERGY DEMAND PLATEAUS UNDER THE BAU SCENARIO

While buildings sector FED declined by an overall 6.8% in the period 2000-16, the trends of its two subsectors behaved divergently. Improving economic conditions and growth in disposable income have driven energy demand in the services subsector to fuel a vast increase in floor area for office space and large shopping malls. In the residential subsector, despite the improving quality of life and high speed of residential buildings construction, which has exceeded 80 million square metres (m^2) per annum since 2012 (GKS, 2018b), improved thermal performance standards and revised utility prices have reduced energy demand, especially for district heating and coal.[78] In 2016 Russia's electrification rate was 100% and urbanisation rate was 74% (GKS, 2018c).

Although energy demand in buildings decreased in the period 2000-16 at a CAGR of -0.44%, it remains relatively flat over the Outlook period, peaking in 2035 before declining to 147 Mtoe in 2050, slightly below its 2016 value of 152 Mtoe. Buildings sector energy demand in 2016 was met primarily by heat (39%), natural gas (33%) and electricity (18%) (Figure 16.2). Over the projection period, heat demand increases in both value (0.13% CAGR) and share (to 43%), as does electricity (0.44% CAGR, to 22%), offsetting the decline of natural gas (-0.52% CAGR, to 28%).

Figure 16.2 • Russia: Buildings final energy demand by fuel and subsector, 2000-50





Sources: APERC analysis and IEA (2018a).

[78] Since the early 2000s, the government has introduced policies to reduce and ultimately eliminate cross-subsidies to reflect true utility prices in the residential subsector. While prices are still regulated, they are periodically reviewed and generally follow market trends. In addition to individual electricity meters, individual hot and cold water and heating meters have also been installed.

Residential energy demand decreases from 115 Mtoe in 2016 to 107 Mtoe in 2050. While energy demand for space heating maintains the largest share over the Outlook period, declining slightly from 59% to 56%, space cooling becomes the fastest growing end-use (6.3% CAGR), mainly due to a very low base year level. Lacking policy support, renewables decline at 2.4% CAGR over the Outlook period. Solid biomass makes up the largest share of renewable energy, while solar water and space heating have a small but expanding share. Government programs, including energy efficiency labelling schemes, individual heat and water meter installations, and switching from one- to two-tariff power meters, are the main drivers of falling demand in residential energy demand. A heating services reform aims to increase investment into the deployment of modern heating systems. Regional governments are also developing pilot programs such as the 'smart region' concept in the Sverdlovsk (DIS, 2018) and Ulyanovsk regions (IT Fund, 2017), which are responsible for introducing innovative digital monitoring and control systems.

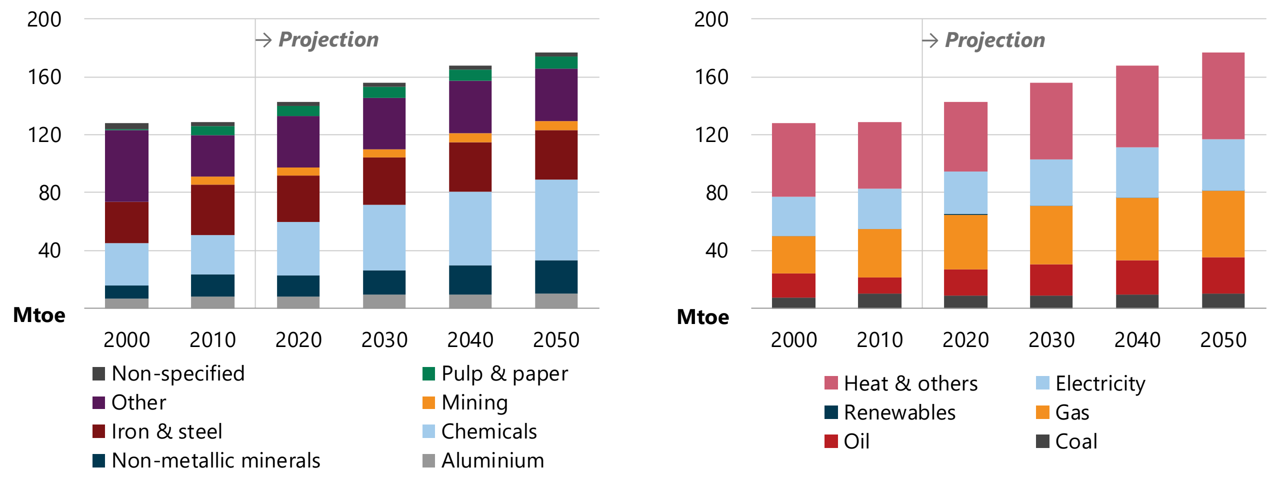
Services floor area increases from 1 450 million m^2 to 2 319 million m^2 (60%) over the Outlook, which exceeds energy intensity improvements (from 0.026 tonnes of oil equivalent per square metre [toe per m^2] to 0.017 toe per m^2), and results in energy demand increasing by 6.7% from 37 Mtoe to 40 Mtoe. Under the BAU, energy demand for space heating accounted for 55% (21 Mtoe) of services total demand in 2016 but declines slightly to 42% (17 Mtoe) in 2050. The fastest growing end-use in the services subsector over the Outlook period is space cooling at 2.1% CAGR, followed by water heating (1.3% CAGR) and other end-uses—including office equipment or electrical appliances (1.2% CAGR). By contrast, space heating and lighting decrease at a CAGR of -0.60% and -0.37%, respectively. Heat and electricity dominate the energy mix, although oil and natural gas also play significant roles, primarily because of diesel-use in generators and natural gas in boilers.

INDUSTRY: CHEMICAL AND PETROCHEMICAL DRIVES DEMAND GROWTH

Industrial sector energy demand has increased 6.0% since 2000 (from 128 Mtoe to 136 Mtoe in 2016). The large fall in the 'other' subsector (main drivers being machinery and construction in that subsector) was entirely offset by growth in non-metallic minerals, iron and steel, mining, and pulp and paper. The three key subsectors—iron and steel, chemical and petrochemical, and non-metallic minerals—accounted for 57% of industry energy demand in 2016. Heat (as hot water and steam) is the largest fuel (33%) and is used mainly by the chemical and petrochemical and iron and steel subsectors. Natural gas (27% of total), used mainly for the iron and steel and non-metallic minerals subsectors, and electricity (21%), mainly for non-ferrous metals, are the other dominant fuels.

Industrial energy demand increases at a CAGR of 0.79% over the Outlook period, reaching 177 Mtoe in 2050 (Figure 16.3). Chemical and petrochemical leads this growth with a CAGR of 1.6% (24 Mtoe); followed by non-metallic minerals (1.5% CAGR and 9.4 Mtoe); and aluminium (0.88% CAGR and 2.6 Mtoe). Primary production in these subsectors also increases for non-metallic minerals (1.5% CAGR), aluminium (0.88% CAGR), and chemicals and petrochemicals (0.60% CAGR). Energy demand in iron and steel, despite a 25% increase in primary output, increases by only 8.4% due to efficiency improvements. Under the BAU, heat maintains the largest share of FED (33%), followed closely by natural gas, which decreases from 27% to 26% over the Outlook period. Electricity demand remains strong at about a 20% share, driven by use in the chemical and petrochemical and non-metallic minerals subsectors. Oil increases slightly, from 12% to 14%, driven primarily by use in chemicals and petrochemicals.

Figure 16.3 • Russia: Industry final energy demand by subsector and fuel, 2000-50



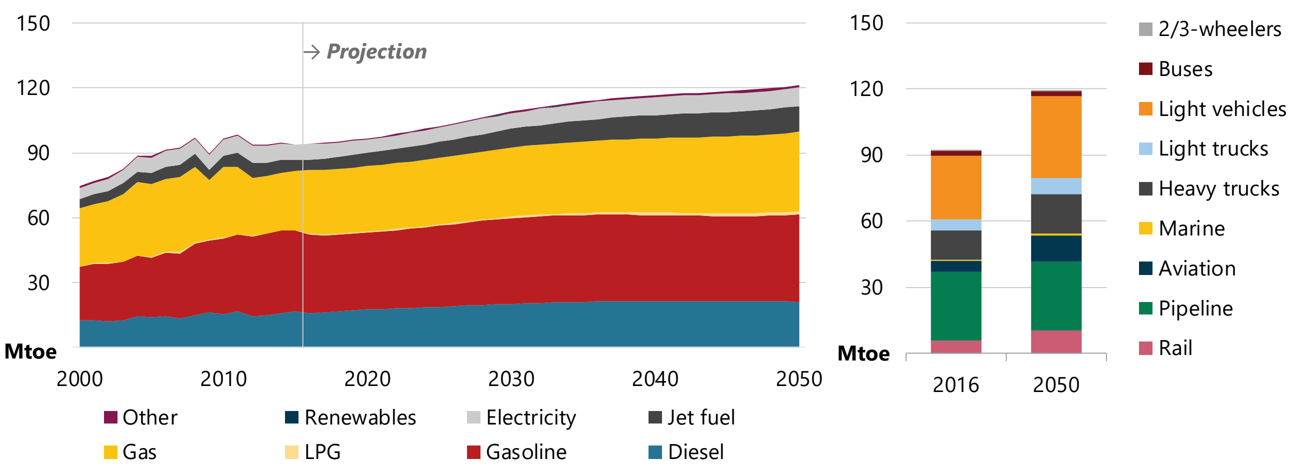
Sources: APERC analysis and IEA (2018a).

Annual economic growth of 1.8% over the Outlook, coupled with a continued reliance on industry, increases industrial primary output which in turn drives up energy demand in the sector. A number of sectoral and technology-specific guidelines have been adopted to reduce the level of anthropogenic GHGs and improve energy and materials efficiency (MoE, 2018d). In addition, 300 factories with Class 1 negative impact on the environment are expected to adopt BATs in 2019[79]. A further 15 000 Class 2-4 factories are expected to complete their transition by 2029 (BuroNDT, 2016).

TRANSPORT: ENERGY DEMAND FOR PIPELINES IS THE HIGHEST IN THE WORLD

Under the BAU, domestic transport increases from 94 Mtoe in 2016 to 121 Mtoe in 2050, at a rate of 0.74% CAGR, which is half its growth speed of 1.5% CAGR in the period 2000-16 (Figure 16.4). Russia has significant land area and well developed public transport system. However, increasing penetration of passenger vehicles and significant share of heavy road freight drives per person energy intensity in the transport sector from 0.65 toe in 2016 to 0.91 toe in 2050.[80] Key government policy for domestic transport supports more modern systems, such as transport hubs for passengers and freight logistics centres.

Figure 16.4 • Russia: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

[79] As defined in by the Ministry of the Environment (MNRE, 2015).
[80] For comparison, Canada (the second largest APEC economy) had 1.68 toe per person in 2015 and 1.39 toe per person in 2050, and China (the third largest) had 0.21 toe per person in 2016 and 0.37 toe per person in 2050.

Freight activity increased from 3 515 billion tonne-kilometres (Gtkm) to 5 136 Gtkm (2.4% CAGR) in the period 2000-16. Despite growth in oil and natural gas volumes transported by pipeline, efficiency improvements saw the share of pipeline transport energy demand decrease from 39% to 33% in 2000-16. Similarly, rail transport's share declined from 6.7% to 6.1% in the same period despite increases in the transport of coal and other minerals. Total energy demand for freight increased from 38 Mtoe to 56 Mtoe in 2000-16, a trend that continues over the Outlook period, as demand increases a further 22% to reach 68 Mtoe, driven by increasing road trucking (37%).

Despite being the dominant share of passenger transport in Russia, light private passenger vehicle activity is not monitored or officially estimated; only several city-level studies are available. Passenger transport increased significantly in the period 2000-16 from 707 billion passenger kilometres (Gpkm) to 1 293 Gpkm. Energy demand for light-duty vehicles (LDV) reached 29 Mtoe in 2016, accounting for 79% of passenger demand. Domestic passenger demand continues to grow—by 41% to 51 Mtoe in 2050—as the light vehicle stock increases from 44 million vehicles to 60 million. By 2050, LDV demand accounts for 72% of energy demand for passenger transport.

Under the BAU, petroleum products, such as gasoline and diesel, remain key transport fuels, although their share declines from 55% to 51% over the Outlook period. Natural gas for pipelines remains important, but its share in transport FED slightly declines from 31% to 30%. Domestic aviation becomes the major mode of transport for distances over 2 000 kilometres (km) raising the share of jet fuel from 5.2% to 9.8%. The share of conventional LDVs fuelled by gasoline, diesel, liquefied petroleum gas (LPG), or natural gas decreases slightly from 100% to 96% as 2.1 million technologically advanced vehicles (flex-fuel, gasoline hybrids, plug-in hybrids, battery and fuel-cell electric) enter the fleet by 2050.

Government support for natural gas-powered vehicles includes procurement of domestically manufactured heavy-duty trucks, buses and urban services vehicles fuelled by CNG, liquefied natural gas (LNG) and natural gas-diesel bi-fuel. Infrastructure for CNG and LNG refuelling and electrical charging points, including high-speed charging stations, are currently being developed. Advances in road transport infrastructure, including the development of roads and streets, public transport, pedestrian walkways, and freight logistics, further improve domestic transport (MoT, 2017). Studies on the efficacy of these advances are being carried out in several cities such as Kazan (NIPITRTI, 2015a) and Kaliningrad (NIPITRTI, 2015b).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Russia is one of the world's leading energy producers with huge resources spread across the economy. Energy resource mining regulation and tax collection come under the remit of federal authorities, while regional authorities monitor environmental and safety regulation compliance. The export duty on both crude oil and petroleum products is gradually being lowered and mining taxes raised to maintain low retail petroleum prices and minimise the pass-through effects of global crude oil price fluctuations (MinFin, 2015). The electricity market is managed by the Trading System Administrator (ATS) while the System Operator of United Power System (SO) operates the power grid.

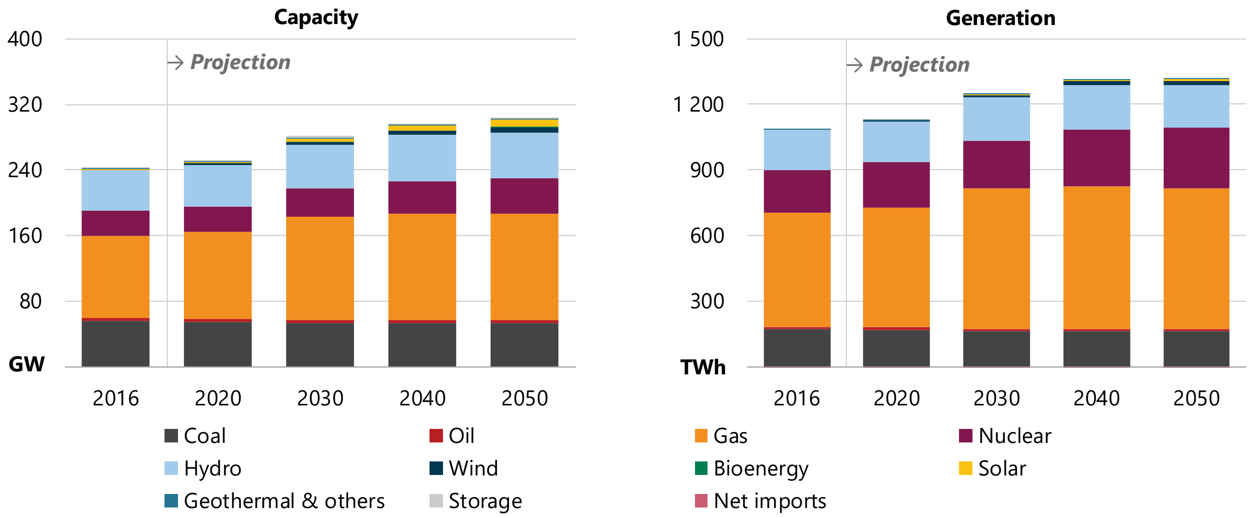
ENERGY INDUSTRY OWN-USE: MAJOR REFINERY UPGRADES ARE UNDERWAY

Russia has 80 oil refineries with a total crude oil processing capacity of over 310 million tonnes per annum (Mtpa) (MoE, 2018e). These refineries are spread throughout the economy near urban centres. A major economy-wide refinery upgrade program that started in 2011 is due to be completed in 2020 with upgrades of 135 refining units (these upgrades affected 130 Mtpa of total capacity). When the upgrade program is complete, refinery yield should increase from 74% to 91%, and the share of gasoline, diesel and kerosene combined will also increase from 59% to between 70% and 79% as fuel oil production shrinks (MoE, 2017c). Russia jumped from the EURO-III to EURO-V fuel standard with the share of EURO-V gasoline increasing from 1.4% in 2011 to 95% in 2017 and EURO-V diesel increasing from 17% to 86%.[81] Duty on petroleum products is adjusted in line with the crude oil production tax and export tax to stimulate exports of high-quality, value-added fuels, such as EURO-V gasoline and diesel. Even under very conservative refining capacity plans there will be a significant surplus of capacity for export.

POWER SECTOR: NATURAL GAS CONTINUES TO DOMINATE

Russia's Ministry of Energy coordinates the power sector and oversees the operations of SO and ATS. The power grid is well interconnected, with only a few isolated systems in Siberia and the Russian Far East. Total installed capacity was 244 GW in 2016 and comprised mainly of natural gas (41%), renewables (23%, which are mostly large-scale hydro), coal (21%) and nuclear (12%). Under the BAU, capacity increases to 304 GW by 2050, with natural gas combined heat and power (CHP) maintaining the largest share (43%) at 105 GW, renewables increasing to 71 GW (24%) and nuclear increasing to 43 GW (14%) (Figure 16.5).

Figure 16.5 • Russia: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

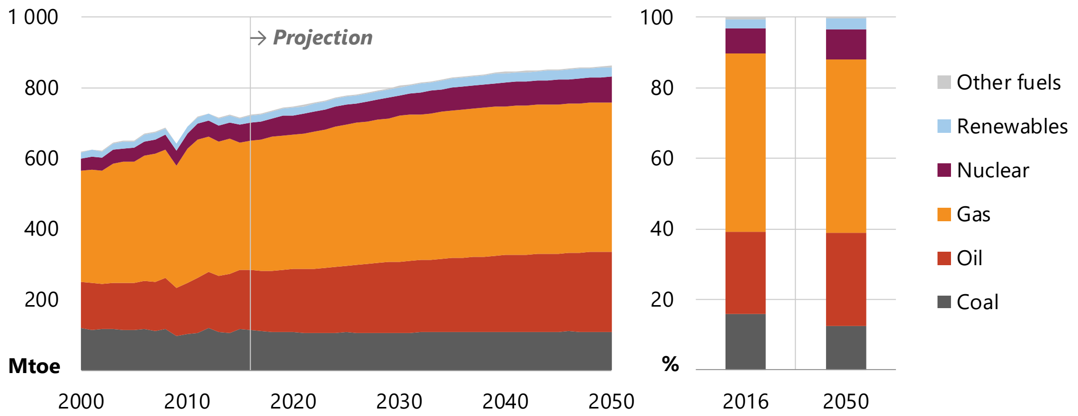
Electricity generation increases from 1 089 terawatt-hours (TWh) in 2016 to 1 319 TWh in 2050 (0.56% CAGR). Natural gas accounted for 48% of power generation in 2016, followed by nuclear (18%) and coal (16%). In 2016, renewables also accounted for 16% of power generation, mainly from large-scale hydro and some from small- and medium-scale hydro. Under the BAU, natural gas-fired generation increases from 522 TWh in 2016 to 640 TWh in 2050, driven mainly by natural gas CHP plants. Despite several retirements, nuclear generation increases by 42%, from 197 TWh to 279 TWh. Coal remains the key fuel for power and heat generation in regions with undeveloped natural gas transmission infrastructure; coal-fired power generation, however, decreases by 8.4 TWh. Renewables capacity also expands, including utility-scale solar (8.0 GW), wind (6.2 GW) and large-scale hydro (5.7 GW).

[81] The key difference between Euro-V (EUR-Lex, 2009a) and Euro-III (EUR-Lex, 1993) fuel standards is tighter control of sulfur, particulate matter (PM) and nitrogen oxides for gasoline and diesel vehicles.

TOTAL PRIMARY ENERGY SUPPLY: NATURAL GAS DOMINATES OVER THE OUTLOOK

Russia's TPES was dominated by fossil fuels, with shares of natural gas at 50%, oil at 23% and coal at 16% in 2016. Nuclear (7.1%), renewables (2.6%) and other fuels (0.46%) accounted for the remainder. TPES increased by 17%, reaching 731 Mtoe, in the period 2000-16. Major sources of growth were natural gas (53 Mtoe) and oil (44 Mtoe), driven by expanding private passenger vehicle ownership, and nuclear (17 Mtoe). Coal maintained roughly the same level.

Figure 16.6 • Russia: Total primary energy supply by fuel, 2000-50



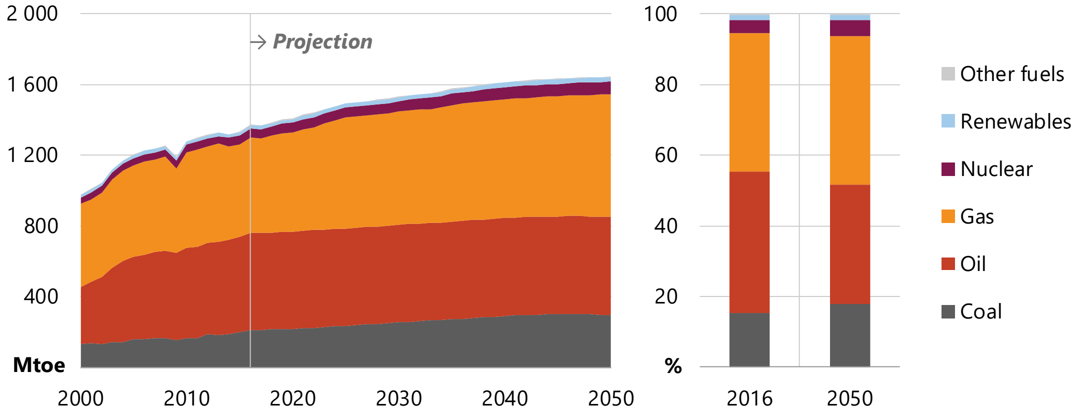
Sources: APERC analysis and IEA (2018a).

Under the BAU, TPES grows at a CAGR of 0.54%, increasing from 731 Mtoe in 2016 to 877 Mtoe in 2050 (Figure 16.6). Natural gas and oil contribute 57 Mtoe each to the growth, followed by nuclear (22 Mtoe). Under the BAU, the share of natural gas declines to 48% by 2050, while oil's reaches 26% and coal's drops to 12%. Hydro decreases its share of total renewables, down from 83% in 2016 to 64% by 2050, as more solid biomass, solar and wind enter the electricity generation fuel mix. Nuclear increases from 7.1% to 8.3% under the BAU as Russia continues developing technology to maintain its position as a world leader in nuclear reactor construction. Current pressurised water reactor technology will be complemented by fast-breeder reactors with metal oxide fuel and molten sodium as the working fluid. The use of nuclear reactors, to both the Russian economy and other economies, can provide feasible decarbonisation solutions despite their higher capital costs.

ENERGY PRODUCTION AND TRADE: NATURAL GAS OVERTAKES OIL

In 2016, Russia's energy production reached its highest level since the dissolution of the Soviet Union at 1 372 Mtoe; equivalent to 188% of TPES. Crude oil accounted for the largest share of total production (40%) in 2016; this decreases to 34% in 2050 (Figure 16.7). With the gradual depletion of existing oil fields, new centres of oil production will be established in Eastern Siberia to maintain output. Natural gas grows to the highest share of energy production (increasing from 39% in 2016 to 42% in 2050) as resources in Yamal, Eastern Siberia and Sakhalin are developed. The majority of coal is exported in the Outlook period as price competition with natural gas in the domestic market limits growth in coal production. Total production rises at a CAGR of 0.54% over the Outlook period, reaching 1 645 Mtoe by 2050.

Figure 16.7 • Russia: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

As of 2016, Russia is the second-largest producer of natural gas in the world, behind the United States, and the largest exporter. Natural gas development is situated in remote areas and depends on a 200 000 km pipeline network to move it over the economy's long distances. Thermal coal for power and heat generation is marginalised over the Outlook period, with the majority of domestic coal consumed by the iron and steel subsector. Russia has limited uranium reserves and is thus actively engaged in uranium mining abroad, such as in Kazakhstan and the United States.

Russia is one of the largest energy exporters in APEC and the world. Historically, crude oil and natural gas have mainly been exported by pipeline and shipping volumes has increased recently. Net exports accounted for a record high of 624 Mtoe in 2016, compared with a low of 293 Mtoe in 1993. The majority of exports are crude oil (40%), followed by natural gas (27%), coal (17%) and petroleum products (16%). Under the BAU, net exports increase by 19%, reaching 743 Mtoe in 2050. The export fuel mix in 2050 is more balanced: natural gas accounts for 35%, followed by crude oil (27%), coal (26%) and petroleum products (12%).

Major export destinations for crude oil are the European Union (EU), China and the Commonwealth of Independent States (CIS)[82]. As of 2016, 65% of crude oil was exported by pipeline to the EU, mainly the Netherlands and Germany, 19% to China and 6.7% to CIS economies. Major export destinations for petroleum products include the EU (59%) and the United States (13%) (BP, 2018). China, Japan and Korea remain key export destinations in APEC over the Outlook period.

Natural gas is exported by pipeline to the EU (87%), mainly to Germany, Turkey and Italy, and the CIS (13%). Over the Outlook period, while pipeline exports to the EU remain high, China's share rises to 20% by 2030 following the construction of several major pipelines. LNG exports are mainly directed towards Japan (68%), Korea (17%) and Chinese Taipei (12%) (BP, 2018). Russia's LNG export capacity exceeds 100 Mtpa by 2050, the third-largest in the APEC region behind Australia and the United States.

[82] CIS includes 12 former USSR states of Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to reflect Russia's current energy supply and demand trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increased energy intensity and renewables deployment, and reduced CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that are sufficient, in unison with worldwide efforts, to give a 50% chance of limiting the global average temperature increase to 2°C by 2050.

Relative to the BAU, FED is 13% lower and CO_2 emissions are 19% lower under the TGT. Under the 2DC, Russia's FED is 26% lower and CO_2 emissions are 49% lower. The share of renewables in TPES is 5.2% in the TGT, compared to 2.9% and 15% in the BAU and 2DC respectively.

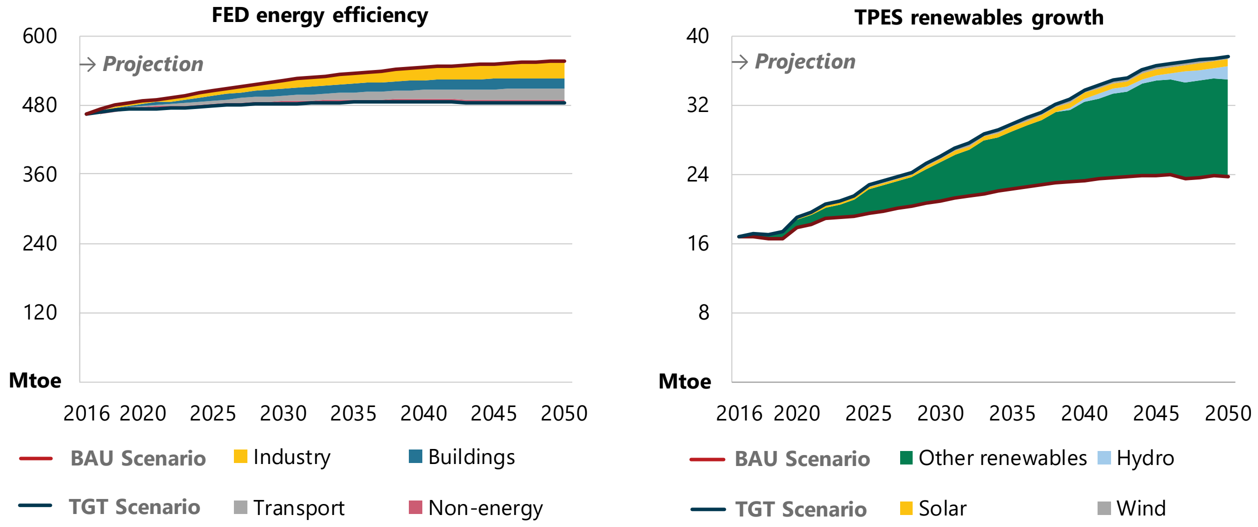
APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC aspirational goals to reduce energy intensity and increase the deployment of renewables. Although the APEC goals do not stipulate economy-specific or sector-specific targets, Russia's energy efficiency regulations, which target polluting industries and promote modernisation, have historically achieved energy intensity reduction. Rising energy demand, driven by improving living standards, large distances between urban and industrial centres, and a large share of heavy industry, has often been outpaced by GDP growth, resulting in energy intensity falling (measured as FED per unit of GDP).

APERC modelling makes several assumptions providing a useful comparison of energy efficiency among scenarios. GDP, industrial output, residential floor area and agricultural energy demand remain constant in all three scenarios over the Outlook period. In addition, the floor area in services is held constant under both the BAU and TGT

Russia's FED under the TGT is 13% lower in 2050 than in the BAU, which is an energy demand reduction of 73 Mtoe. A cumulative energy demand reduction of 1 508 Mtoe is achieved over the TGT, with the largest declines coming from industry (544 Mtoe or a 36% of cumulative demand reduction). Demand reduction in buildings over the Outlook in the TGT is 422 Mtoe (28%), followed by domestic transport at 381 Mtoe (25%) and non-energy at 160 Mtoe (11%) (Figure 16.8).

16.8 • Russia: Energy efficiency and renewable development, TGT to BAU, 2000-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Increased efficiency in industry is achieved by government interventions in a number of areas to: improve scrap recycling rates; lower clinker-to-cement ratios; increase the deployment and direct use of renewables; shorten plant lifespans to stimulate stock turnover; improve process efficiency; and, adopt BATs. In buildings, more efficient building envelopes and increased adherence to electrical appliance standards make the sector more energy efficient. In transport, improved efficiency is achieved by implementing fuel economy standards, improving infrastructure and increased levels of urban planning to reduce the vehicle kilometres driven, and by introducing a higher share of technologically advanced vehicles into the vehicle stock.

Russia's power generation has a high share of fossil fuels, accounting for 65% (707 TWh) in 2016, with 18% (197 TWh) from nuclear and 17% (186 TWh) from renewables. Under the TGT, the share of renewables grows to 18% (214 TWh) in 2030 and 22% (262 TWh) by 2050. The most significant capacity increase comes from solar (9.0 GW), wind (7.9 GW) and hydro (7.7 GW) over the Outlook.

The overall share of renewables in the electricity mix is 4.8% higher in the TGT compared to BAU. Other than large-scale hydro, renewables are developed with additional government financial support that focuses on regional markets that comply with one of the following conditions: (i) regions with a high share of imported fuels, for instance, solar projects in remote areas; (ii) regions with under-utilised renewables, for instance agricultural and farming waste; or (iii) regions with economically viable renewables, for instance cost-effective municipal solid waste combustion for power generation (MoE, 2018f). An increase in other renewables is driven by solid biomass use in the heat sector and industry.

TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APERC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Russia will have to undergo various levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy

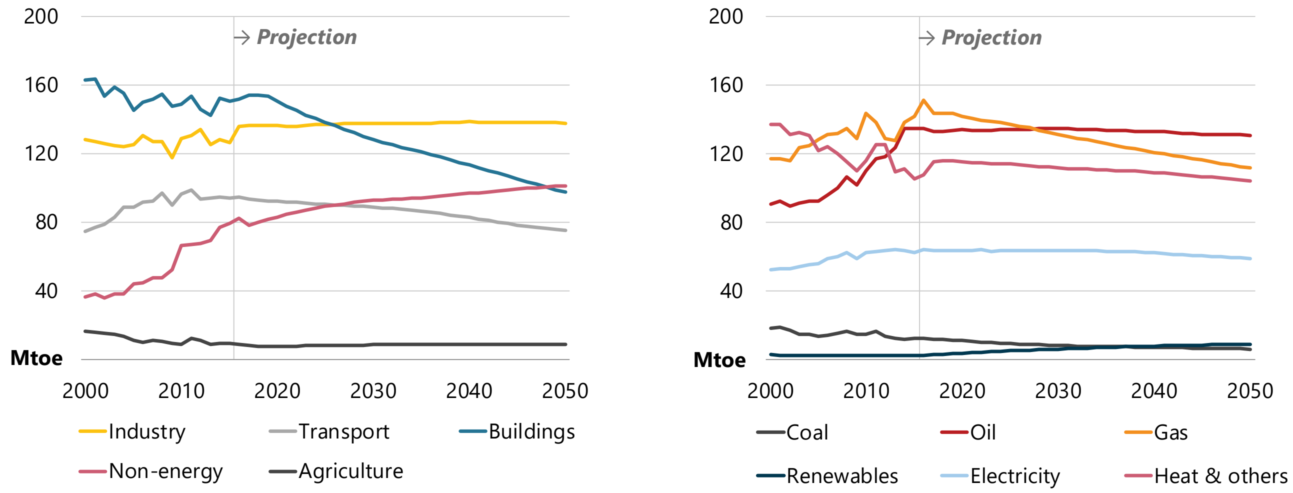
Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

The proposed 2DC low-carbon pathway is driven by a number of assumptions on maximising efficiency in all demand sectors, such as switching to LED lighting and insulating residential buildings, and a noticeable switch from carbon-intensive fossil fuels, mainly coal and oil, to less carbon-intensive natural gas and carbon-neutral bioenergy. Strong efforts are also aimed at decarbonising the power sector by using additional renewables and nuclear energy and increasing electrification in demand sectors. APERC 2DC pathway analyses the potential impact of global energy demand changes on Russia's energy exports.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

In the 2DC, FED is 26% (145 Mtoe) lower in 2050 than in the BAU. Russia achieves a cumulative energy demand reduction of 2 893 Mtoe in the Outlook period, with the largest reduction occurring in the buildings sector (1 002 Mtoe or 35%). The next largest cumulative reduction is in the transport sector at 830 Mtoe (29%), followed by industry with 740 Mtoe (25%) and non-energy at 320 Mtoe (11%) (Figure 16.9).

Figure 16.9 • Russia: Final energy demand in the 2DC by sector and fuel, 2000-50



Source: APERC analysis and IEA (2018a).

Oil overtakes natural gas in 2028 and remains the primary fuel over the remainder of the Outlook period with a 31% share (131 Mtoe) in 2050, compared with 27% (112 Mtoe) for natural gas. This change is driven largely by the transport and non-energy sectors. Heat at 25% (103 Mtoe) and electricity at 14% (59 Mtoe) are the other main fuels in 2050. Fossil fuels still account for the majority of FED by 2050, contributing 59% compared with 64% in the BAU.

Under the 2DC, buildings achieve the largest sectoral demand reduction with 49 Mtoe in 2050. In terms of fuel reductions, oil and natural gas decline the most, and this is driven by improved vehicle fuel efficiency, reduced mileage of heavy trucks and declining gas pipeline throughout caused by reductions in gas-fired power generation. The share of advanced vehicles increases to 21%, led by hybrids accounting for 15% and BEV (4.3% in 2050, compared with 0.07% in the BAU). However, the respective increase in electricity demand for BEV charging cannot offset the reduction from buildings, which sees total electricity demand fall by 35% over the Outlook in the 2DC.

Under the 2DC, the total energy demand reduction in buildings is 36% below BAU levels in 2050. Oil and coal use are both significantly reduced, together accounting for only 2.1% of the buildings sector energy demand in 2050, down from 8.5% in 2016. The share of heat reaches 55% (from 40% in 2016), highlighting the importance of centralised heat generation in all scenarios. Under the 2DC, renewables increase by 3.8 Mtoe in 2050 compared with the BAU, given the additional deployment of solar heat in southern Russia and solid biomass throughout the economy.

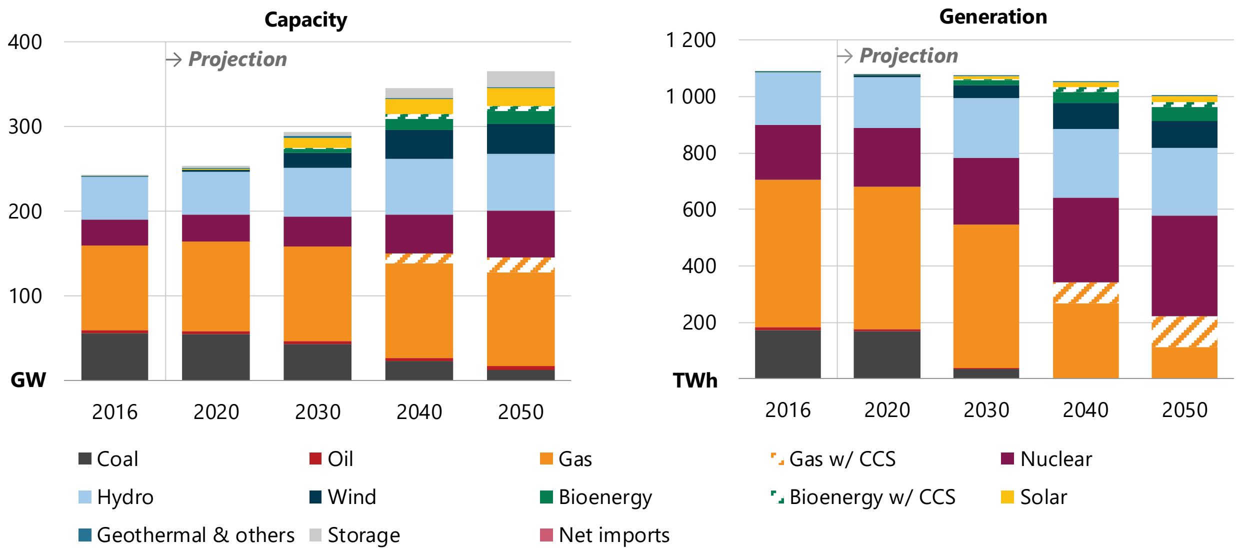
Energy demand in industry, which remains flat for much of the Outlook period, is 22% below the BAU levels in 2050. Oil demand increases by 12%, driven largely by the chemical and petrochemical subsector, while most of the energy demand reduction comes from natural gas. All other energy demand reductions are driven by the accelerated adoption of BATs, increased heat usage, and the reduced use of both natural gas and coal. Direct use of renewables, mainly biogas and biomass, expands from near zero to 1.1 Mtoe in 2050.

TRANSFORMATION AND SUPPLY IN THE 2DC

Oil and natural gas extraction and refineries have driven demand growth in the energy industry own-use sector, with electricity accounting for 40% of own-use demand in 2016 and natural gas accounting for 23%. Under the 2DC, energy industry own-use shows a modest increase (5.5%) to 62 Mtoe in 2050, compared with 72 Mtoe (24% increase) under the BAU. Under the 2DC, heat in the energy industry own-use sector reaches 21 Mtoe in 2050, up from 7.7 Mtoe in 2016, and oil grows to 12 Mtoe, up from 12 Mtoe. Lower production of natural gas and petroleum products, as a result of decreased domestic and global demand associated with a decarbonising world, drive this change.

Russia’s electricity generation sector changes significantly in the 2DC: electricity demand declines by 7.8% over the Outlook, deployment of both renewables and nuclear energy significantly increases, carbon capture and storage (CCS) is introduced, and coal-fired power plants retire rapidly (Figure 16.10). Renewable energy capacity expands from 21% (51 GW) in 2016 to 40% (145 GW) of total installed capacity in 2050, which more than doubles that of the BAU. This upward trend is largely due to increased wind (from near zero to 9.7% in 2050), bioenergy (from near zero in 2016 to 6.9% in 2050) and solar photovoltaics (PV) (from 0.19% in 2016 to 5.9% in 2050). Nuclear capacity grows from 30 GW to 55 GW, with its share in power generation increasing from 18% to 36% (compared with 21% in the BAU).

Figure 16.10 • Russia: Power capacity and electricity generation in the 2DC by fuel, 2016-50

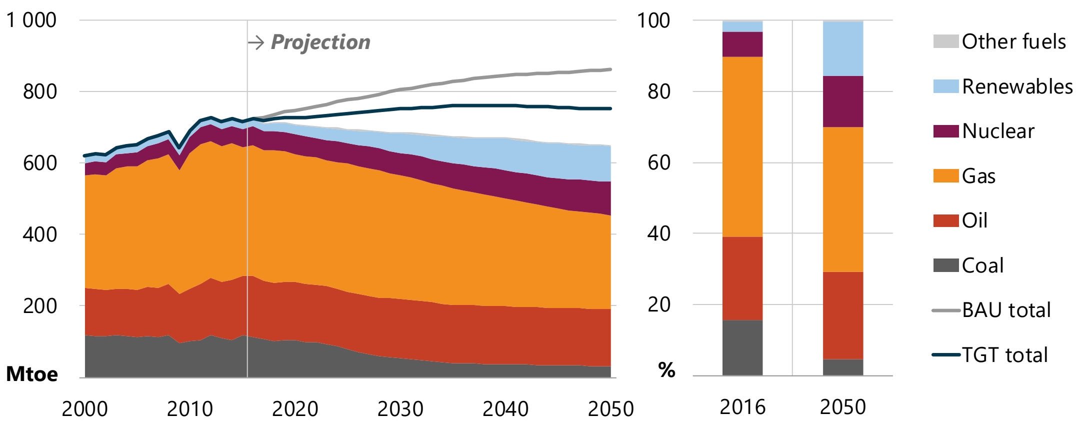


Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

Under the 2DC, total electricity generation declines to 1 004 TWh in 2050, 24% lower than the BAU. Coal- and oil-fired generation ceases by 2035. Non-CCS gas-fired capacity grows by 29% from 100 GW to 129 GW, but the average capacity factor falls from over 80% to only 22% in the Outlook period. By 2050, the accelerated development of CCS-equipped gas (18 GW), solid biomass for CHP (20 GW) and nuclear (55 GW) all provide carbon-neutral baseload generation. Renewables in power generation increase from 186 TWh in 2016 to 421 TWh in 2050, driven by policy support aimed at relaxing power market access, the domestic manufacturing of renewable technology and the greater use of solid municipal waste combustion.

TPES and total primary production both decrease under the 2DC. Production decreases at a CAGR of -0.12% to 1 319 Mtoe in the 2DC over the Outlook period, while in the BAU it increases from 1 372 Mtoe to 1 645 Mtoe (Figure 16.11). Improved energy efficiency, process flow optimisation and lower energy production reduce TPES in the 2DC by 9.1% overall, from 731 Mtoe in 2016 to 664 Mtoe in 2050, or at a CAGR of -0.28%. Net energy exports increase the least in this scenario due to the global energy demand reductions in the 2DC scenario.

Figure 16.11 • Russia: Total primary energy supply by fuel, 2DC vs BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

While fossil fuels still account for the majority of Russia's TPES and production in the 2DC, the share declines compared with the BAU. Under the BAU, fossil fuels account for 94% of production and 85% of TPES in 2050; these shares decline to 85% of production and 67% of TPES in the 2DC.

Box 16.1 • Russia: Floating nuclear power unit 'Akademik Lomonosov' takes to the sea

In April 2018, the world's first floating nuclear power unit (FNPU) 'Akademik Lomonosov', built in the period 2009-18, was towed from a shipbuilding wharf in Saint-Petersburg. It will be fuelled in Murmansk and parked in Pevek, Chukotka (in the Russian Far East) by late 2019. This model FNPU is a non-motorised/towable barge with a displacement capacity of 21 000 tonnes and two KLT-40S reactors installed, with 70 megawatts (MW) of nominal electrical capacity and 58 MW of thermal energy (ROSATOM, 2018). The FNPU will replace a local coal-fired plant and an aging nuclear power plant, to supply carbon-neutral energy to a town of 5 000 inhabitants, without having a detrimental impact on the vulnerable Arctic ecosystem. The pier with electrical and heat grid connection points, hydraulic engineering structures, switchyards and auxiliary buildings is being erected in Pevek. The lifespan of the FNPU is 40 years with a possible extension to 50 years. This is expected to be the first pilot installation to try FNPU as an energy solution for remote, isolated regions or areas with extreme temperatures.

ROSATOM is currently working on a second-generation FNPU, referred to as an 'Optimised Floating Power Unit' (OFPU). This is expected to be a smaller barge equipped with two RITM-200M reactors (55 MW nominal capacity). In addition to electricity and heat generation, these units could also produce water desalination and purification at the rate of 100 000 cubic metres per day (m^3 per day) (OKBM, 2017).

Originally developed for ships and submarines, small nuclear power units could provide zero-carbon energy solutions to support mining operations, residential areas and test sites in remote areas or places with an especially harsh climate. Some projects allow for underwater installation. Russian companies NIKIET, OKBM Afrikantov, JSC AKME Engineering and the Kurchatov Institute are developing a variety of small modular reactors that include the following specifications:

- electrical capacity ranges from 35 MW to 200 MW and thermal capacity up to 116 MW.
- designed for land- and marine-based operation.
- water-cooled and high temperature methane-cooled, fast-breeder technology (IAEA, 2016).

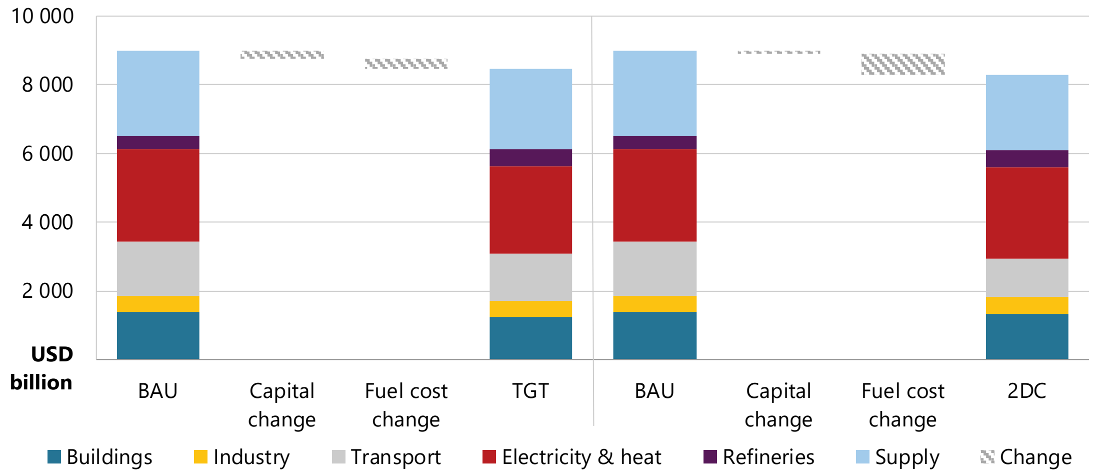
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC Outlook 7th Edition considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[83]

Under the BAU, Russia's total energy investment, which includes capital investment and fuel expenses, over the Outlook period equals USD 8 997 billion (Figure 16.12). Capital investment comprises USD 4 972 billion, of which 46% (USD 2 294 billion) goes to power and heat to install an additional 60 GW of electrical and 99 GW of heat generation capacity. Supply-side investment (upstream, downstream and energy transport) accounts for 43% of capital investment. Refineries account for 2.9% and demand-side efficiency investment (transport, buildings and industry) accounts for the remaining 8.3%. Fuel cost expenditures amount to USD 4 025 billion, with 34% in transport, and the rest in buildings (29%), industry (12%), electricity and heat (9.9%), supply (9.0%), and the refinery sector (5.7%).

Figure 16.12 • Russia: Total capital investment and fuel costs, by scenario, 2016-50



Sources: APERC analysis and IEA (2018a).

Total energy investment decreases to USD 8 460 billion in the TGT Scenario. Capital investment is almost unchanged at USD 4 739 billion, but fuel efficiency improvement brings the fuel cost down by 7.5% in the TGT, which can be attributed mainly to buildings and transport. Under the TGT, supply-side investment decreases by 5.2% compared with the BAU (to USD 2 016 billion) given the slowdown in energy demand and exports.

Total investment in the 2DC decreases 7.9% compared with the BAU to USD 8 289 billion, as a 15% reduction in fuel costs (USD 3 426 billion total) is combined with a 2.2% capital investment decrease (USD 4 863 billion). Capital investment is mainly driven by the electricity and heat and buildings sectors, although declining energy supply and exports reduce supply-side capital investment by 11%. Investment in power decreases by 10% although gas-fired power plants with CCS and renewables require substantial capital outlays. As buildings rely on centralised heating, installed capacity reaches 369 GW, which results in a 1.9% increase in investment

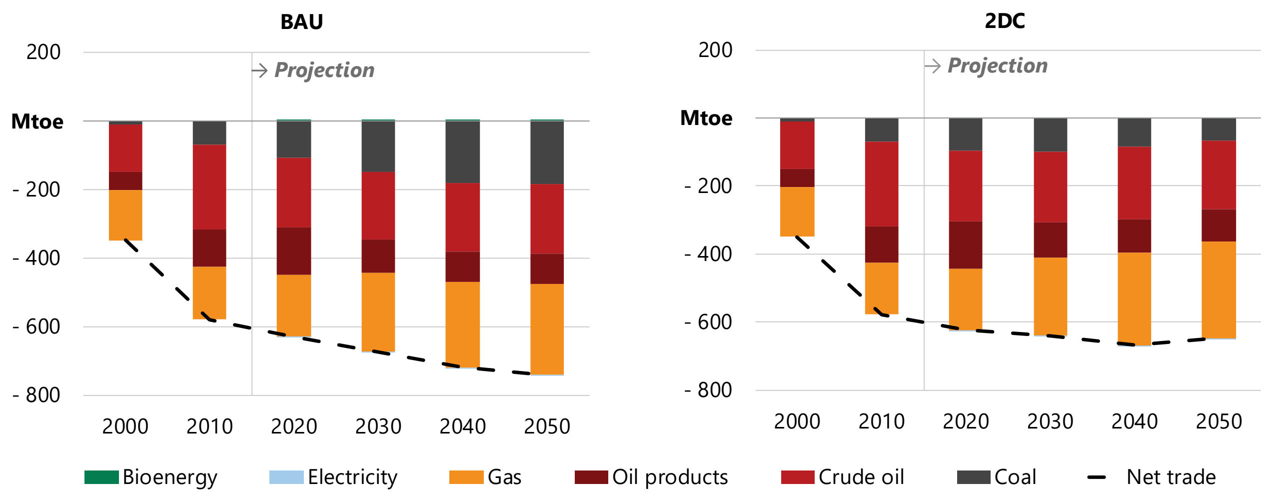
[83] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

compared to BAU. Total demand-side capital investment nearly doubles (is USD 390 billion higher) compared with the BAU, which in turn results in an economy-wide USD 599 billion worth of fuel savings through lower demand and improved efficiency.

ENERGY TRADE AND SECURITY

Development of Russia's energy supply sector has historically been closely linked to the European energy market, which was a large consumer of Russia's crude oil (61%) and natural gas (82%) exports in 2017 (BP, 2018). A number of installed pipeline systems provide strong ties among these economies. Given the large distances from the centres of oil production in Russia to European markets, there has been an ongoing effort by the government to diversify export destinations. Sustained economic growth in APEC has been driving natural gas demand growth, which provides promising new trade opportunities for Russian exports. Under the BAU, natural gas increases to 35% of total exports by 2050 and to 43% under the 2DC, both up from 27% in 2016. Recent extensions of the pipeline network to Pacific Ocean oil terminals coupled with the first LNG supplies from Yamal in Northern Russia, which require a fleet of ice-breakers to operate throughout the year, facilitate this increase. In both the BAU and 2DC, crude oil and oil products exports decline by about 20% over the Outlook (Figure 16.13). Although Russia has electrical interconnections with 10 other economies and the average capacity factor of gas-fired power generation halves over the Outlook period, electricity exports remain below 1.8% of total generation in the 2DC.

Figure 16.13 • Russia: Net energy trade, BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Russia remains self-sufficient in all fossil-fuels across all scenarios (Table 16.4). The established pipeline system, rail transport and heavy truck deliveries ensure that even remote provinces are well supplied, especially during winter. The economy's energy security policy focuses on key infrastructure, such as power plants, government buildings and transport hubs, to ensure sufficient on-site fuel reserves.

Table 16.4 • Russia: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	100	100	100	100	100	100	100
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Crude oil self-sufficiency (%)	100	100	100	100	100	100	100
Primary energy supply diversity (HHI)	0.33	0.33	0.33	0.32	0.31	0.29	0.25
Coal reserve gap (%)	0.18	3.1	2.9	2.5	8.2	7.0	4.6
Gas reserve gap (%)	1.2	19	19	18	49	47	43
Crude oil reserve gap (%)	4.9	75	74	73	177	169	167

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

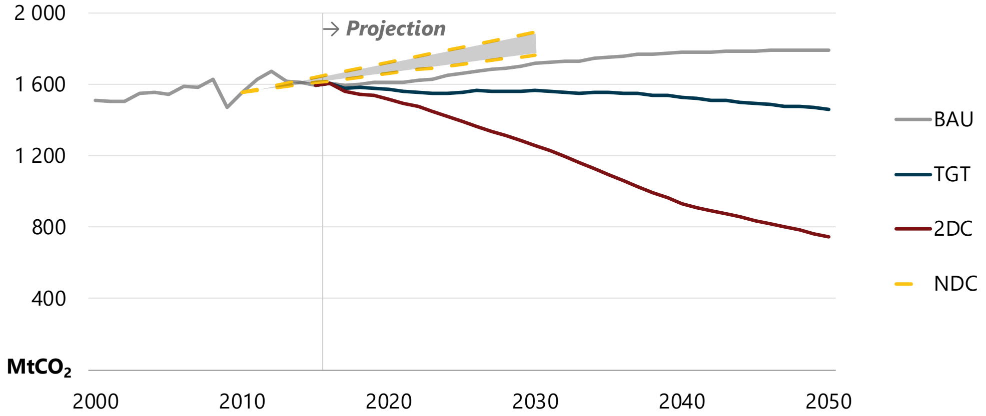
SUSTAINABLE ENERGY PATHWAY

During preparation for COP21 in 2015, Russia submitted its INDC, which aims to limit anthropogenic GHG emissions to between 70% and 75% of the 1990 level by 2030, subject to the maximum possible absorption capacity of forests (UNFCCC, 2015). This addition is important as Russia has significant CO_2 absorption potential. Some UNFCCC Member Parties objected, however, suggesting that it is fair to include only anthropogenic emissions. It is important to note that the economy's policy directly regulates the amount of pollutants and monitors GHGs.[84]

Since 1990, Russia has reduced its CO_2 emissions from fuel combustion by 28% from 2 230 million tonnes of carbon dioxide ($MtCO_2$) in 1990 to 1 605 $MtCO_2$ in 2016. This relates to the significant reduction in energy-intensive heavy industry in the period 1990-98 when CO_2 emissions reduction reached 36% (1 432 $MtCO_2$). Economic recovery caused CO_2 emissions to start rising again at the rate of 0.45% CAGR between 1999 and 2016 (Figure 16.14).

[84] Pollutants include sulphur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC) and others. GHGs include carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (NO_2), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs), sulphur hexafluoride (SF_6) and others, excluding water vapour.

Figure 16.14 • Russia: Total CO_2 emissions under BAU, TGT and 2DC, 2000-50



Note: The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, where applicable. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

The absence of policy directly regulating GHG emissions in Russia leads to a steady increase under the BAU, reaching 1 775 $MtCO_2$ in 2050 (11% above the 2016 level). Heat plants are the key driver (43% increase compared with the base year), followed by industry (31% increase) and domestic transport (30% increase). By contrast, buildings show a 22% reduction, as a result of insulation policy and continued efficiency improvements in centralised heating supply. The electricity sector remains the key emitter (36% of the total in 2050) over the Outlook period because of the high share of thermal power generation (over 55%) in the BAU. However, Russia still achieves its INDC in the BAU.

Under the TGT, the wide range of energy efficiency and renewable energy policies results in emissions declining slightly (-10%). In 2050, emissions from oil combustion are 22% lower than the BAU, mainly due to road oil demand dropping by 21%, driven by fuel switching to more fuel efficient vehicles and renewable alternatives. Emissions from natural gas and coal combustion are also significantly lower (-18% for both), given the reduced demand in power generation. Industry emissions remain at similar levels as in 2016, while domestic transport increases slightly (3.9%) and buildings emissions decrease by 41%.

Under the 2DC, strong efforts to reduce emissions result in a 55% reduction by 2050 (to 720 $MtCO_2$), and 59% reduction compared with the BAU. Rapid expansion of nuclear and renewable energy and the deployment of CCS contributes to a 92% reduction of CO_2 emissions in electricity generation compared to 2016. In buildings, the high share of centralised heat supply for water and space heating contributes to a 70% reduction in CO_2 over the Outlook. However, emissions from the heat sector decrease only marginally despite the share of renewables increasing from 0.98% in 2016 to 33% in 2050 to replace coal (16% to 3.0%), due to robust heat demand growth. Emissions from coal combustion fall rapidly (-74%) due to the decarbonisation of the electricity sector. Strong reliance on liquid fuels, however, limits further emissions reduction in the domestic transport sector (-44%).

OPPORTUNITIES FOR POLICY ACTION

As Russia's upstream energy sector provides significant budget revenues, the government should work towards a stable taxation system that encourages continued investment in the energy sector. As per recommendations outlined in the *Science and Technology Development Forecast 2035* (MoE, 2016a), advanced oil extraction technologies should be piloted and promoted throughout the industry. In transport, a transition to the EURO-VI (EUR-Lex, 2009b) emissions standard by no later than 2030 should be considered. Further development of natural gas infrastructure would facilitate the switch to natural gas in all sectors, especially in buildings and transport, releasing more crude oil and petroleum products for export. Further developing LNG export terminals would secure Russia's position as a reliable supplier and increase its global market share. It is important that revenue from energy exports is used to fund energy programs, particularly the modernisation of energy infrastructure. Crude oil exploration will need to be maintained to enlarge reserves so that Russia can continue to meet domestic needs and fulfil its long-term contractual export obligations.

The coal industry requires a progressive suite of policies to stimulate productivity gains and maintain high safety levels. As more and more coal is exported, transport infrastructure, mostly rail and sea terminals, will need to be constructed. This would be a great opportunity to stimulate the development of the Russian Far East region as coal demand in APEC increases.

The performance of the 'Alternative Boiler house' pricing methodology for heating should be closely monitored. Substantial investment is needed to renovate Russia's aging heat distribution infrastructure, of which over 68% is fully deteriorated (MoE, 2016b), or risk it being replaced by less efficient, decentralised heat generation. Federal funding to renovate existing residential buildings and continued improvement of the building code regulations will help reduce the heating demand while maintaining living standards.

The power sector needs further capacity upgrades. Mechanisms to attract investment to modernise equipment and accelerate the retirement of inefficient plants should be prioritised. Reduction of transmission and distribution losses can be achieved through more efficient use of the power grid network. The power system planning horizon should be extended to 20 years from today's seven years. The economy-wide technology initiative 'EnergyNET', which includes the development of smart grid infrastructure, intelligent distribution systems, demand-response services and the 'Internet of Energy' should be supported and appropriate funding made available (Energynet, 2018).

Renewable energy has already become cost competitive in remote and isolated systems. Regional ministries should start developing re-electrification programs. Global cooperation with renewable energy experts such as the International Renewable Energy Agency (IRENA) and Renewable Energy Policy Network for the 21st Century (REN21), is essential to developing the domestic capability and capacity to implement renewable energy solutions. A good example of APEC-level cooperation is the 'Atlas of remote areas and islands of APEC economies for sustainable energy development' project.

Energy efficiency policy in Russia should be strongly supported and provided with ongoing funding. In addition to the rational use of resources and materials, it could release a substantial amount of energy for export. Russia's technology import substitution programs could also eventually lead to manufacturing leap-frogging to the next generation of equipment. Such programs complement Russia's long-term vision to reduce revenue from energy exports while increasing technology exports.

17. SINGAPORE

KEY FINDINGS

- **Singapore has no domestic hydrocarbon resources and is a global oil refining, transport and chemical export hub.** It imports all the fossil fuels required to meet domestic energy demand and the needs of its three oil refineries. In 2016, Singapore imported 179 Mtoe of oil, gas and coal but consumed less than half of that amount domestically.

- **The power sector continues to be dominated by gas in all three scenarios,** accounting for more than 85% of generation throughout the Outlook period.

- **Despite efforts to expand renewable energy, Singapore's land and geological constraints limit the development of renewable electric capacity.** Solar capacity increases to 578 MW in 2050 in the BAU and 3.8 GW in the 2DC. Waste-to-energy capacity is constant across all scenarios.

- **Oil and gas continue to dominate the energy mix throughout the Outlook period.** As Singapore relies on imports for fossil fuel resources, it needs to diversify its fuel mix to enhance energy security.

- **Singapore already has relatively low CO_2 emissions levels and achieves its emissions intensity (CO_2 emissions per unit of GDP) reduction goals, even under the BAU.** Emissions intensity is 60% below 2005 levels by 2030 under the BAU, exceeding the NDC commitment of 36%. However, only the TGT and the 2DC achieve the target of stabilising emissions by 2030, as emissions continue growing in the BAU.

ECONOMY AND ENERGY OVERVIEW

Singapore is a small city-state in south-east Asia with a land area of approximately 720 square kilometres (km^2). Completely urbanised, it is the Asia-Pacific Economic Cooperation (APEC) economy with the highest population density (7 796 people per km^2). While it has the third-smallest population in the APEC region (5.6 million in 2016), Singapore's gross domestic product (GDP) per capita has been the highest in APEC since 2008, reaching USD 87 910 in 2016 (Table 17.1).

Table 17.1 • Singapore: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	222	391	494	578	803	1 037	1 293
Population (million)	3.9	5.1	5.6	5.9	6.3	6.6	6.6
GDP per capita (2016 USD PPP)	56 775	76 988	87 910	97 383	126 657	158 010	196 613
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	21	25	27	28	29	30	31
TPES per capita (toe)	5.3	4.8	4.8	4.7	4.6	4.6	4.7
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	93	63	55	48	36	29	24
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	8.3	15	18	19	20	21	22
FED per capita (toe)	2.1	3.0	3.3	3.3	3.2	3.2	3.3
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	37	40	37	33	25	20	17
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	52	51	52	53	54	56	57
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis; IEA (2018a); IPCC (2018); OECD (2018); UN DESA (2018); World Bank (2018a and 2018b).

Singapore is a global hub for oil trading and refining, chemical exports, biomedical science, international aviation and shipping, and financial activities. Its top three export destinations are the APEC economies of the China (14% of exports in 2017); Hong Kong, China (12%); and Malaysia (11%) (MTI, 2018). The economy is completely urbanised and highly industrialised, with the services subsector accounting for the bulk of GDP (67% in 2017), followed by goods production at 23% and dwelling ownership[85] at 3.6%. As the economy has developed, the Singapore Government has prioritised highly productive, higher-level value-added industries (such as electronics, chemicals, biomedical science and transport engineering) to stay internationally competitive and maintain robust economic growth.

Domestic energy consumption has been much lower than total primary energy supply (TPES) because of Singapore's extensive oil refining sector. In 2016, final energy demand (FED) was 18 million tonnes of oil equivalent (Mtoe), while TPES was 27 Mtoe and net energy imports amounted to 81 Mtoe. Singapore is the fourth-largest refinery export hub in the world, with a total refining capacity of more than 1.4 million barrels (Mbbl) per day (69 Mtoe per year) from its three refineries. In 2017, domestic oil exports were almost

[85] Refers to housing services provided by owner-occupiers and individuals who let out their residential properties.

USD 85 billion, accounting for 16% of the economy's total export revenue (MTI, 2018). Energy plays a major role in Singapore's economy with respect to both domestic energy demand and international oil trading and refining, bunkering, shipping and aviation activities.

ENERGY RESOURCES

Singapore has no domestic hydrocarbon resources. It imports all the fossil fuels required to meet domestic energy demand and the needs of its three oil refineries. In 2016, Singapore's total energy imports (crude oil, petroleum products, natural gas, coal and other energy products) amounted to 179 Mtoe and exports to 98 Mtoe.

Land scarcity and lack of suitable geological conditions limit large-scale deployment of renewable energy to diversify energy supplies. Solar, biomass and waste-to-energy technologies are the only viable renewable energy options, and they currently contribute 3.0% to the power mix (EMA, 2018a).

Solar energy is the most viable renewable energy option for Singapore, as solar irradiance is relatively high in the tropical sun belt. The government has therefore been introducing policies to increase solar deployment and in 2014, it set a target of 350 megawatts (MWp) [86] of solar capacity by 2020. Adoption of solar photovoltaic (PV) systems has since accelerated from 30 grid-connected installations in 2008 to 2 155 in 2018 (EMA, 2018a). Singapore currently does not have plans for nuclear energy because it deems presently available nuclear energy technologies are not yet suitable for deployment in densely-populated areas. Singapore continues to monitor the progress of such technologies so as to keep its energy options open for the future (MTI, 2012).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

As a small, open economy with no hydrocarbon resources, Singapore is constantly reviewing strategies to balance energy security, economic competitiveness and environmental sustainability.

Natural gas, traditionally imported via pipeline from Malaysia and Indonesia, has become increasingly important to the power mix in recent years. To diversify supply sources and enhance energy security, Singapore's first liquefied natural gas (LNG) import terminal began operating in May 2013 (SLNG, 2014). This terminal in western Singapore made it possible to procure LNG from other gas-exporting economies, such as Australia and the United States. The government is studying options for a second terminal to further diversify its LNG import infrastructure. In 2016, the Energy Market Authority (EMA) launched a feasibility study of potential sites for a floating LNG storage and regasification unit, but no decision has been made.

To further diversify its power mix away from gas, Singapore has been exploring ways to increase solar deployment. It launched the SolarNova program to aggregate demand across government agencies and catalyse private-sector adoption of solar energy (HDB, 2017). The government also announced solar power research funding of USD 24 million in 2017 (Straits Times, 2017).

To improve market competitiveness, the economy has implemented measures to establish itself as a regional LNG trading hub, including expanding the LNG terminal capacity from 6.0 million tonnes per annum (Mtpa) to 11 Mtpa in 2018 (SLNG, 2018); allowing third-party spot LNG imports; and starting small-scale LNG bunkering activities in 2017. The government has also introduced new policies to encourage more competition in the

[86] APERC models electricity capacity using alternative current capacity (MWac) not MWp, which measures the peak electricity that can be produced by a solar PV panel without an inverter. However, this chapter includes numerous references to MWp as many Singapore solar capacity targets are measured in MWp.

electricity market and allow more options for end-users. In April 2015, the EMA partnered with the Singapore Exchange to launch Asia's first electricity futures market, through which electricity consumers can enter into derivatives contracts to hedge their exposure to spot electricity prices (SGX, 2017). As of 1 May 2019, all electricity consumers in Singapore can choose their electricity retailer under the Open Electricity Market (EMA, 2018b).[87]

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Singapore under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant polices already in place or planned (Table 17.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 17.2 • Singapore: Key assumptions and policy drivers under the BAU

Buildings	Continued improvement owing to the target of applying sustainable construction standards to 80% of buildings by 2030 (SSB, 2018). Policy initiatives include mandating minimum environmental sustainability standards for new buildings, providing incentives for building owners to adopt energy efficiency measures, and raising household appliance MEPS.
Transport	Extensive Mass Rapid Transit expansion and controlled personal vehicle fleet growth.
Energy supply mix	A continued increase in oil (crude oil and petroleum products) and gas imports.
Power mix	No coal or nuclear power plants.
Renewables	Increased solar PV penetration, approaching the target of 350 MWp of solar capacity by 2020, equivalent to 5% of EMA's expected peak electricity demand.
Energy security	Continued diversification of energy import sources and energy mix, with no indigenous hydrocarbon resources. Reliance on 60-day fuel reserves held by power generation companies as alternative fuel sources during contingencies.
Climate change	Work towards NDC target of emissions intensity reduced by 36% from 2005 level by 2030 and emissions stabilised with the aim of peaking around 2030.

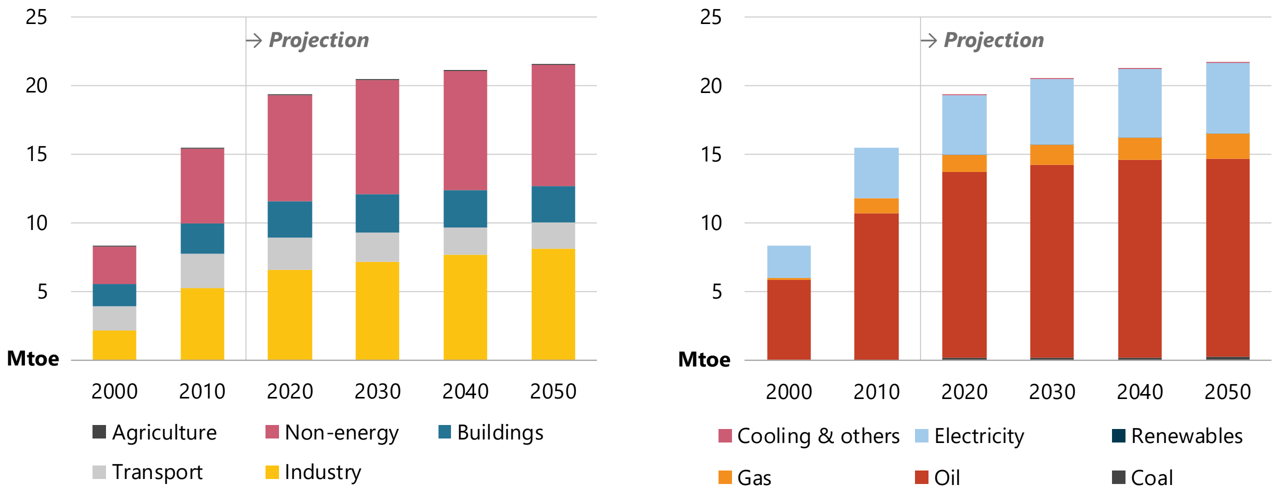
Notes: MEPS = minimum energy performance standards. NDC = Nationally Determined Contribution. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies. MWp = megawatt-peak.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Singapore's FED has grown rapidly since 2000, more than doubling from 8.3 Mtoe to 18 Mtoe in 2016, underpinned by expansion in the industry and non-energy sectors. Non-energy use (i.e. energy products used as raw materials but not consumed as fuels or transformed into another fuel) and industrial energy consumption accounted for 73% of the economy's FED in 2016. These two sectors grow steadily over the Outlook period (2016-50) at a compound annual growth rate (CAGR) of 0.57% for non-energy and 0.80% for industry, owing to extensive activity in the oil refining and chemical and petrochemical sectors. However, the expansion of overall FED is slower, at 0.46% CAGR, as buildings demand is flat and domestic transport declines, which partially offset the increases in industry and non-energy use. FED reaches 22 Mtoe in 2050 (Figure 17.1).

[87] Before launch of the Open Electricity Market, only large electricity consumers (contestable consumers) could choose their electricity retailer, while small consumers (non-contestable consumers) could purchase electricity only from designated market support services companies at regulated tariffs.

Figure 17.1 • Singapore: Final energy demand by sector and fuel, 2000-50



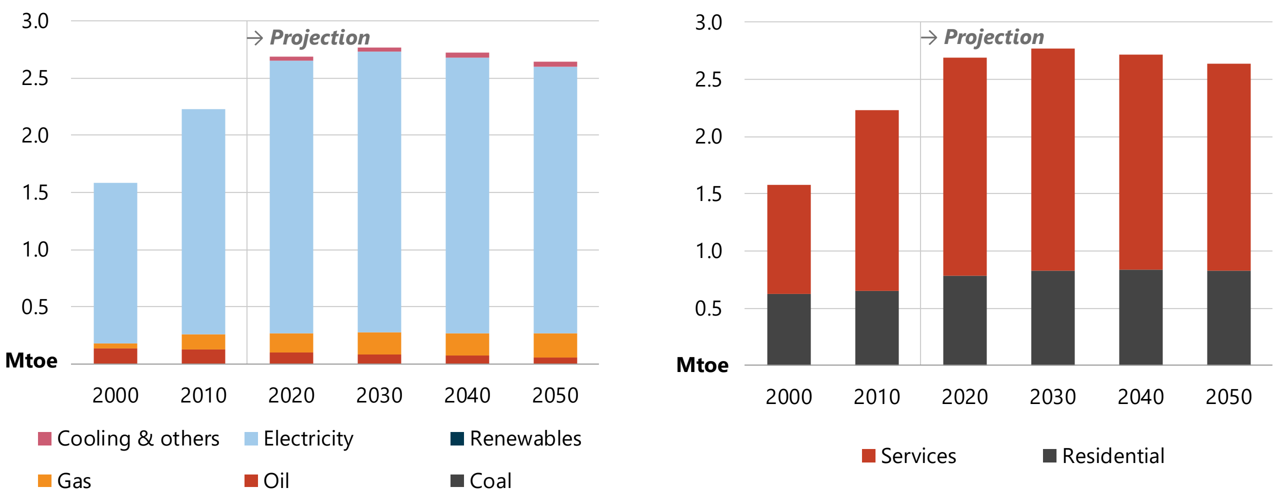
Sources: APERC analysis and IEA (2018a).

Oil continues to meet most of Singapore's FED (70% in 2016 and 67% in 2050) owing to significant demand from the chemical and petrochemical subsector. Electricity also remains important for domestic consumption, as its share of FED remains steady, between 22% and 24% throughout the Outlook period. Gas's role in FED increases from 6.4% in 2016 to 8.7% in 2050, mainly due to rising use in industry.

BUILDINGS: GREATER EFFICIENCY MITIGATES RISING ENERGY DEMAND

Singapore's buildings sector FED is almost unchanged over the Outlook at 2.6 Mtoe, but peaks in 2030 (at 2.8 Mtoe) as energy efficiency measures offset rising population and per-capita GDP afterwards (Figure 17.2). The services subsector dominates energy use in buildings, having grown rapidly (4.1% CAGR) between 2000 and 2016 as the economy became an important global hub for aviation, shipping, tourism, and financial and trade services. Services continue to claim the bulk (69%) of buildings FED in 2050 (down from 71% in 2016). Electricity has been the main energy source for the buildings sector since at least 1990, but its share of FED decreases slightly during the projection period, from 90% to 89%, peaking at 2.5 Mtoe in 2030.

Figure 17.2 • Singapore: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

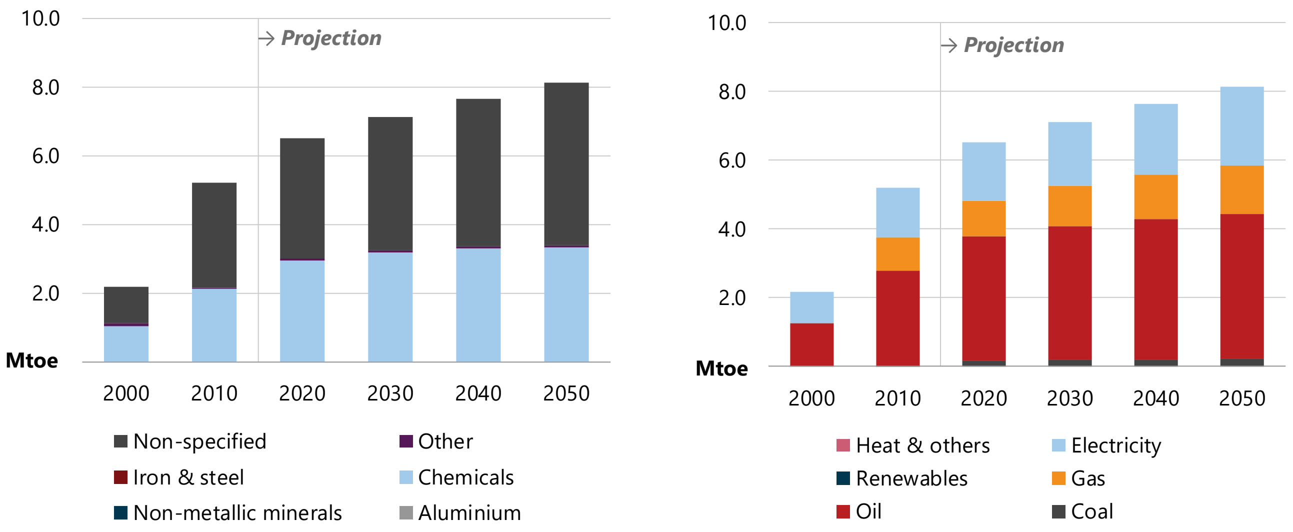
Other end-uses (such as office machinery, commercial cooking and electric motors) and space cooling account for over 80% of services FED. The government has been encouraging more energy efficient buildings as part of efforts to decrease carbon dioxide (CO_2) emissions. In 2005, the Building and Construction Authority introduced the Green Mark rating scheme to assess the energy efficiency, water efficiency, indoor environmental quality and environmental protection of buildings, as well as other 'green' features and innovations. Under the Building Control Act, building owners must comply with the minimum Green Mark standards, and in January 2017, the government introduced the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations to require buildings with centralised cooling systems and gross floor area greater than 5 000 square metres (m^2) to comply with the revised act when cooling systems are installed or replaced (E^2PO, 2018a).[88] Over the Outlook period, improved energy efficiency results in a marginal decline in FED (by 0.49%) despite floor area growing by 17%.

In the residential subsector, space cooling was responsible for the largest share (36%) of FED (and of electricity demand) in 2016, reflecting the economy's tropical climate. Singapore's National Environment Agency (NEA) first introduced minimum energy performance standards (MEPS) in 2011 and prohibited the sale of non-compliant air conditioners and refrigerators. MEPS were subsequently extended to include lighting and clothes dryers. As the NEA reviews the MEPS regularly, average appliance and lighting energy efficiency are projected to improve, reducing appliance energy consumption from 18% of FED in 2016 to 16% in 2050 and lighting energy consumption from 11% to 6.8%. Improved efficiency also limits residential energy demand increases to 13% despite floor area increasing by 38%.

INDUSTRY: ENERGY DEMAND DRIVEN BY MANUFACTURING

Singapore divides its industry sector into four subsectors: manufacturing, construction, utilities and other industry-related production. Manufacturing is the largest economic driver in Singapore, with electronics and precision engineering contributing the most to GDP growth (MTI, 2018). In addition, Singapore was the world's seventh-largest exporter of chemicals in 2016, with a value of USD 46 billion (WTO, 2017).

Figure 17.3 • Singapore: Industry final energy demand by subsector and fuel, 2000-50



Note: CCS= carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

Non-specified uses, including prominent subsectors such as electronics and biomedical manufacturing, accounted for the bulk of FED (54%) in 2016, followed by chemicals at 45% (Figure 17.3). Industry FED grows at

[88] Exceptions apply to industrial buildings, railway premises, port and airport facilities, religious buildings, data centres, utility buildings and residential buildings other than serviced apartments.

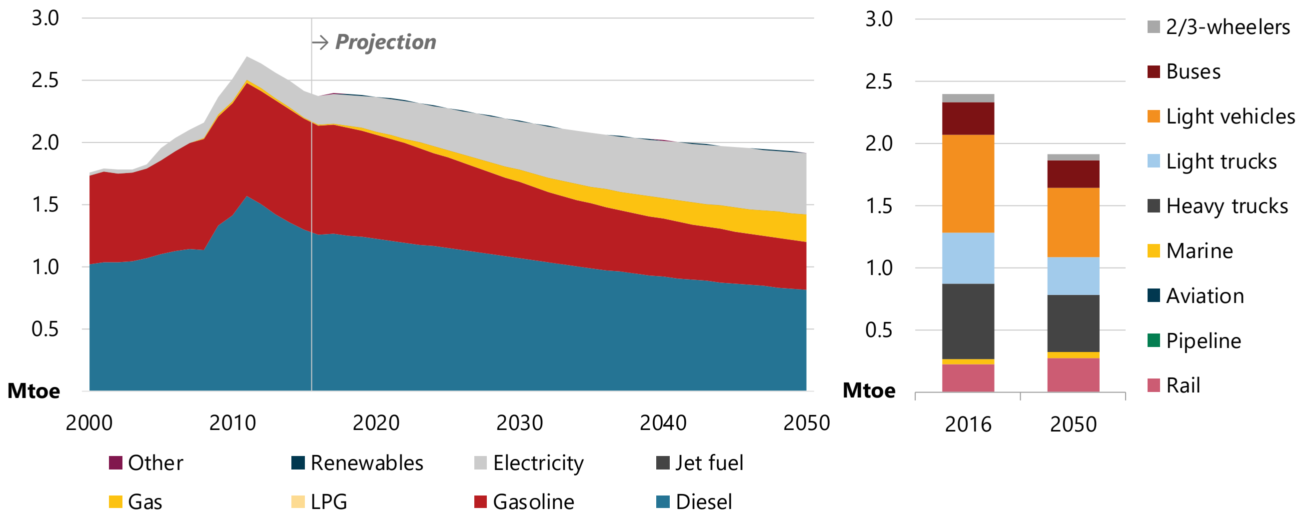
a CAGR of 0.80% to 8.1 Mtoe in 2050 (from 6.2 Mtoe in 2016). While oil remains the mainstay fuel, its share declines, from 55% in 2016 to 52% in 2050, as the economy steps up efforts to reduce CO_2 emissions, and electricity and gas shares increase marginally.

In 2016, the government unveiled the Industry Energy Efficiency Roadmap, identifying technological potential and opportunities to reduce energy use from BAU levels by 2030. The estimated technical potential by 2030 is a 5.7% reduction in energy demand from 30 emerging technologies—13% with the adoption of the 167 best available technologies (BATs) and practices (NEA and EDB, 2016). These estimates build on existing initiatives to promote energy efficiency, such as the Energy Efficiency National Partnership programme, which helps companies reduce consumption through courses, workshops and energy efficiency-related resources, recognition, and incentive schemes, which co-funds efficient design of new facilities, energy assessments and adoption of energy efficient equipment and technologies (E^2PO, 2018b). In 2018, the government announced the Enhanced Industry Energy Efficiency package to increase support for companies in their drive to become more energy efficient.

INTERNATIONAL TRANSPORT ENERGY DEMAND DWARFS DOMESTIC FED

Singapore's domestic transport FED declines 19% over the Outlook period, to 1.9 Mtoe in 2050 (Figure 17.4). The continued rise in economic and population growth is outweighed by greater use of public transport as the Mass Rapid Transit system expands, and by policies to control private vehicle ownership. Road transport accounted for 89% of the sector's FED in 2016, followed by rail (9.6%) and sea (1.5%). Rail transport displaces some road transport by 2050, with the share of rail rising to 14% of FED and that of road declining to 83%. This follows the government's plan to reduce private car use and increase the length of the rail network to 360 kilometres (km) by 2030 (MoT, 2018), a network length comparable to London's and New York City's systems (LTA, 2018a).

Figure 17.4 • Singapore: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

As diesel and gasoline are the main fuels used for motorised road vehicles, they accounted for the bulk of FED (90%) in 2016; electricity used to power the rail network accounted for 9.6%. The electricity share rises to 26% in 2050 and that of oil falls to 63% as the economy shifts towards greater rail transport. Gas use in road transport becomes more prominent over the Outlook, reaching 11% of FED in 2050, as the role of compressed natural gas vehicles increases in all vehicle classes.

Roads currently occupy 12% of Singapore's total land area (MoT, 2017), but with limited land availability and competing needs, the economy's scope to expand the road network is limited. Therefore, in addition to improving and expanding the public transport system, the government has adopted several strategies to reduce road usage and increase efficiency in the sector. These include limiting the number of private vehicles and encouraging carpooling and non-motorised transport, such as cycling and walking. The Land Transport Authority (LTA) is increasing the total length of cycling paths to 700 km by 2030, ensuring that each housing development has a cycling network, and plans to add more bicycle-friendly infrastructure, such as bicycle crossings and parking facilities, to encourage cycling (LTA, 2018b).

Singapore imposes a quota on the number of cars by issuing ownership permits. Owning a car requires first purchasing a Certificate of Entitlement (CoE). The government controls the number of CoEs available, while the price is determined based on monthly auctions. Starting in February 2018, no additional CoEs were made available for passenger cars and motorcycles, as the LTA lowered the vehicle growth rate from 0.25% per year to zero (LTA, 2017). The government plans to review the vehicle growth rate in 2020. The economy also launched an electric vehicle (EV) car-sharing program in December 2017, progressively rolling out 1 000 EVs and 2 000 charging points across Singapore—the second-largest such program after Paris (Reuters, 2017).

Due to its importance as a global trading hub, Singapore's energy demand for international transport (at 55 Mtoe in 2016) is nearly three times FED for the entire economy. Energy demand for international transport increases as the economy's importance as a key global hub grows, to 69 Mtoe in 2050. International aviation energy consumption rises, from 7.8 Mtoe in 2016 to 9.6 Mtoe in 2050. Marine transport demand also grows, from 47 Mtoe in 2016 to 59 Mtoe in 2050.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Singapore's refineries play a significant role in its energy sector. Refineries import almost all their crude feedstock and are responsible for approximately a quarter of oil product exports. Furthermore, at 55 Mtoe in 2016, their oil consumption doubles the TPES of the economy. Through increasing imports of natural gas by pipeline and LNG, Singapore's electricity sector has helped gradually ease the economy's reliance on oil products, which have had their share in TPES reduced from 94% in 2000 to 64% in 2016.

ENERGY TRANSFORMATION: REFINERIES REMAIN DOMINANT

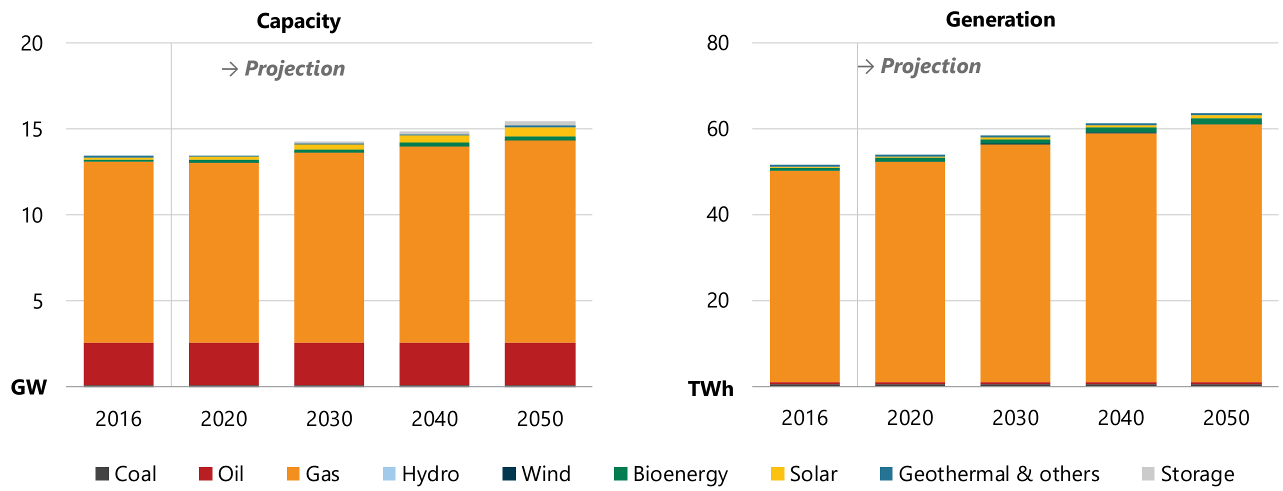
Singapore is one of the world's top refinery export hubs, so oil products are a major source of export revenue. Capacity is currently 1.4 Mbbl per day (69 Mtoe per year) from three major refineries: ExxonMobil's 0.59 Mbbl per day (30 Mtoe) refinery, the company's largest; Shell's 0.50 Mbbl per day (25 Mtoe) refinery, again the company's largest; and Singapore Refining Company's 0.29 Mbbl per day (14 Mtoe) refinery (a joint venture between the Singapore Petroleum Company and Chevron). In April 2019, ExxonMobil announced an expansion of its Singapore refinery, which will enable the facility to convert fuel oil and other bottom-of-the-barrel crude products into higher-value based stocks and distillates (Reuters, 2019).

Under the BAU, total crude oil consumption in the refinery sector decreases, from 55 Mtoe in 2016 to 52 Mtoe in 2050, while production of refined products increases marginally, from 50 Mtoe in 2016 to 51 Mtoe in 2050. Oil consumption in the refinery industry was 2.1 Mtoe in 2016, falling to 2.0 Mtoe in 2050. Because Singapore is a global shipping and aviation hub, demand for bunker fuels (diesel and gasoline) and jet fuel, both primary refinery products, is considerable.

POWER SECTOR: GAS REIGNS SUPREME IN THE POWER SECTOR

Singapore's electricity sector is dominated by gas, which has accounted for more than 95% of the power generation fuel mix since 2014 as new combined-cycle gas turbine plants have replaced oil-fired steam turbines (Figure 17.5). While some oil-fired generation capacity still exists, it is mainly used as backup generation. Renewable energy, mainly in the form of waste-to-energy and solar energy production, accounted for 1.9% of the power mix in 2016 and has a 3.2% share in 2050, due to the economy's efforts to promote renewable power generation.

Figure 17.5 • Singapore: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

Total power generation capacity expands moderately under the BAU, from 13 gigawatts (GW) in 2016 to 15 GW in 2050 (0.41% CAGR), with all additions being renewables-based capacity. This expansion is modest as a result of current electricity oversupply and relatively low electricity demand growth over the Outlook period (0.63% CAGR).

The economy has laid out plans to liberalise its electricity market fully in phases starting in November 2018 through the Open Electricity Market, allowing all electricity consumers to choose their electricity retailer. Greater efforts to promote renewable power generation will also increase competition in the electricity market. Singapore currently has four waste-to-energy plants, which incinerated 2.8 million tonnes of waste in 2016 (MEWR, 2017), and the NEA plans to build a new 120 megawatt (MW) waste-to-energy plant in 2019 (Hyflux, 2018).

While Singapore is not projected to reach its target of 350 MWp of solar capacity by 2020 in the BAU, there is growing momentum behind solar adoption. In 2014, the Housing and Development Board (HDB) and the Economic Development Board (EDB) initiated the SolarNova program to aggregate demand for solar energy across government agencies to achieve economies of scale and prompt solar industry expansion. By December 2018, the program issued four solar leasing tenders, with a total solar capacity of 230 MWp committed for 4 550 housing blocks, achieving part of its pledge to install 220 MWp of solar panels and have 5 500 housing blocks queued for installation by 2020 (HDB, 2018). Moreover, since May 2017, all public housing blocks with at least 400 m^2 of open roof space have been designed with solar-ready roofs for more productive and efficient solar panel installation. The government has also been studying ways to increase solar technology penetration by overcoming land constraints in its heavily urbanised environment. Possibilities include interim moveable solar panels on vacant land and open-air car parks, as well as floating solar modules on reservoirs (Box 17.1).

Box 17.1 • Singapore: Overcoming land constraints with floating solar PV test bed

In land-scarce Singapore, deployment of large-scale utility or rooftop solar PV panels is limited. The economy has thus been exploring various alternatives to build up urban solar capabilities, and one of the options is floating solar PV systems.

In October 2016, Singapore's Public Utilities Board commissioned a floating solar PV test bed comprising 10 solar PV systems with a total capacity of 1.0 MWp, making it the world's largest test bed for a floating system (Straits Times, 2016).

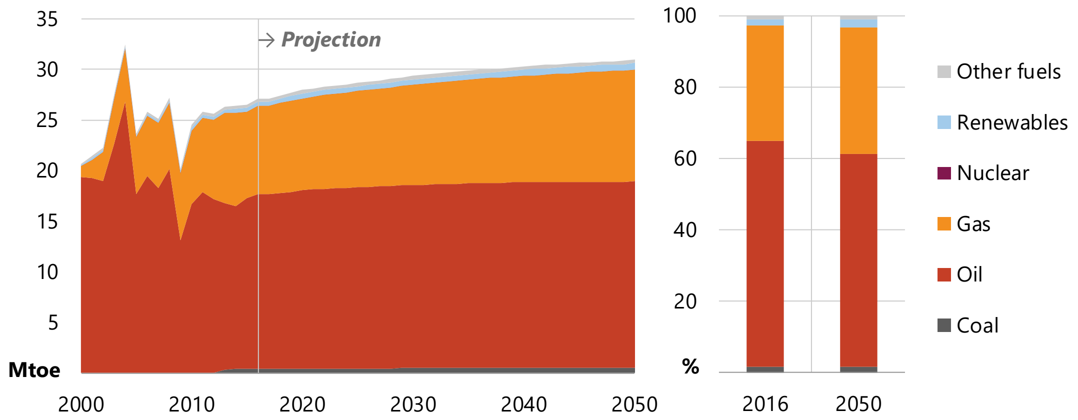
Interim study results in 2017 found that, in addition to reducing evaporative losses from the reservoir, the floating solar PV system performed better than a typical rooftop system (PUB, 2017). This aligns with research elsewhere showing that floating solar PV systems can be up to 20% more efficient than rooftop systems in tropical countries, and 5% more efficient in temperate countries. The pilot project is also examining impacts on water quality and aquatic wildlife, with no negative effects reported so far.

Given these positive results, the government decided to scale up the trial and announced a call for tenders in September 2017 for two additional floating solar PV systems totalling 57 MWp and in November 2018 released a request for information to explore the feasibility of developing a 100 MWp system (EDB, 2018). Since the projected capacity of rooftop PV in 2020 is limited (171 MW in the BAU), installing floating solar PV systems could be an effective means of achieving the economy's target of 350 MWp of total solar PV capacity by 2020. To expand beyond reservoir capacity, Singapore is also developing offshore solar panels that can withstand harsher ocean conditions, such as stronger winds and wave action (Straits Times, 2018).

TOTAL PRIMARY ENERGY SUPPLY: FOSSIL FUELS REMAIN DOMINANT

Under the BAU, Singapore's TPES increases from 27 Mtoe in 2016 to 31 Mtoe in 2050 (Figure 17.6). The energy supply mix is dominated by fossil fuels, which are derived entirely from imports. Oil and gas account for over 95% of TPES currently and throughout the Outlook, while coal and renewables make up the remaining shares. The share of oil falls marginally by 2050, while gas increases slightly, mainly as a result of fuel substitution in the buildings sector.

Figure 17.6 • Singapore: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Singapore's energy supply also contains a small amount of coal (0.43 Mtoe in 2016) for its biomass clean-coal cogeneration plant at the Tembusu Multi-Utilities Complex. The cogeneration plant combusts a mix of coal and biomass to produce steam and electricity for chemical companies. In efforts to reduce CO_2 emissions, Singapore has no plans to develop new coal plants, but due to increases in non-specified industry demand, coal TPES increases to 0.50 Mtoe in 2050. Although Singapore has focused efforts on increasing the uptake of renewable energy sources (mainly solar power and bioenergy), fossil fuel demand for the economy's large refining and chemical and petrochemical sectors far outweighs renewables growth, which reaches only 2.3% of TPES in 2050 (from 1.5% in 2016).

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Singapore's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increased renewables deployment, and reduced energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050.

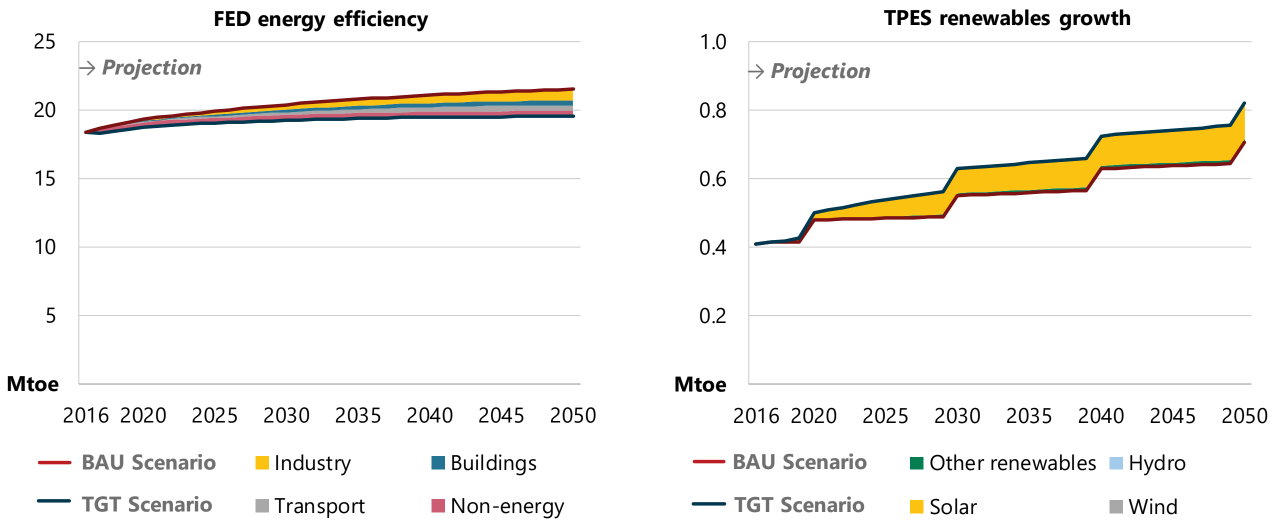
Relative to the BAU, 2050 FED is 9.2% lower while energy-related CO_2 emissions are 10% lower under the TGT. Under the 2DC, Singapore's 2050 FED is 18% lower and CO_2 emissions are 25% lower. The 2050 share of renewables in TPES is 3.0% in the TGT and 4.5% in the 2DC, both higher than the 2.3% in the BAU.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. To assist in meeting the APEC goal of reducing energy intensity, Singapore has implemented policies across all sectors to reduce energy consumption and improve efficiency. Under the BAU, Singapore reduces final energy intensity to 52% below the 2005 level by 2035 and to 65% below by 2050.

In the TGT, cumulative energy demand over the Outlook period is 43 Mtoe lower than the BAU (Figure 17.7). About one-third of this reduction comes from industry owing to greater energy efficiency and lower demand in the chemical and non-specified subsectors, and 30% is attributable to greater energy efficiency in the non-energy use of energy by the industrial sector. A further 19% comes from energy demand reduction in transport, reflecting improved road vehicle efficiency and lower demand for marine oil. Buildings make up 17% of the cumulative difference between scenarios, mainly resulting from improved appliance efficiency in services.

Figure 17.7 • Singapore: Energy efficiency and renewables, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewable growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

In April 2013, the government introduced the Energy Conservation Act to mandate energy efficiency and management practices for large energy users. In March 2017, it announced enhancements to the Act, to take effect in 2018, towards achieving its Nationally Determined Contributions (NDCs),[89] including strengthening measurement and reporting requirements for greenhouse gas (GHG) emissions; requiring companies to undertake regular energy efficiency opportunity assessments; and introducing MEPS for common industrial equipment and systems. Establishment of the Energy Efficiency Programme Office in 2007 also launched various energy efficiency programs targeting industry, transport and buildings, and the residential subsector (NCCS, 2018a). Continuing to enhance and strengthen these regulations and standards is essential to achieving the energy demand reduction in the TGT.

Renewable energy supply increases slightly more in the TGT (from 0.41 Mtoe in 2016 to 0.84 Mtoe in 2050) than in the BAU (0.71 Mtoe in 2050). Whereas the BAU assumes renewables are used solely for power generation, the TGT deploys biofuels to replace some fossil fuels for industrial heating, boosting the renewables share of TPES to 3.0% in 2050. Solar also accounts for a significantly larger share of electricity capacity in 2050 under the TGT at 11%, compared with 3.7% in the BAU.

[89] The Nationally Determined Contributions (NDCs) reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement'.

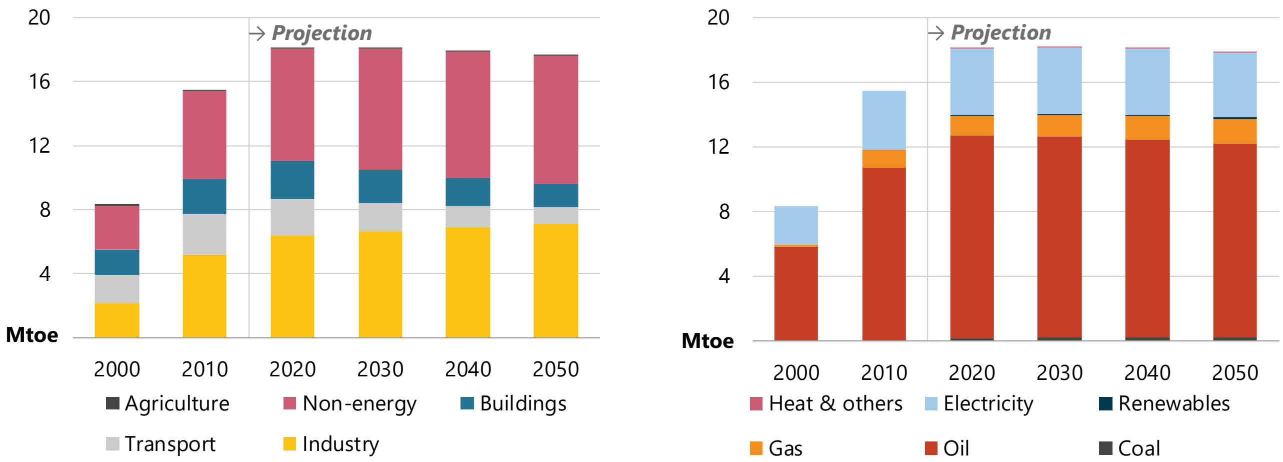
TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Singapore will have to undergo deep decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA) (2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Cumulative energy demand is 87 Mtoe lower in the 2DC than in the BAU, and 44 Mtoe below the TGT, as industry, buildings and transport all reduce energy consumption considerably (Figure 17.8). The share of renewables in FED increases slightly in the 2DC, to 0.69% in 2050, but is limited due to decreasing overall FED. Oil demand retains the largest share because of persistent demand in the non-energy use sector.

Figure 17.8 • Singapore: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

In 2050, industry FED is 7.1 Mtoe in the 2DC, compared with 7.3 Mtoe in the TGT and 8.1 Mtoe in the BAU. These decreases result from lower energy demand in the chemical and non-specified subsectors. Most of this is driven by a 22% increase in energy efficiency in the chemical and petrochemical sector. Demand reductions from the non-energy sector are limited to 9.1% below BAU levels.

In buildings, energy demand declines to 1.5 Mtoe in 2050, compared with 2.3 Mtoe in the TGT and 2.6 Mtoe in the BAU, primarily owing to greater energy efficiency which results in lower electricity consumption for space cooling. In services, telecommuting is assumed to become more widespread, which helps to reduce floor area growth (from growing 17% over the Outlook in the BAU to declining 5.6% in the 2DC) and hence energy demand.

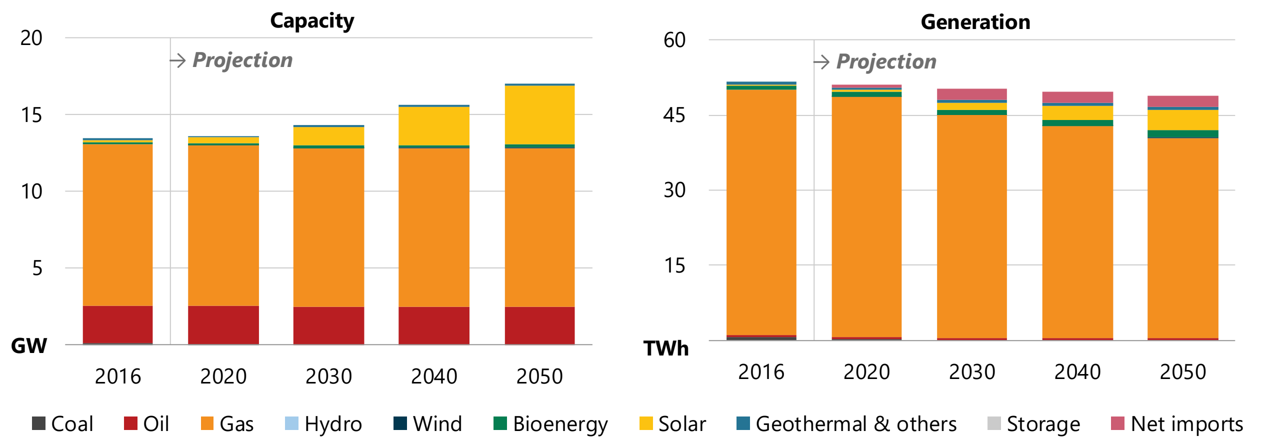
Domestic transport FED in 2050 is down to 1.1 Mtoe, compared with 1.9 Mtoe in the BAU. This reduction is attributable to fuel economy improvements in passenger and freight vehicles and significant modal shifting in the passenger sector from vehicles to mass transit options. Average energy use per kilometre driven decreases 56% in 2DC and passenger-kilometres travelled via light-duty vehicles (LDVs) decreases 37%, while those via buses and rail increase 63%. Demand by road vehicles falls to 0.71 Mtoe in 2050 in the 2DC, with energy demand for heavy-duty vehicles and LDVs falling 38% and 63% below their respective BAU levels. International transport

FED is 62 Mtoe, compared with 69 Mtoe in the BAU, as increases in vessel efficiency reduce demand in marine transport.

TRANSFORMATION AND SUPPLY IN THE 2DC

Installed oil- and gas-fired capacity remain the same as under the BAU, but Singapore's small coal-fired plant is retired in the 2DC. Solar generation capacity in 2050 expands from 0.58 GW in the BAU to 3.8 GW in the 2DC and meets Singapore's goal of 350 MWp of solar capacity by 2020. By 2050, renewables make up 24% of electric capacity. Oil-fired generation remains unchanged across scenarios, and the capacity remains as backup plants until the end of their lifespans (Figure 17.9).

Figure 17.9 • Singapore: Power capacity and electricity generation in the 2DC by fuel, 2016-50

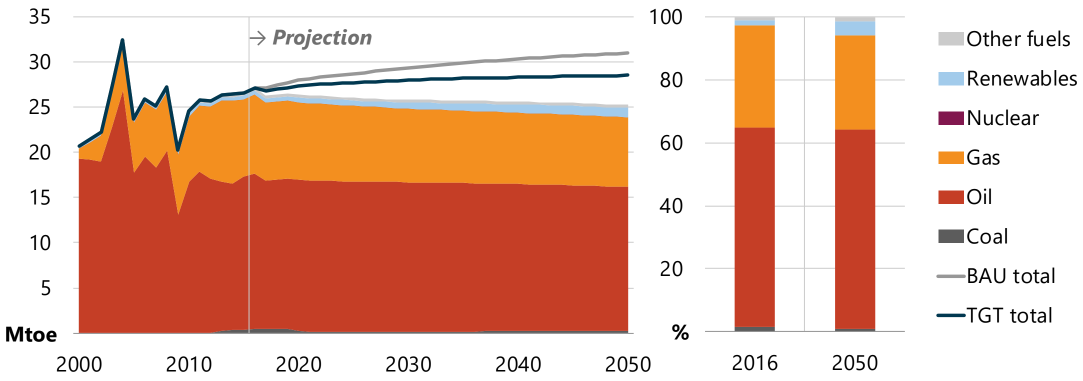


Sources: APERC analysis and IEA (2018a).

In contrast with rising electricity generation under the BAU and the TGT, electricity generation declines continuously from 52 terawatt-hours (TWh) in 2016, reaching 47 TWh in 2050. Gas-fired generation, the economy's most significant source of power generation, declines 18% (in contrast to a 22% increase in the BAU) owing to an accelerated decrease in electricity demand and an increase in renewables.

The share of renewables in TPES also increases, from 2.3% under the BAU to 4.5% under the 2DC (Figure 17.10). This owes to much stronger growth over the Outlook period (177% in the 2DC compared with 73% in the BAU) and a reduction in overall TPES in 2050, from 31 Mtoe in the BAU to 25 Mtoe in the 2DC. Oil's share increases slightly (63% share of TPES in 2050, compared with 60% under the BAU) as overall TPES drops more than oil supply, due to oil's continued role in economic activity as an input in the refineries, international transport and chemical sectors. Gas supply decreases slightly (30% share of TPES in 2050, compared with 36% under the BAU) owing to lower gas-fired electricity generation.

Figure 17.10 • Singapore: TPES in the 2DC versus the BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

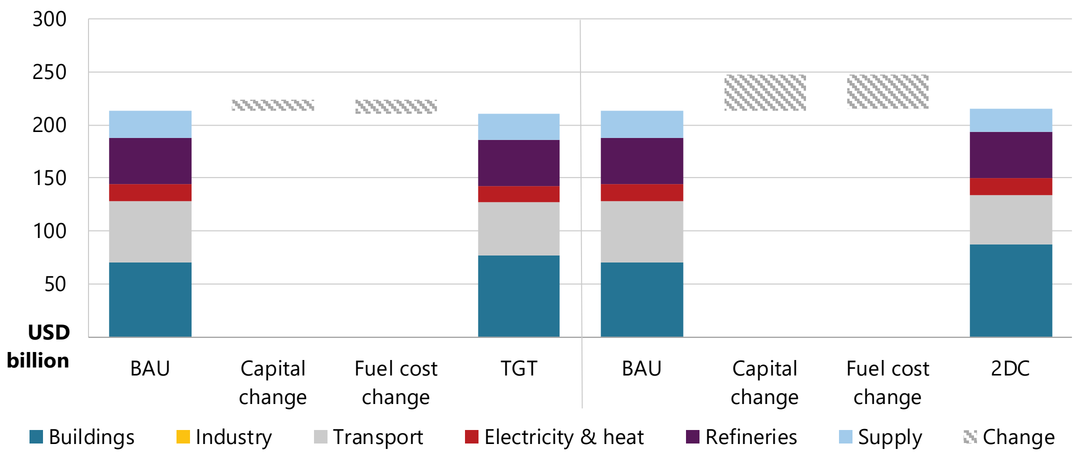
SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[90]

Cumulative energy sector investments are USD 214 billion under the BAU Scenario over the Outlook period (Figure 17.11). Investment is marginally lower in the TGT (USD 210 billion), as fuel savings from buildings and transport outweigh the increased capital costs in the buildings sector. It is, however, marginally higher in the 2DC (USD 215 billion) as those buildings capital outlays outstrip the fuel savings from the buildings and transport sectors.

Figure 17.11 • Singapore: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

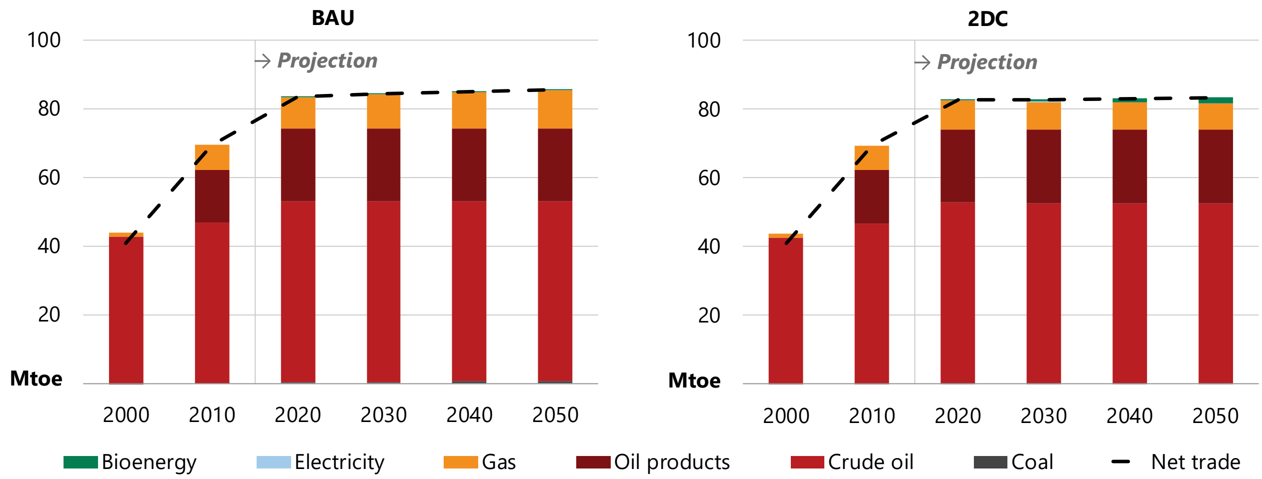
[90] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Capital investment is highest in the 2DC (USD 76 billion) and lowest in the BAU (USD 41 billion). There is a relatively large increase in buildings capital investment in both the TGT and the 2DC, to heighten energy efficiency and reduce electricity consumption in services space cooling. Buildings accounts for 49% of fuel savings in the TGT and 66% the fuel savings in the 2DC, while transport accounts for 47% of fuel savings in the TGT and 31% in the 2DC. There are also marginal fuel savings in the electricity and heat sectors. Refinery investment and fuel costs remain unaffected throughout scenarios.

ENERGY TRADE AND SECURITY

Imported fossil fuels continue to dominate Singapore's energy mix throughout the Outlook period. Net energy imports increase in 2017 before plateauing for overall growth of 5.3% in the projection period. This trend is similar in the TGT, but changes in the 2DC, where net imports begin to slightly decline in 2020 due to lower gas imports (Figure 17.12). Imports far exceed domestic energy consumption because much of the energy entering the economy is eventually exported. Most imported oil products are re-exported from its shipping hub for international consumption and most crude oil is transformed at refineries into oil products and then exported for international consumption.

Figure 17.12 • Singapore: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

More than 95% of Singapore's TPES is made up of fossil fuels, all of which are imported, and net energy imports in the BAU are projected to increase, from 81 Mtoe in 2016 to 85 Mtoe in 2050. Crude oil accounted for over half of net imports in 2016 (59%), followed by oil products (29%), gas (11%) and coal (0.53%). Singapore imports over 82% of its crude oil from the Middle East, with Saudi Arabia and the United Arab Emirates being the primary contributors, and over 77% of its refined petroleum products exports are to APEC economies (OEC, 2018a and 2018b).

Unlike oil, gas imports are primarily for domestic consumption. Prior to opening an LNG terminal in 2013, Singapore imported all its gas via pipeline from Indonesia and Malaysia. With the regasification terminal becoming operational, gas imports increased, from 7.9 Mtoe in 2012 to 8.7 Mtoe in 2016 and are projected to increase a further 28% to 11 Mtoe in 2050. In 2017, EMA issued licences to Pavilion Gas and Shell to develop its second tranche of LNG contracts, allowing the economy to access LNG from new sources, such as the United States, Norway, Qatar, Russia and Brunei Darussalam. EMA also opened up a maximum of 10% of its gas supply to LNG spot transactions (SIEW, 2016). Since Singapore has no domestic fossil fuel resources, maintaining energy security is dependent on promoting a diverse and robust network of trading partners. Primary energy self-sufficiency and supply diversity improve slightly through the Outlook, and more so in the alternative scenarios, due to increased renewables deployment (Table 17.3).

Table 17.3 • Singapore: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	3.0	3.0	3.0	4.0	3.0	4.0	5.0
Primary energy supply diversity (HHI)	0.51	0.50	0.49	0.49	0.49	0.48	0.49

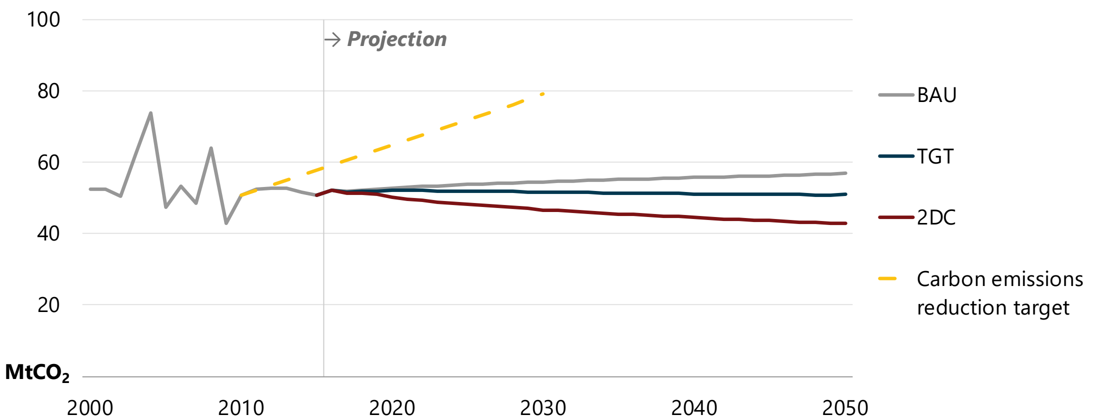
Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

At the 'COP21 Paris Agreement', Singapore announced its Intended Nationally Determined Contribution (INDC)[91] , formalising its pledge to reduce emissions intensity 36% from the 2005 level by 2030 and to stabilise emissions with the aim of peaking around 2030. This pledge builds on its 2009 commitment to reduce GHG emissions 16% below their business-as-usual projections by 2020 (NCCS, 2018b). In September 2016, this INDC was ratified as Singapore's first Nationally Determined Contribution (NDC).

Improving energy efficiency has been Singapore's key strategy for reducing emissions and achieving its NDC target across all sectors. In addition, the economy has implemented a carbon tax in 2019 to help meet its commitment (Box 17.2). Singapore's emissions intensity decreased by 37% between 2005 and 2016, as GDP grew at a higher rate than emissions. The BAU projects an emissions intensity 60% below the 2005 level by 2030, surpassing Singapore's NDC commitment. Despite this improvement, absolute energy-related CO_2 emissions increase throughout the BAU, reaching 57 million tonnes of CO_2 ($MtCO_2$) in 2050, from 52 $MtCO_2$ in 2016 (Figure 17.13).

Figure 17.13 • Singapore: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, where applicable. All NDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

[91] Intended Nationally Determined Contributions (INDCs) reflect policy action to support the agreement reached during the COP21 Paris Agreement.

In the 2DC, emissions decrease significantly (to 43 $MtCO_2$ in 2050) and emissions intensity is reduced 25% below the 2050 level of the BAU. At the same time, the pathway outlined in the 2DC requires greater efforts, which may be challenging for an economy with limited options for renewables, no nuclear energy, and strong but inflexible refining and chemical sectors. Singapore would need to phase out oil-fired power generation by 2020, maximise solar PV penetration for power generation, increase use of biofuels as cleaner alternatives to fossil fuels in both power generation and industrial applications, and begin importing electricity as early as 2020.

The EMA has been studying the feasibility of electricity imports. In December 2011, it issued a consultation paper indicating one option would be to reduce concentration risks of imports by spreading them across various sources (EMA, 2011). There have been no further updates on the status of electricity imports, but it could be a practical solution to help the economy further reduce emissions. In the 2DC, electricity imports begin at 0.47 TWh in 2020 and gradually increase to 2.3 TWh by 2030, where they remain for the rest of the Outlook period. Carbon capture, sequestration and utilisation has not been deployed because of Singapore's lack of land space and the economic viability of CO_2 mineralisation, as the process requires a significant amount of energy. This is consistent with the 2014 carbon capture and storage/utilisation roadmap study, which found that 84% of Singapore's CO_2 emissions are from stationary sources, with most emissions at 3% CO_2 concentration owing to the preponderance of natural gas in the power generation mix. Alongside this issue of low concentration, there are also challenges in finding suitable storage sites and/or demand from products that utilise the captured CO_2 (NCCS, 2014).

Box 17.2 • Singapore introduces south-east Asia's first carbon tax

Singapore contributes only 0.11% of global emissions and has among the world's lowest emissions intensity, despite its significant refining and chemical and petrochemical industries (NCCS, 2018c). Even so, Singapore has pledged to reduce emissions intensity 36% from 2005 levels by 2030, and to stabilise emissions with an aim of peaking around 2030. To this end, the government finalised the details of a carbon tax mechanism in 2018, to be effective the following year. This makes Singapore the first south-east Asian economy to implement an economy-wide carbon tax. Details of Singapore's planned mechanism are (NCCS, 2018c):

- The carbon tax will be levied on all facilities producing 25 000 tonnes of CO_2 equivalent (tCO_2-e) or more of GHG emissions per year; this applies to 30 to 40 large emitters that contribute 80% of Singapore's GHG emissions. The government will assess how to treat the remaining 20%.
- The initial carbon tax rate is set at SGD 5.0 per tCO_2-e (USD 3.7 per tCO_2-e) until 2023, to allow companies time to adjust to the carbon tax and implement energy efficiency projects.
- The carbon tax will apply uniformly to all sectors, with no exemptions. Taxable facilities will pay the carbon tax by purchasing and surrendering fixed-price carbon credits corresponding to their verified emissions of the previous year.
- The government will review the rate by 2023, with the intention of raising it to between SGD 10 per tCO_2-e (USD 7.4 per tCO_2-e) and SGD 15 per tCO_2-e (USD 11 per tCO_2-e) by 2030, depending on international developments, Singapore's progress in emissions mitigation and economic competitiveness.

With large taxable facilities in the petroleum refining, chemical and semiconductor sectors, and a power generation mix dependent on natural gas, the carbon tax will affect all sectors of the economy. With the implementation of carbon tax, the electricity tariff increased by ~1% or SGD 0.0021 per kilowatt-hour (kWh) (USD 0.0016 per kWh) (NCCS, 2018d).

Singapore adopted a carbon tax of SGD SGD 5.0 per tCO_2-e (USD 3.7 per tCO_2-e) for the initial 5 years to provide companies a transition period to adopt energy efficiency projects. This impact may be felt more heavily by companies exposed to international trade, such as those in the refining, petrochemical and semiconductor industries. However, business competitiveness will be threatened if energy efficiency improvements do not keep pace with any further tax raises. The government estimates that the carbon tax would generate nearly SGD 1.0 billion (USD 1.3 billion) of revenue in the first five years of implementation, which would be recycled to help support worthwhile projects to reduce emissions and improve energy efficiency (Singapore Government, 2018).

Note: All exchange rate calculations in this chapter are based on the 2018 daily average Singapore/US foreign exchange rate as of 29 November 2018 (FRED, 2018).

OPPORTUNITIES FOR POLICY ACTION

Singapore surpasses its NDC goal under all three scenarios, and while CO_2 emissions increase throughout the BAU, they peak in 2019 under the TGT and decrease throughout the 2DC. The economy may consider renewing its NDC targets and embracing the 2DC's more ambitious requirements, which could be achieved through stronger policy implementation or more ambitious carbon pricing. The government has already announced it will consider doubling or tripling the rates after five years, but any increase is likely to raise concerns of economic competitiveness. Such discussions may benefit from reconsidering differentiated rates, which can take into account varying market conditions in each sector. They may also incentivise energy efficiency and adoption of BATs among relatively light emitters within the targeted scope. The time frame of any raises also needs to be studied carefully, as it could change short- to mid-term investment decisions, and ultimately impact both cumulative and peak emissions.

Strengthening building energy efficiency is another area of opportunity. For example, district cooling is an effective way to reduce energy use by leveraging economies of scale. It has already been adopted in several sites, such as Marina Bay, where a 5 km centralised piping network cools buildings using chilled water (ABB, 2011). It also has the merit of freeing individual buildings' roof space (otherwise necessary for a cooling tower) for the use of solar PV. While Marina Bay has proven a success, there is still potential for policy-led initiatives to help overcome obstacles to further deployment and retrofits, such as high up-front capital costs.

With renewable energy options limited and nuclear power currently unfeasible, the economy continues to rely predominantly on fossil fuels through 2050 in all scenarios; import diversity, therefore, remains vital to enhancing energy security. Developing grid interconnections with neighbouring economies, in line with the ASEAN Power Grid program set up in 1997, would benefit Singapore's electricity network and reduce emissions. Interconnections can realise more effective development and utilisation of renewable energy resources, especially for Singapore, which has very different economic and geographic characteristics than other regional economies. Hydro, geothermal and large-scale solar PV are examples of resources that would otherwise be unavailable. Policymakers clearly have a leading role to play in this area; aside from the EMA consultations in 2011, several ideas have been considered, such as the Batam (Indonesia)-Singapore, Peninsular Malaysia-Singapore, and Singapore-Sumatra (Indonesia) transmission lines (EMA, 2016).

Leveraging its knowledge in the deployment of floating solar installations at a higher scale would reduce Singapore's emissions and reduce Singapore's need to rely on fossil fuels or electricity imports from neighbouring economies. See Box 17.1 for more details on the made-in-Singapore solution to building renewable capacity in the smallest APEC economy by land area.

18. CHINESE TAIPEI

KEY FINDINGS

- **Chinese Taipei's TPES peaks at 111 Mtoe in 2020 in the BAU Scenario** and gradually declines to 99 Mtoe in 2050 as energy demand decelerates, especially in industry and buildings.

- **FED shrinks marginally in the BAU Scenario, from 70 Mtoe in 2016 to 65 Mtoe in 2050,** and non-energy use and industry are the main consumers. FED declines to 57 Mtoe in the TGT and 51 Mtoe in the 2DC owing to greater energy efficiency efforts in industry, buildings and transport.

- **Natural gas accounts for 44% and renewables account for 42% of the electricity generation mix in 2050 in the 2DC, with gas up from 32% in 2016 and renewables up from 4.2%.** The share of coal falls to zero as all coal-fired plants are retired by 2039.

- **Energy intensity improves by 37% from 2016 to 2050 in the BAU, 44% in the TGT and 50% in the 2DC.** The largest reduction is in transport as more advanced vehicles, particularly EVs, replace conventional ones.

- **The 2DC achieves INDC and Greenhouse Gas Reduction and Management Act targets.** In the 2DC, CO_2 emissions of 165 Mt in 2030 and 77 Mt in 2050 fall below target maximums, and represent a significant improvement on 2016 emissions (264 $MtCO_2$).

ECONOMY AND ENERGY OVERVIEW

Chinese Taipei is a subtropical archipelago comprising the islands of Kinmen, Matsu, Penghu and Taiwan. Located off the south-east coast of the People's Republic of China and the south-west coast of Japan, with an area of 36 193 square kilometres (km^2) (MOI, 2018), Chinese Taipei is a natural gateway to east Asia.

Following a period of rapid economic growth in the late 20th and early 21st centuries, Chinese Taipei has become a developed economy with a per-capita gross domestic product (GDP) of USD 48 093 in 2016, more than twice the Asia-Pacific Economic Cooperation (APEC) region average of USD 22 536. Its economic structure has changed substantially over the past decade, with focus shifting from industrial production to the services sector. In 2016, services accounted for 63% of total GDP, followed by industry (36%) and agriculture (1.8%) (BOE, 2018a).

Chinese Taipei is one of the most densely populated areas in the world, but population growth is relatively flat, with a compound annual growth rate (CAGR) of 0.33% from 2010 to 2016. Because having a child may be a financial burden, as wages have lagged behind cost-of-living increases, Chinese Taipei has the world’s third-lowest birth rate (Taiwan News, 2017). The population is projected to decline from 24 million in 2016 to 23 million in 2050 (Table 18.1).

Final energy demand (FED) grew from 49 million tonnes of oil equivalent (Mtoe) in 2000 to 70 Mtoe in 2016 at a CAGR of 2.3% along with growing economy. Similarly, per-capita GDP grew from USD 30 694 in 2000 to USD 48 093 in 2016 (2.8% CAGR). However, per-capita GDP grows more slowly after 2016, from USD 48 093 to 72 306 in 2050 (1.2% CAGR). This slower growth is reflected in FED, which declines from 70 Mtoe in 2016 to 65 Mtoe in 2050 (-0.25% CAGR).

Table 18.1 • Chinese Taipei: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	670	984	1 133	1 251	1 504	1 627	1 646
Population (million)	22	23	24	24	24	24	23
GDP per capita (2016 USD PPP)	30 694	42 588	48 093	52 522	62 272	68 256	72 306
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	86	112	110	112	110	107	100
TPES per capita (toe)	3.9	4.9	4.7	4.7	4.5	4.5	4.4
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	128	114	97	90	73	66	61
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	49	68	70	70	71	69	65
FED per capita (toe)	2.2	2.9	3.0	3.0	3.0	2.9	2.8
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	73	69	62	56	48	42	39
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	226	265	264	279	286	280	266
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis; IEA (2018a); IPCC (2018); OECD (2018); UN DESA (2018); World Bank (2018a and 2018b).

ENERGY RESOURCES

Chinese Taipei has very modest domestic fossil fuel resources and therefore relies on imports to meet domestic energy demand. From 2000 to 2016, imported energy accounted for 98% of total primary energy supply (TPES) (BOE, 2018a). The economy has only 2.4 million barrels (Mbbl) of oil reserves (EIA, 2016) and limited coal reserves (the exact amount is not known because reserves have not been estimated since production stopped in 2001).

In 2016, domestic crude oil production accounted for 0.02% of total crude oil supplies, and domestic natural gas accounted for 1.4% of total natural gas supplies (BOE, 2018a). To boost domestic energy production, state-owned oil and gas company Chinese Petroleum Corporation (CPC) completed 2D seismic surveys on 113 km^2 of the Pingtung Plain, a high-precision gravity survey of the Fengshan mud structures and geological surveys covering 73 km^2, and repaired three production wells in 2016. There are currently 33 oil- and natural gas-producing wells spread over Chan Mountain and Qing Cao Lake in Taichung City, Jing Shui and Chu Kuang Keng in Miaoli Prefecture, and Guang Tien in Tainan City, yielding 266 million cubic metres of natural gas and 5 407 kilolitres of condensate annually. CPC is also cooperating with Husky Energy of Canada on exploration of deepwater blocks in the Tainan Basin, as well as with China National Offshore Oil Corporation (CNOOC) and France's TOTAL to start a 2D seismic survey in deepwater areas of the Taiwan Strait (CPC, 2018).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

Energy policy in Chinese Taipei changed significantly following the inauguration of a new government in May 2016. To meet its zero-nuclear target in 2025 and to address the precarious energy situation, the government announced its New Energy Policy in May 2016 (BOE, 2016). In April 2017, the Ministry of Economic Affairs expanded the core values of the Guidelines on Energy Development (originally released in 2012) to reflect the economy's energy transition (BOE, 2017).

The main purposes of the New Energy Policy are to initiate an energy system transition and reform power market regulation. Its two main objectives are to:

- Enlarge the share of clean energy[92] in the power mix by increasing the renewable energy share to 20% (from 4% in 2015) and the natural gas share to 50% (from 31% in 2015) by 2025, and reduce the share of coal in the power mix to 30% (from 45% in 2015).
- Decommission the three existing nuclear plants when their authorised 40-year lifespans expire between 2018 and 2025 to achieve a 'nuclear-free homeland' by 2025.

The New Energy Policy's overarching goals are to:

- Stabilise power generation sources and strengthen demand management to ensure power supply security.
- Promote energy efficiency and reduce energy consumption.
- Diversify the energy mix, especially by developing clean energy.
- Accelerate implementation of power storage systems and strengthen the stability of the power grid.
- Promote smart grids and smart meters.
- Integrate domestic resources into the clean-energy system.
- Reform power market regulation and reduce power system losses.

[92] In the New Energy Policy, natural gas is considered a form of clean energy because it is less CO_2 emissions-intensive than coal.

The revised Guidelines on Energy Development still serve as the primary policy guidance for energy development, energy policy programs, standards and action plans. The expanded core values include energy security, green economy goals, environmental sustainability and social equity. The guidelines are based on the Energy Administration Act and aim to ensure balanced development in the core value areas to achieve the nuclear-free homeland target by 2025 and develop the energy system sustainably. The guidelines also announced plans for an Energy White Paper to promote the energy transition, which the Bureau of Energy (BOE) began working on in February 2018. The white paper will include more detailed measures and policy tools for future energy system development, and the government aims to submit annual reports summarising achievements and to conduct periodic reviews every five years.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy assumptions and projections for Chinese Taipei under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 18.2). Definitions used in this Outlook may differ from government targets and goals published elsewhere.

Table 18.2 • Chinese Taipei: Key assumptions and policy drivers under the BAU

Buildings	MEPS and labelling programs maintained at current levels.
Industry	Manufacturing processes made more efficient and low-carbon technologies adopted. Production scale of energy-intensive subsectors, such as iron and steel, non-metallic minerals, and chemicals and petrochemicals, assumed not to expand because of environmental concerns.
Transport	Continuation of current fuel efficiency standards.
Energy supply mix	Renewables development accelerated, especially solar and wind. Third LNG terminal completed by 2025 and LNG storage facilities enlarged.
Power mix	Long-term power development plan for efficient coal-fired (5.2 GW by 2027) and CCGT (16 GW by 2027) plants (Taipower, 2018). All existing nuclear reactors retire by 2025 in line with the Electricity Act (LRDROC, 2017).
Renewables	Renewables-based capacity and generation enlarged, especially for solar and wind.
Energy security	No explicit energy security policies and targets.
Climate change	Economy works towards reducing GHG emissions by 20% below 2005 level by 2030.

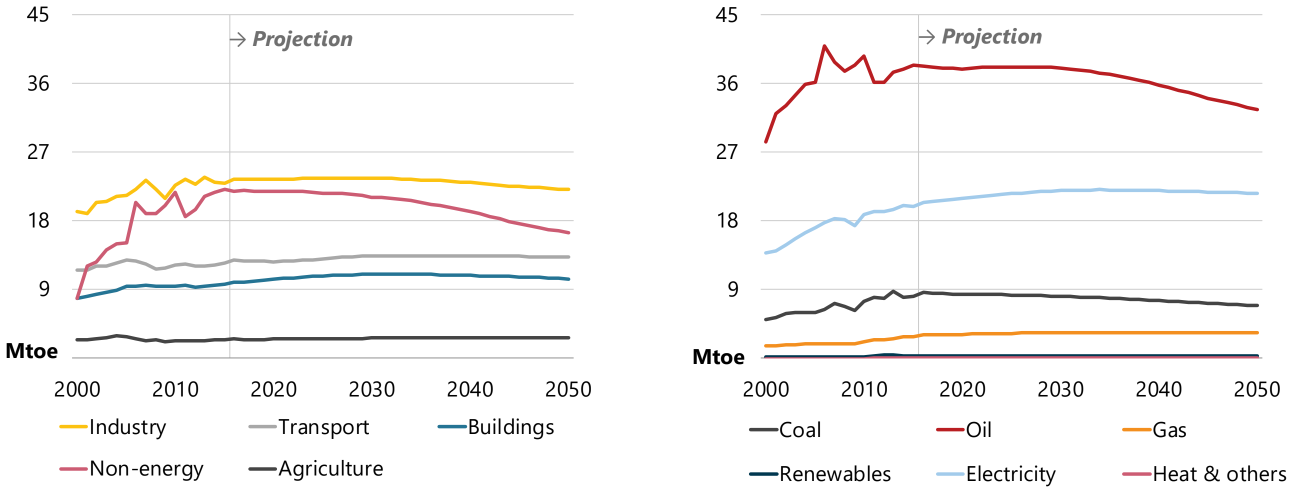
Notes: MEPS = minimum energy performance standards. LNG = liquefied natural gas. GW = gigawatts. CCGT = combined-cycle gas turbine. GHG = greenhouse gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

FED in Chinese Taipei grew at a CAGR of 2.3% between 2000 and 2016 to reach 70 Mtoe in 2016 under the BAU Scenario (Figure 18.1). Growth in wealth[93] (2.8% CAGR) rather than population (0.47% CAGR) was the main driver of FED. Although GDP continues to rise over the Outlook period (2016-50), FED growth declines and it reaches 65 Mtoe in 2050.

[93] In terms of GDP per capita.

Figure 18.1 • Chinese Taipei: Final energy demand by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

The demand sectors that claimed the largest shares of FED in 2016 were industry (33%) and non-energy use (31%), followed by domestic transport (18%), buildings (14%), and agriculture and non-specified (3.4%). These shares remain largely stable to 2050, except non-energy use's share drops to 25% because Chinese Taipei is not expanding any chemical and petrochemical plants.

Energy intensity, measured as FED per unit of GDP, declines at a CAGR of 1.3%, from 64 tonnes of oil equivalent (toe) per 2016 USD million purchasing power parity (PPP) in 2016 to 40 toe per 2016 USD million PPP in 2050, owing to policies developed in the BOE's Energy Saving Target and Roadmap. The aim of the Energy Saving Target and Roadmap, which promotes the Guidelines on Energy Development, is to cut energy intensity by 2.4% per year and electricity intensity by 2.0% per year between 2017 and 2025. The roadmap includes implementation plans for the building envelopes, residential and services,[94] industry, and transport sectors. It aims to reduce energy consumption to 5.0 Mtoe or 17 terawatt-hours (TWh) in these four sectors below the 2016 level by 2025 (BOE, 2018b).

[94] The buildings sector classification in Chinese Taipei's Energy Saving Target and Roadmap is different from APERC's classification, which splits buildings between residential and service subsectors. Chinese Taipei's roadmap also includes building envelopes as a separate sector.

Box 18.1 • Chinese Taipei: Demand reduction targets in demand sectors

In February 2018, the BOE released an Energy Saving Target and Roadmap for each of the building envelopes, residential and services, industry, and transport sectors:

Building envelopes (BOE, 2018c)

Target: improve and strengthen consumption reduction-related regulations and measures. Reduce energy demand by 0.63 Mtoe or 3.2 TWh below the 2016 level by 2025.

Roadmap: improve design index by 10% for new building envelopes and add 500 green building materials and candidate certificates every year. Strengthen current measures for reducing energy consumption of existing buildings. Promote transparency of building energy consumption. Develop internet-based demand reduction simulation tools to estimate consumption. Conduct zero-energy-building feasibility studies.

Residential and services (BOE, 2018d)

Target: improve energy efficiency to reduce electricity demand by 6.5 TWh and oil consumption by 0.03 Mtoe from 2016 levels by 2025.

Roadmap: promote energy audits and provide consumption reduction counselling for service sectors. Improve energy efficiency management for residential and services sector. Strengthen basic consumption reduction measures in local areas and expand public participation.

Industry (BOE, 2018e)

Target: reduce energy intensity by 45% below the 2005 level by 2025. Reduce energy consumption by 2.3 Mtoe and carbon dioxide (CO_2) emissions by 7.0 million tonnes of carbon dioxide ($MtCO_2$) in 2016-25.

Roadmap: promote the transition to lower-intensity industry by increasing efficiency of manufacturing processes and retrofitting factories to use low-carbon fuels. Provide energy saving and CO_2 emissions reduction counselling for manufacturers. Promote regional resource integration and establish incentive mechanisms.

Transport (BOE, 2018f)

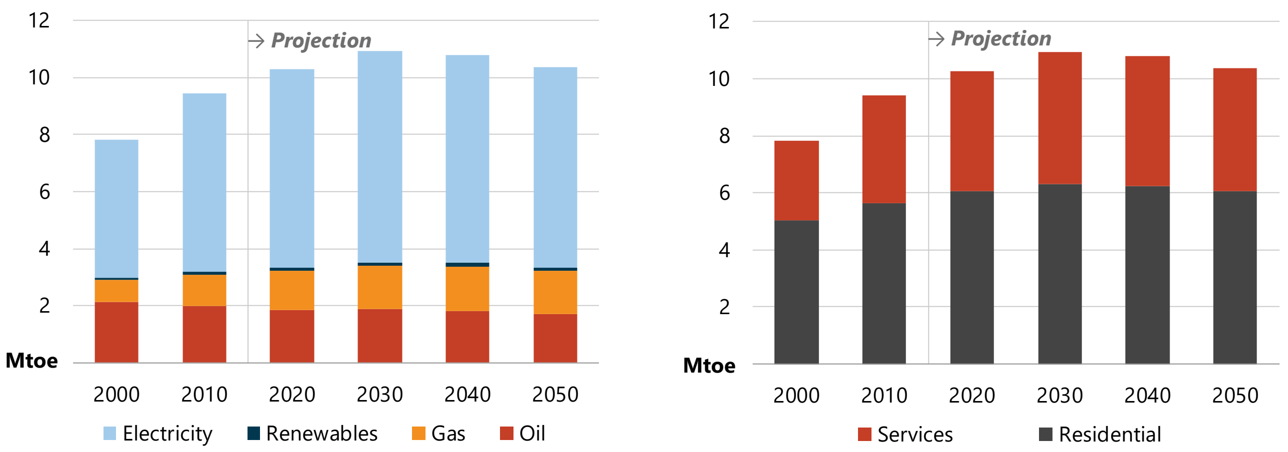
Target: reduce gasoline consumption by 0.85 megalitres (ML) (723 toe) and diesel consumption by 0.10 ML (84 toe) from the 2017 level by 2020. Increase electricity use by 406 megawatt-hours above the 2017 level by 2020. Reduce transport CO_2 emissions by 2.0 $MtCO_2$ below the 2017 level by 2020.

Roadmap: retire 80 000 first- and second-phase heavy-duty diesel vehicles by 2019. Expand public transport capacity by 2.0% above the 2015 level by 2020 to serve 1.2 billion passengers per year. Improve fuel economy standards above the 2014 level by 10% for scooters, 30% for passenger cars and 25% for trucks by 2022. Complete rail electrification by 2022. Have 10 000 electric buses operating by 2030. Sell only electric scooters by 2035. Sell only electric cars by 2040.

BUILDINGS: DEMAND PEAKS IN 2033 THEN SLIGHTLY DECLINES BY 2050

Building energy demand, which includes the residential and services subsectors, grows from 9.8 Mtoe in 2016 to 11 Mtoe in 2030 under the BAU, then gradually declines to 10 Mtoe in 2050 (Figure 18.2). Residential and service shares remain almost unchanged over the Outlook period (the services share of total buildings FED grows marginally, from 40% in 2016 to 42% in 2050).

Figure 18.2 • Chinese Taipei: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

Residential FED grows, from 5.9 Mtoe in 2016 to 6.1 Mtoe in 2050. Because of space constraints, average floor area remains at 152 square metres per household throughout the Outlook period, as a marginal population decrease is met by a slight increase in the average building stock size. Electricity is still the dominant fuel in 2050; the share is slightly lower (66% in 2050 from 69% in 2016). Natural gas' share expands slightly as its use for water heating and cooking increases, while use of renewables for water heating expands marginally as solar hot water system uptake grows.

Chinese Taipei's subtropical climate means there is no heating demand, and cooking is the largest residential end-use of energy, accounting for 30% of the subsector's consumption in 2016. Space cooling, which has been growing rapidly, accounts for 19% of energy consumption, followed by water heating (16%). End-use shares are similar in 2050, as energy demand growth is minimal. Consumption declines for space cooling (-4.7%), lighting (-53%) and appliances (-2.4%) owing to saturation, implementation of minimum energy performance standards (MEPS) and wider deployment of more energy efficient technologies. Energy consumption for water heating, cooking and other end-uses increases by 7.1% to 33% over the Outlook period.

Services FED has grown rapidly, from 2.8 Mtoe in 2000 to 3.9 Mtoe in 2016, as the structure of the economy shifted away from industry. Demand peaks in 2033 at 4.6 Mtoe, then gradually declines to 4.3 Mtoe in 2050 as energy efficiency improvements outweigh slight growth in floor area. Lighting energy demand declines the most among services end-uses, falling from 0.38 Mtoe in 2016 to 0.27 Mtoe in 2050 as efficient LED lamps replace incandescent bulbs. In terms of fuels, oil demand declines the most (-35%) as space and water heating shift to more efficient natural gas and electricity.

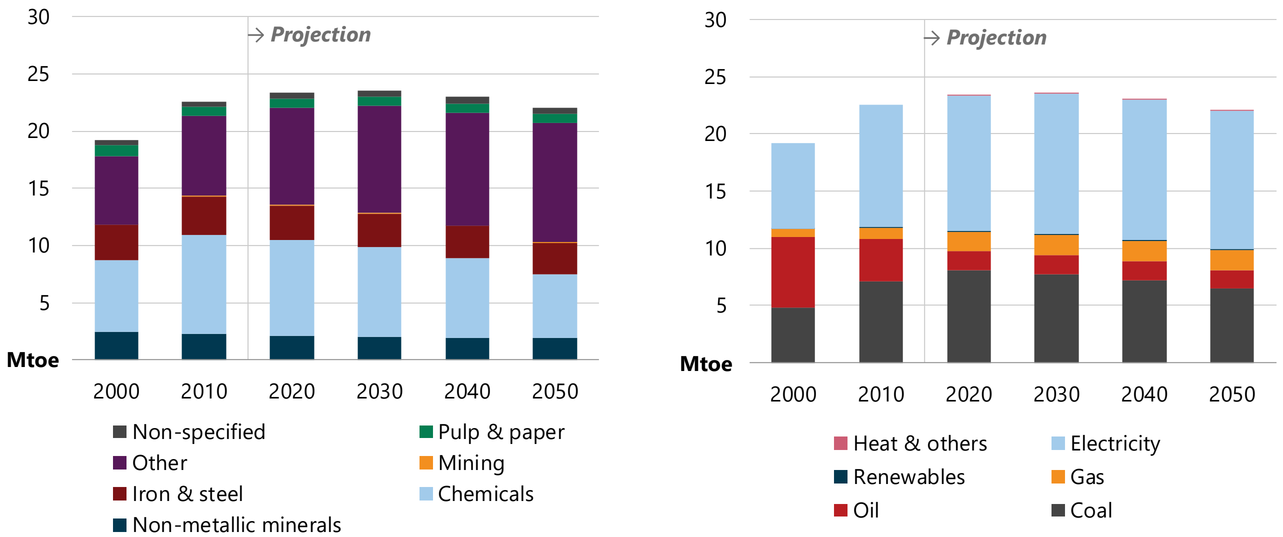
INDUSTRY: CHEMICAL SUBSECTOR DRIVES MODERATE DEMAND GROWTH

Industry is the largest energy-consuming sector in Chinese Taipei, accounting for 33% of FED in 2016. This owes largely to the chemical and petrochemical subsector, which accounted for 36% (8.4 Mtoe) of industry demand in 2016. The 'other' subsector[95] is the second largest industry energy demand subsector (at 35%), and has grown steadily in recent years (Figure 18.3).

The development of the chemical and petrochemical subsector originates with the Kaohsiung refinery and Taiwan Fertilizer Company, two plants built by the Japanese government early in the 20th century (LTN, 2014). FED in this subsector declines from 8.4 Mtoe in 2016 to 5.6 Mtoe in 2050. The negative growth is because most petrochemical companies have chosen to invest in new projects in China and the United States to take advantage of lower feedstock prices, rather than expanding new capacity or plants in Chinese Taipei.

In terms of fuel use, electricity is dominant (50% in 2016), followed by coal (35%), oil (8.0%), natural gas (7.2%) and renewables (0.40%). The electricity share increases to 55% in 2050 with the switch away from coal (which has a slightly smaller [30%] share in 2050) as industry moves to more low-carbon fuels in manufacturing processes.

Figure 18.3 • Chinese Taipei: Industry final energy demand by subsector and fuel, 2000-50



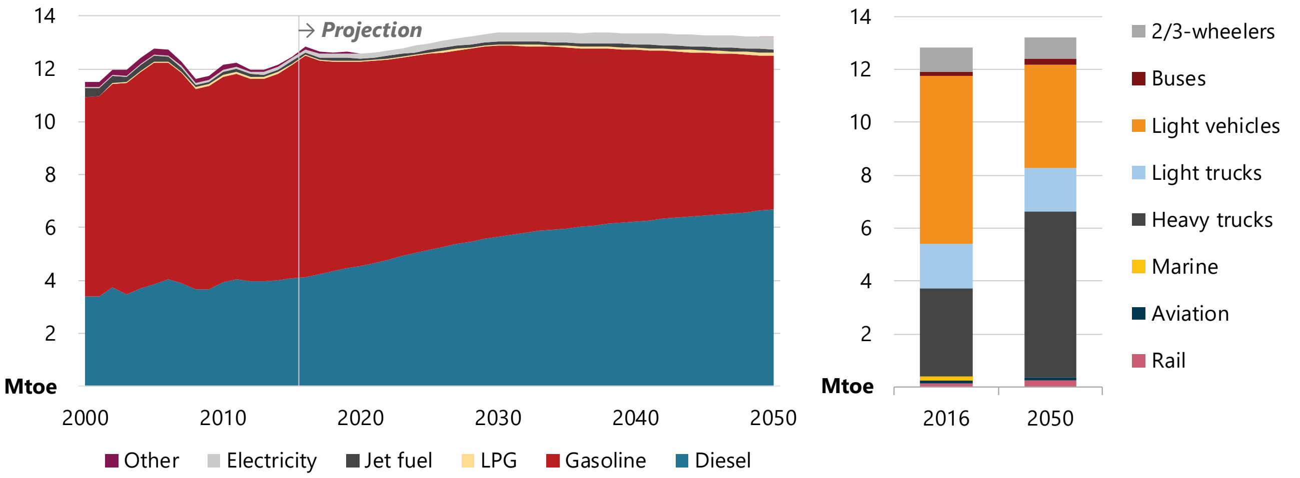
Sources: APERC analysis and IEA (2018a).

TRANSPORT: DEMAND PEAKS IN 2030 BEFORE EFFICIENCY-LED DECLINE

Domestic transport energy demand grew steadily between 2000 and 2006, then began to decline with the introduction of the high-speed rail line connecting Chinese Taipei's two largest cities, Taipei and Kaohsiung, in 2007. Demand has been growing modestly since then and reaches 13 Mtoe in 2030 before plateauing over the remainder of the Outlook as increased kilometres travelled is offset by improved fuel efficiency and electric vehicles (EVs) replacing conventional ones (Figure 18.4).

[95] The 'other' subsector includes non-ferrous metals except aluminium, transport equipment, machinery, food and tobacco, wood and wood products, construction, and textiles and leather, of which machinery is the largest energy consumer at 22% of total industry FED in 2016.

Figure 18.4 • Chinese Taipei: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

As Chinese Taipei is a small archipelago, road dominates transport, accounting for 97% of FED in 2016. Demand shares by mode remain stable to 2050, with road transport still consuming 97% and rail gaining a small amount (1.7%). Within road transport, the largest share of energy demand is from light-duty vehicles (LDVs) (51% in 2016), followed by heavy-duty trucks (27%) and light-duty trucks (14%). Shares by vehicle type remain similar in 2050, apart from a slightly larger share from heavy-duty trucks relative to light-duty trucks as fuel efficiency improves more in the latter. Gasoline and diesel dominate the fuel mix through the Outlook, accounting for 97% of domestic transport FED in 2016, while electricity supplied only 0.91%. The electricity share increases to 3.6% in 2050 as EVs, particularly two- and three-wheelers, become more widespread.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Because of its modest domestic energy reserves and zero-nuclear target, Chinese Taipei has been striving to diversify fuel types and employ more renewables and natural gas, particularly in the electricity sector. However, the transition is costly and may take a long time, resulting in energy security remaining on ongoing concern.

ENERGY INDUSTRY OWN-USE: TRANSPORT EFFICIENCIES AFFECT REFINERIES

Chinese Taipei has two oil refining companies: CPC with three refineries (Taoyuan, Kaohsiung and Da-ling) and Formosa Petrochemical Corporation with one (Mai Liao). Combined capacity in 2016 was 65 Mtoe, which significantly exceeded production (45 Mtoe in 2016). Production of oil products declines by 11% in the BAU Scenario to 39 Mtoe in 2050 as a result of a significant shift in LDVs from gasoline- and diesel-powered to hybrid and battery electric-powered.

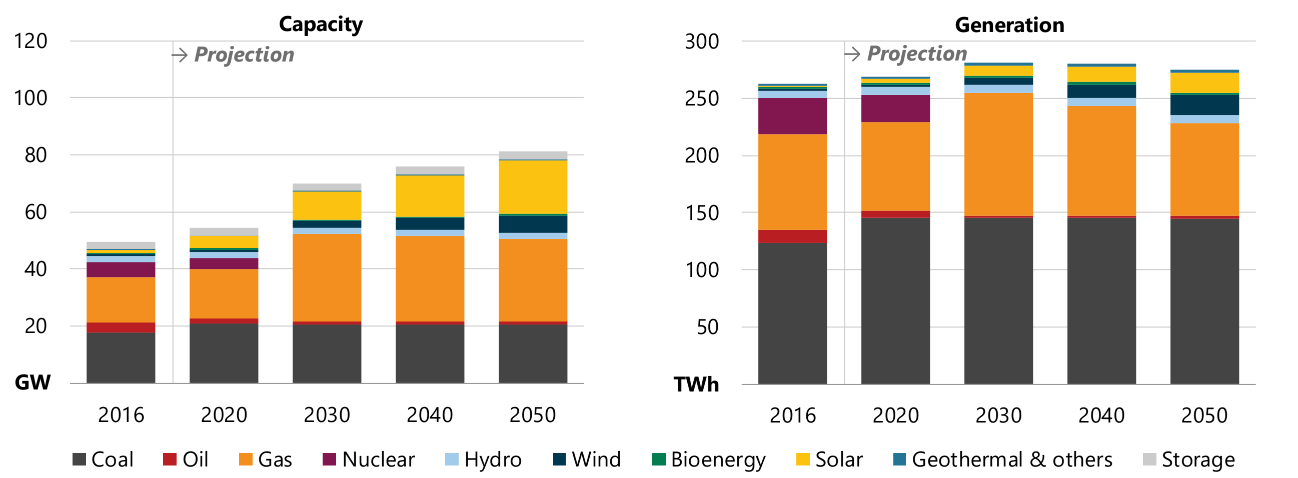
POWER SECTOR: SOLAR AND WIND SHARES GROW CONSIDERABLY

Chinese Taipei has three interconnected power grids: north, central and south. The north area, where Taipei is located, has the largest demand in peak hours, so it is common for power to flow north from the central grid. Until 1990, the Taiwan Power Company (Taipower) was responsible for all power generation, transmission, distribution and sales. Since then, the sector has been opened up to allow private companies to establish power plants, creating competition in the generation sector. As of December 2018, there were 25 independent power producers (IPPs)[96] in Chinese Taipei.

Chinese Taipei's power sector relies heavily on imported fossil fuels. Coal accounted for 36% total power capacity in 2016 and natural gas for 32%, followed by nuclear (11%), renewables (8.8%), oil (7.5%) and storage[97] (5.2%) (Figure 18.5). Generation capacity expands rapidly in the BAU, from 50 gigawatts (GW) in 2016 to 70 GW in 2030 as several new power plants come online. In January 2018, the state-owned power company released its Long-Term Power Plan, which aims to expand renewable capacity by 0.30 GW in 2021 and fossil fuel capacity by 10 GW in 2025, largely to replace retiring nuclear plants (Taipower, 2018). In April 2018, the government approved 11 offshore wind farms (operated by 7 companies, including Taipower and China Steel Corporation and 5 foreign companies) with an expected combined capacity of 3.8 GW by 2025 (CNA, 2018). After 2030, capacity expands more slowly, from 70 GW in 2030 to 81 GW in 2050, as electricity demand growth decelerates. By 2050, renewables share in the power generation mix increases significantly, reaching 34% as it replaces closing nuclear capacity.

Power generation generally follows capacity trends, with coal accounting for 47% of the fuel mix in 2016 and natural gas for 32%. Coal accounts for more of the mix as it operates at a higher utilisation rate than natural gas because some of the natural gas installations are intermediate plants. Total generation increases marginally over the Outlook, from 263 TWh in 2016 to 276 TWh in 2050. In 2050, the fuel mix is less diversified: coal accounts for 53% of power generation, followed by natural gas (30%) and renewables (16%). Nuclear-based generation is entirely phased out, replaced with natural gas and renewables.

Figure 18.5 • Chinese Taipei: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

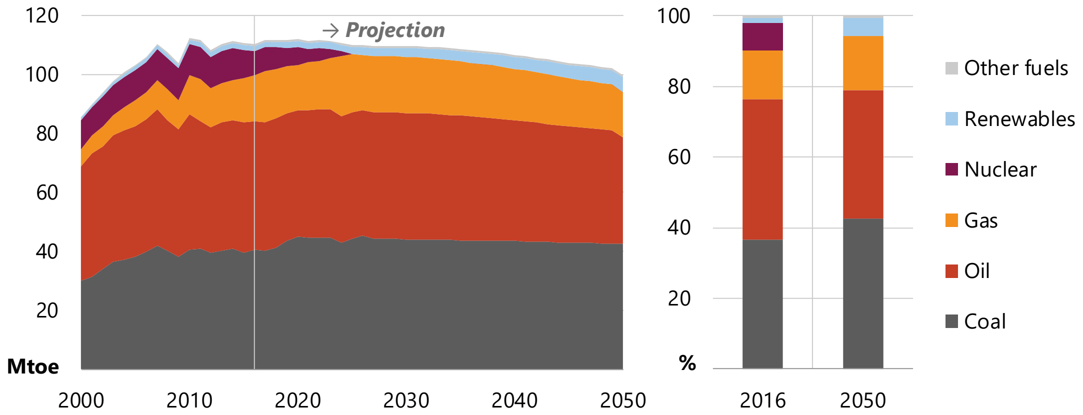
TOTAL PRIMARY ENERGY SUPPLY: DECLINES GENTLY OVER THE OUTLOOK PERIOD

Imported oil, coal and natural gas dominate Chinese Taipei's TPES in the BAU, with smaller amounts of domestically produced nuclear and renewable energy. TPES grew from 86 Mtoe in 2000 to 110 Mtoe in 2016 as a result of expanded coal use in the power and industry sectors and more recent expansion in gas-fired generation (Figure 18.6). TPES peaks at 111 Mtoe in 2020 under the BAU before declining to 99 Mtoe by 2050 as consumption in demand sectors shrinks, especially in the non-energy use and industry sectors.

[96] 25 IPPs include 3 hydro companies, 9 solar photovoltaic companies and 13 wind power companies.
[97] Which is all pumped hydro in Chinese Taipei.

Oil had the largest share of TPES (39%) in 2016, followed by coal (37%), natural gas (14%), nuclear (7.5%) and renewables (1.5%). In 2025, the nuclear share declines to zero under the BAU as Chinese Taipei retires its three nuclear plants. To fill the supply gap, shares of other fuels increase, especially natural gas, which grows to 18%. In 2050, as solar and wind projects come online, the share of renewables rises to 5.1%, while natural gas shrinks to the 2016 level (15%). Coal and oil shares remain largely the same.

Figure 18.6 • Chinese Taipei: Total primary energy supply by fuel, 2000-50

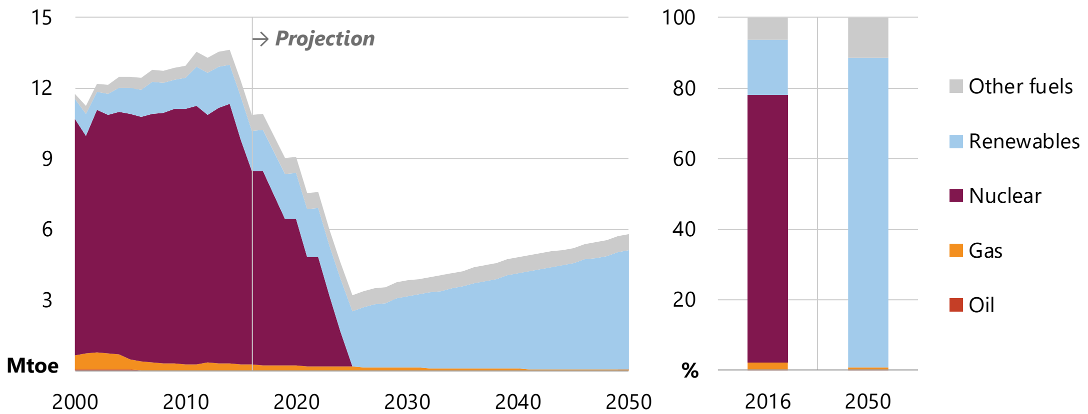


Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: IMPORTED FOSSIL FUELS CONTINUE TO DOMINATE

Because Chinese Taipei's fossil fuel and renewable resources are modest, net imports have long exceeded primary energy production. Total primary energy production started to decline in 2014 because of ongoing oil and gas reserve depletion, and the suspension of four nuclear reactors[98] due to annual maintenance and full spent fuel pools.[99] Production continues to decline to 3.2 Mtoe by 2025 in the BAU with the phase-out of nuclear power, which is counted as domestic production despite the raw uranium being imported (Figure 18.7). After 2025, production gradually increases to 5.8 Mtoe in 2050, with strong growth in renewables-based power generation.

Figure 18.7 • Chinese Taipei: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

[98] There are three nuclear plants in Chinese Taipei; each has two reactors. The first nuclear plant is scheduled to be decommissioned in 2018 and 2019, the second in 2021 and 2023, and the third in 2024 and 2025.
[99] Spent fuel pools are storage pools for spent fuel from nuclear reactors.

Total net energy imports grew from 79 Mtoe in 2000 to 103 Mtoe in 2016—in line with TPES, as production did not change much. Crude oil is the primary fuel import (44% of total net energy imports) and most of it comes from the Middle East (78% in 2016) (BOE, 2018g). Coal is the second-most-imported fuel (39% of total energy imports in 2016), supplied mostly by Australia (52%) and Indonesia (31%) (BOE, 2018a). Natural gas made up 16% of fuel imports in 2016 in the form of liquefied natural gas (LNG) from Qatar (42%), Malaysia (17%) and Indonesia (14%) (BOE, 2018a). Total net energy imports decline over the Outlook, from 103 Mtoe in 2016 to 98 Mtoe in 2050, because of less demand of crude oil.

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Chinese Taipei's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 13% lower while energy-related CO_2 emissions are 38% lower in the TGT by 2050. Under the 2DC, Chinese Taipei's FED is 21% lower and CO_2 emissions are 72% lower. The share of renewables in TPES is 8.0% higher in the TGT and 11% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. In Chinese Taipei's buildings sector, MEPS and increased appliances efficiency from stricter and broader coverage of labelling schemes are major drivers of reduction in demand. Best available technology (BAT) is assumed to be adopted in all industrial subsectors. In the iron and steel subsector, this results in greater use of electric arc furnaces over blast furnace-basic oxygen furnaces[100] and higher scrap steel recycle rates relative to the BAU. Lower clinker-to-cement ratios also reduce the most energy-intensive cement production process without reducing output in the non-metallic minerals subsector.

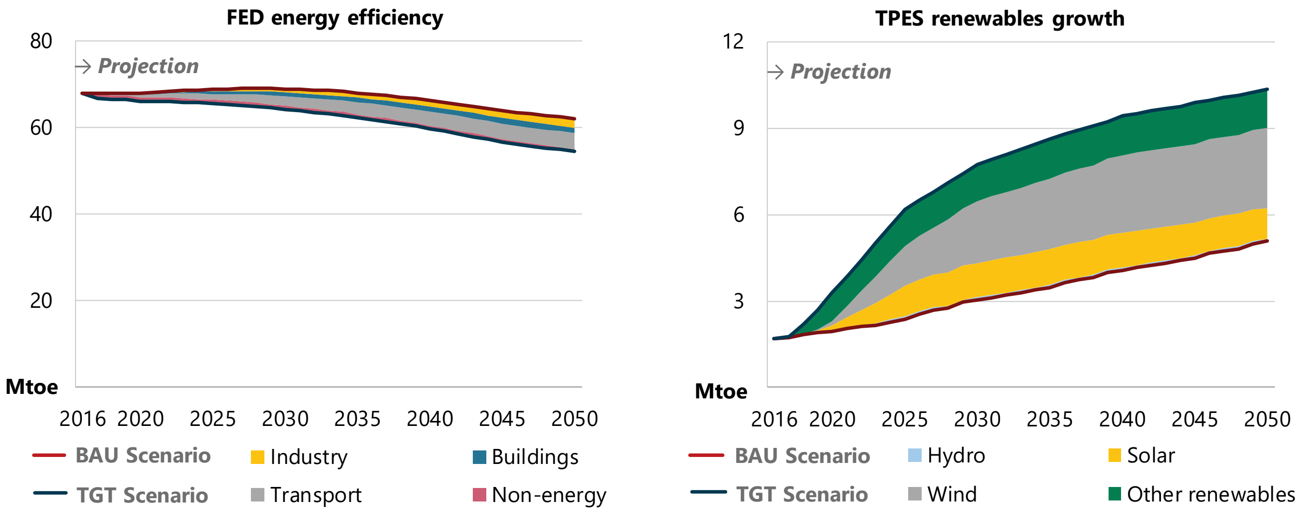
Key assumptions in transport include advances in engine and motor manufacturing, lightweight materials, and improved utilisation, which drives improved fuel economy in all vehicle types and drive trains. A greater share of renewables is achieved through stronger government support of banning the sale of nonelectric motorcycles in 2035 and nonelectric cars in 2040.

Energy demand is 7.6 Mtoe lower in 2050 than under the BAU, for a cumulative 171 Mtoe reduction over the Outlook period (Figure 18.8). The largest reduction (48% or 3.6 Mtoe) is in transport as more advanced vehicles, particularly battery EVs, replace conventional ones. Industry demand falls 2.0 Mtoe (26% of the total) resulting from BAT adoption. Buildings account for 18% of the reduction, or 1.4 Mtoe, owing to more efficient space

[100] There are two types of crude steel making processes: blast furnace-basic oxygen furnace and electric arc furnace. The latter requires only one-fifth of the energy use of the former.

cooling, lighting and space heating, for which energy intensity declines 20% to 45% by 2050. Non-energy use contributes 0.63 Mtoe, or 8.3% of total reductions, in 2050.

Figure 18.8 • Chinese Taipei: Energy efficiency and renewables, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Renewables in TPES grow from 1.7 Mtoe in 2016 to 10 Mtoe in 2050, compared with 5.1 Mtoe in the BAU. In 2016, the electricity sector consumed the most renewables (89% of the total), followed by buildings (6.0%) and industry (5.5%). The primary energy supply of renewables in 2050 increases to 9.5 Mtoe in the electricity sector (96% more than in the BAU), 0.65 Mtoe in industry (a more than sixfold increase over the BAU as more biomass is used in manufacturing processes) and 0.23 Mtoe in buildings (71% more than in the BAU).

Renewable electricity generation in 2016 amounted to 11 TWh (4.2% of total power generation), of which 59% was from hydro power, followed by biomass (17%), wind (13%) and solar (10%). In the TGT, renewables account for 25% of total power generation in 2030 and 36% in 2050, compared with 8.9% in 2030 and 17% in 2050 under the BAU. Use of wind and solar power grows the most: wind-based generation increases, from 1.5 TWh in 2016 to 50 TWh in 2050, and solar power expands, from 1.1 TWh in 2016 to 29 TWh in 2050, propelled by stronger government incentives.

TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

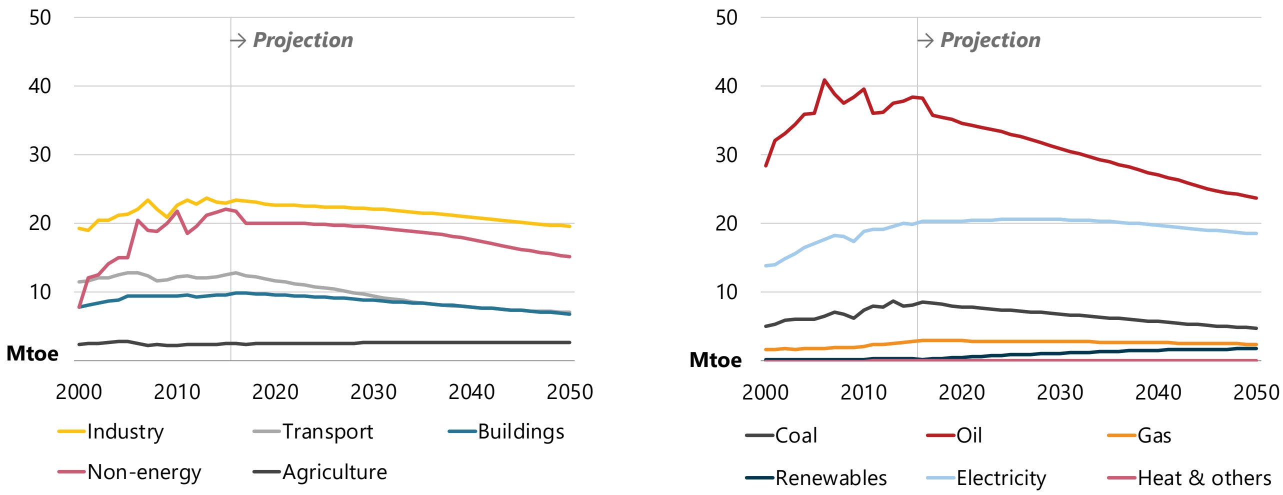
The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Chinese Taipei will have to undergo significant decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

Even though Chinese Taipei's current policy is to phase out nuclear energy by 2025, it is included in the power mix in the 2DC, since CO_2 emissions are much lower than those of other non-renewable fuels. The 2DC can therefore serve as a point of reference, demonstrating a cost-optimised power mix free of any fuel prejudice.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

In Chinese Taipei's 2DC, FED declines 28% to 51 Mtoe in 2050 (Figure 18.9)—6.0 Mtoe below the TGT and 14 Mtoe below the BAU. The reduction mainly results from lower energy demand in transport (46% less in 2050 compared with 2016) and buildings (31% less). While improved energy efficiency cuts demand in most sectors, it increases slightly by 2050 in the agriculture and non-specified sector (5.9%) because of less potential for improvement. Key drivers of improvement in buildings include improved energy efficiency of new and retrofitted buildings through aggressive application, and constant updating, of building energy codes; rapid deployment of energy efficient appliances; and switching from oil to electricity and modern biomass. In transport, electrification of vehicles and shifting from private to public transport are two key assumptions in the 2DC. As in the TGT, industry is widely assumed to achieve BATs, but with greater use of electric arc furnaces and a lower clinker-to-cement ratio.

Figure 18.9 • Chinese Taipei: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

In domestic transport, road demand falls the most (-47%) to 6.6 Mtoe in 2050 (from 12 Mtoe in 2016) as a result of stricter fuel economy standards and more advanced vehicles. LDV demand drops 87% to 0.84 Mtoe in 2050 as the share of conventional gasoline LDVs declines from 99% in 2016 to 1.5% and that of advanced LDVs (including both hybrid and battery electric vehicles) grows from 0.77% to 99%. Energy use by buses and rail increases significantly from the BAU as a result of improved behavioural change and improved urban planning.

Buildings demand declines 31% to 6.8 Mtoe in 2050 (from 9.8 Mtoe in 2016), mainly owing to greater efficiency and advanced technology in all services end-uses. Services demand underpins most of this decline, falling by 50% (to 2.0 Mtoe in 2050) over the Outlook. The average energy intensity of space cooling drops the most in services (-76%) to 11 kilowatt-hours per square metre (kWh per m^2) in 2050, followed by lighting (-67% to 5.7 kWh per m^2) with the elimination of incandescent bulbs.

Although industry energy demand falls 17% to 20 Mtoe in 2050 (from 23 Mtoe in 2016), the reduction is not as large as in other sectors as opportunities to improve efficiency through more advanced technologies are limited. Reduction comes mainly from the iron and steel, and chemical and petrochemical subsectors. Iron and steel demand drops 47% to 1.7 Mtoe as more steel production utilises electric arc furnaces, which require one-fifth the energy of blast furnace-basic oxygen furnaces while adoption of BAT in chemicals and petrochemicals results in energy demand falling 38% to 5.2 Mtoe in 2050.

The fuel mix changes considerably in the 2DC: the portion of renewables increases more than twelvefold, from 0.09 Mtoe in 2016 to 1.2 Mtoe in 2050, while coal shrinks by 47% to 4.4 Mtoe. Replacing coal with biomass in chemical and petrochemical production sees renewables increase to 0.76 Mtoe in 2050, from near zero in 2016. Coal use declines, mainly because the non-metallic minerals subsector adopts BAT, replaces coal with biomass and reduces the clinker-to-cement ratio.

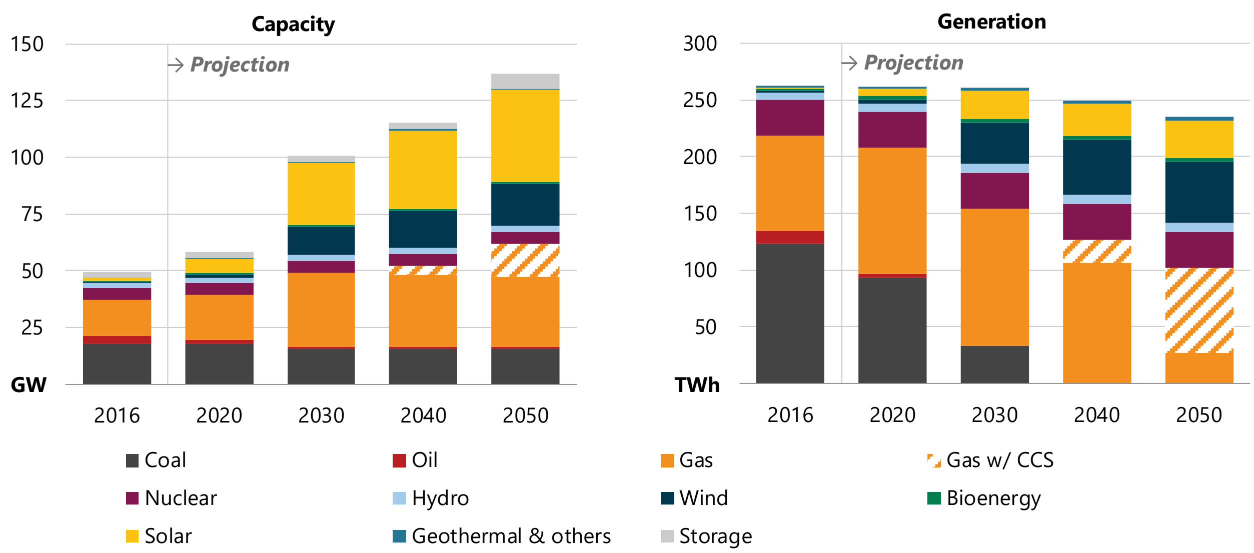
TRANSFORMATION AND SUPPLY IN THE 2DC

To reduce CO_2 emissions, fuel use in Chinese Taipei's electricity sector shifts away from coal and oil, and towards renewables and natural gas (with carbon capture and storage [CCS]). Supercritical and ultra-supercritical coal-fired power plant capacity drops from 13 GW in 2016 to 11 GW in 2027 and remains the same through 2050. Oil-fired power plant capacity falls by 81% to 0.71 GW by 2025 under the 2DC (Figure 18.10).

The amount of installed renewable capacity expands more than 13 times over the projection period to 63 GW in 2050, mainly owing to wind and solar power expansion. With additional government incentives, rooftop solar photovoltaic (PV) and utility solar PV installations expand more than fortyfold to 41 GW, accounting for 30% of the electricity capacity mix in 2050. Wind turbine installations, especially offshore, also increase by more than 26 times to 19 GW.

Changes in the power generation mix reflect capacity adjustments to reduce CO_2 emissions. Coal generation is eliminated by 2039 and oil by 2025. Dominant fuels in the power mix are natural gas (43% in 2050; mostly with CCS) and renewables (42%). Low-emission nuclear energy also accounts for 13%, reflecting its indispensability in a low-carbon scenario.

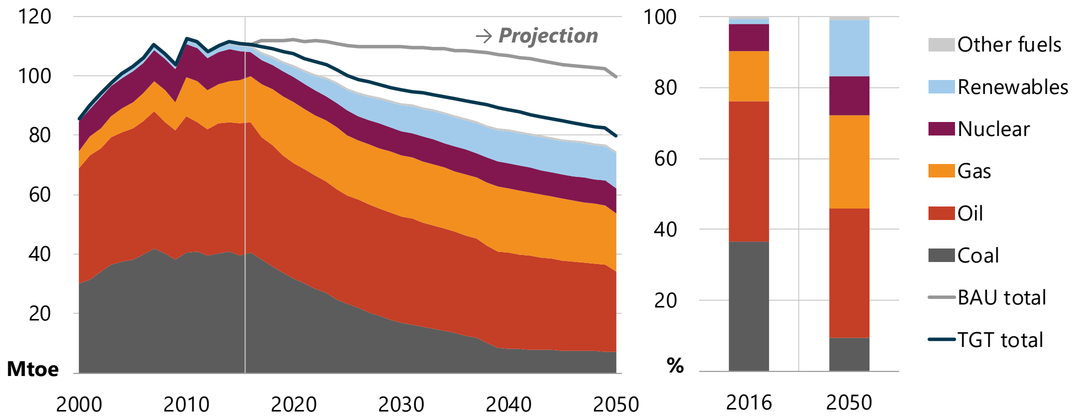
Figure 18.10 • Chinese Taipei: Electricity capacity and generation in the 2DC by fuel, 2016-50



Note: CCS= carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

TPES declines by 33% to 74 Mtoe in 2050 (from 110 Mtoe in 2016), a significant reduction owing mainly to increased energy efficiency efforts as well as biomass replacing coal in industry and the elimination of oil- and coal-fired power plants (Figure 18.11). Natural gas supply in TPES grows 25% and renewables increase by almost six times over the Outlook period owing to greatly expanded use in the power sector.

Figure 18.11 • Chinese Taipei: TPES in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Total energy production grows by 92% to 21 Mtoe in 2050, mainly owing to a nearly sixfold increase in renewable generation (particularly wind, solar and biomass). Renewable energy sources account for 57% of production in 2050. Total energy imports fall 38% to 75 Mtoe in 2050, due to lower demand (as a result, mainly, of improved energy efficiency), and despite a significant increase in natural gas imports, which grow by 22% to 20 Mtoe (and account for 26% of total energy imports in 2050).

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

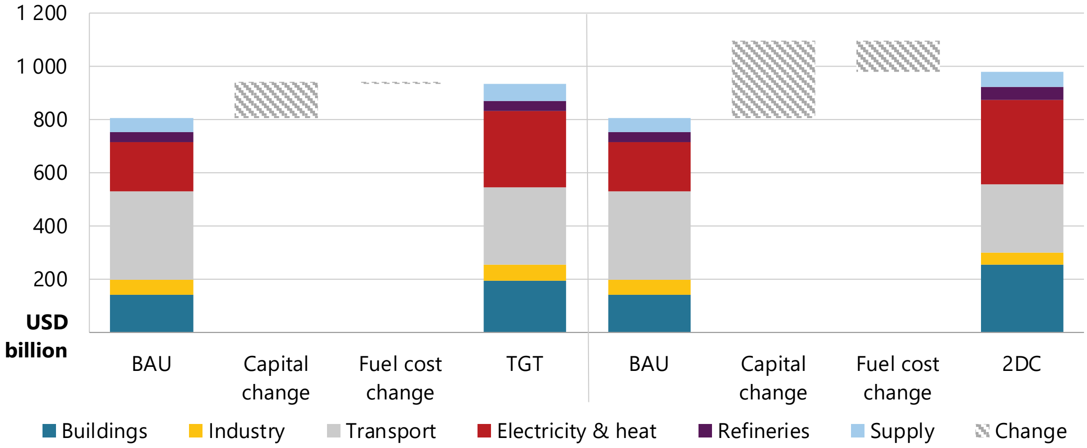
The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[101]

Chinese Taipei's total cumulative capital investment and fuel costs reach USD 933 billion by 2050 in the TGT (USD 128 billion above the BAU) and USD 978 billion in the 2DC (USD 172 billion above the BAU) (Figure 18.12). Capital investment in the 2DC is dominated by the power (54%) and demand sectors (37%), followed by supply (9.3%). In the power sector, much of the investment is for renewables-based generation: USD 97 billion for solar and USD 67 billion for wind, totalling USD 165 billion, which is more than double the investment under the BAU. Investment in gas-fired plants fitted with CCS reaches USD 41 billion by 2050 under the 2DC.

Demand sector investments amount to USD 556 billion in the 2DC (USD 25 billion above the BAU). Both buildings and transport account for 46% of the total, followed by industry (8.0%). Buildings claim the bulk of capital investment because efficient building envelopes and retrofitting are very costly: for instance, a high-performance building envelope requires the use of advanced ventilation systems, well-insulated opaque façade elements or shading devices to reduce external heat gains.

[101] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 18.12 • Chinese Taipei: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

Capital expenditure is USD 291 billion more in the 2DC compared with the BAU and USD 137 billion more than the additional expenditure in the TGT. However, the fuel cost savings in the 2DC compared with the BAU are USD 119 billion, USD 109 billion more than the fuel cost savings in the TGT because more natural gas with CCS replaces coal. Fuel replacement is more costly in terms of both capital and fuel but results in significantly lower energy-related CO_2 emissions, which are 73 million tonnes (Mt) in 2050, 72% below the BAU and 55% below the TGT.

ENERGY TRADE AND SECURITY

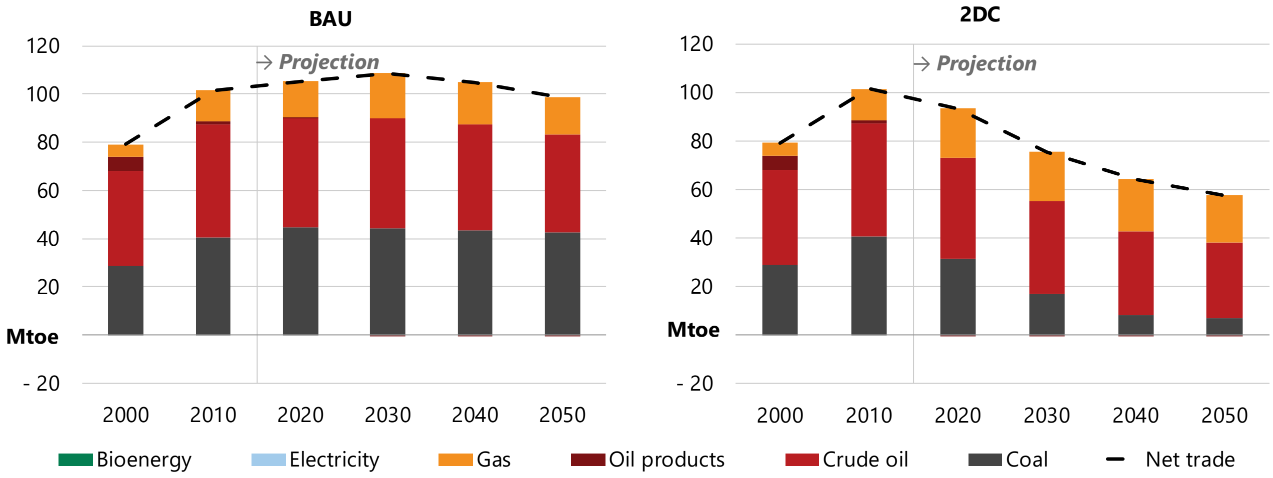
To ensure energy supply stability and security, Chinese Taipei signs long-term contracts with energy exporting economies. Light sweet crude oil is generally imported from the Middle East and West Africa to be refined into more environmentally friendly low-sulphur fuel oil. In 2016, Chinese Taipei imported 46 Mtoe of crude oil (equivalent to nearly 335 Mbbl or 0.92 Mbbl per day), mostly from the Middle East (78%) and Angola (8.3%) (Figure 18.13) (BOE, 2018g). Total coal imports were 41 Mtoe in 2016—mostly used for power generation—with Australia suppling 52% and Indonesia 31%. The most important suppliers of natural gas (as LNG) in 2016 were Qatar (42%), Malaysia (17%) and Indonesia (14%) (BOE, 2018a).

Chinese Taipei's LNG imports hit 17 Mt in 2017, a record high since LNG imports started in 1990—most (more than 86%) was used for power generation. The natural gas share in the power mix was 35% in 2017, so more LNG imports will be required to meet the 50% target and gently rising power demand (BOE, 2018a). Chinese Taipei currently has two LNG receiving terminals: Yung-An Kaohsiung (7.5 million tonnes per annum [Mtpa] receiving capacity) and Taichung (4.5 Mtpa receiving capacity), amounting to 12 Mtpa, which is not enough to meet rising demand.

CPC is planning a third LNG receiving terminal in Guantang Taoyuan to add an additional 6 Mtpa receiving capacity (starting with 3 Mtpa in phase I). It is scheduled to start commercial operation in 2023, alongside the Datan gas-fired power plant (China Times, 2018). Taipower Company has announced plans for a fourth LNG receiving terminal (0.9 Mtpa) in Hsieh-Ho with deployment of a floating storage and regasification unit with 170 000 cubic metres of capacity, scheduled for completion in 2024 (LNG World News, 2018), and a fifth receiving terminal (1.8 Mtpa) in Taichung port terminal also scheduled for completion in 2024 (CNA, 2017). The current Yung-An terminal is expected to expand further to 10.5 Mtpa in 2025, and the Taichung terminal to 10 Mtpa in 2025, which results in a total receiving capacity of 26 Mtpa in 2025 (APEC, 2018).

In the BAU Scenario, net energy imports decline 4.7% to 98 Mtoe in 2050, mainly because of less demand for crude oil in industry and buildings, and less demand for oil products in LDVs as battery EVs replace conventional vehicles. Under the 2DC Scenario, net imports further decline (by 44%) to 58 Mtoe in 2050, of which coal imports fall 83% to 7.1 Mtoe as coal-fired power generation is phased out by 2039.

Figure 18.13 • Chinese Taipei: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Because domestic energy reserves are modest, increasing energy supply self-sufficiency is not a viable option to enhance energy security for Chinese Taipei (Table 18.3). Ensuring supply stability and maintaining a balanced power generation mix after nuclear generation is phased out are more crucial to strengthening security. Chinese Taipei announced a 2025 power mix generation target to enlarge natural gas and renewables use to fill the nuclear gap: natural gas 50%, coal 30% and renewables 20%.

Table 18.3 • Chinese Taipei: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	10	4.1	9.1	20	6.0	14	28
Coal self-sufficiency (%)	0	0	0	0	0	0	0
Gas self-sufficiency (%)	1.5	0.56	0.45	0.52	0.22	0.17	0.17
Crude oil self-sufficiency (%)	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Primary energy supply diversity (HHI)	0.29	0.33	0.30	0.24	0.33	0.28	0.24
Coal reserve gap (%)	0	0	0	0	0	0	0
Gas reserve gap (%)	83	811	811	811	1 211	1 211	1 211
Crude oil reserve gap (%)	0	0	0	0	0	0	0

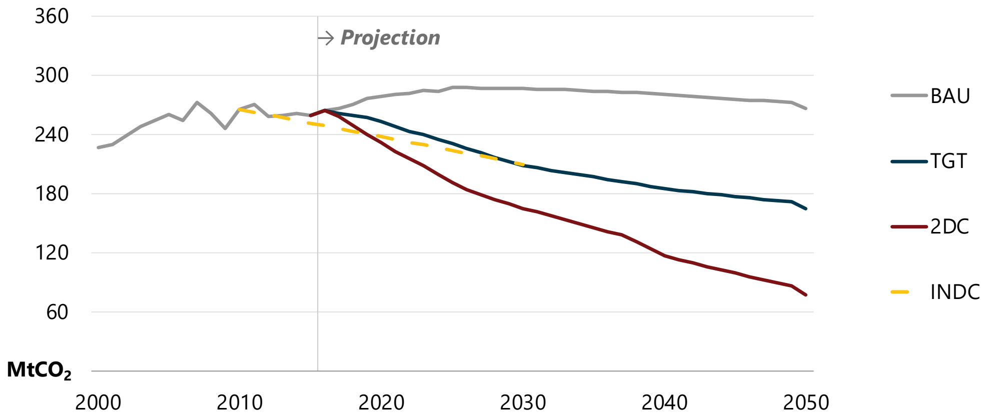
Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

Chinese Taipei enacted the Greenhouse Gas Reduction and Management Act (GGRMA) in July 2015 and adopted the long-term target of reducing CO_2 emissions to 50% of the 2005 level by 2050 (EPA, 2017). In September of that year, in response to the Lima Call for Climate Action, the economy released its Intended Nationally Determined Contributions,[102] pledging to reduce 2030 CO_2 emissions by 50% of the emissions projected under the BAU Scenario (428 $MtCO_2$)—a short-term target compared with the GGRMA goal (EPA, 2015).

The policy target for 2030 is met under both the TGT and 2DC, which with CO_2 emissions reaching 208 $MtCO_2$ (TGT) and 165 $MtCO_2$ (2DC) in 2030 (well below the 214 $MtCO_2$ target). The 2050 target is met only under the 2DC, which projects CO_2 emissions of 77 $MtCO_2$ in 2050 (meeting the 130 $MtCO_2$ target) (Figure 18.14). Enacting the aggressive 2DC assumptions for all demand sectors, however, will be extremely challenging. In industry, the scrap steel recycling rate is assumed to reach 40% in 2050 from 18% in 2016; in transport, average fuel efficiency improves by 32%, compared with 21% in the BAU. Most difficult, perhaps, will be the near total decarbonisation of the electricity generation system undertaken in the 2DC.

Figure 18.14 • Chinese Taipei: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: INDC = Intended Nationally Determined Contribution. The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. All INDCs have been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, EPA (2015), IEA (2016a and 2018a) and IPCC (2018).

OPPORTUNITIES FOR POLICY ACTION

The greatest challenge for Chinese Taipei is not so much to reduce CO_2 emissions as to achieve the targeted power generation energy mix by 2025. For instance, offshore wind capacity needs to reach 5.5 GW by 2025, equivalent to more than two nuclear power plants (LTN, 2017), but strict environmental assessments are a significant barrier to wind farm development as they take a long time to complete.

In the short term, the government should first reassess the feasibility of its 2025 power mix target. In November 2018, a referendum was held to ask voters whether they agree that 'all nuclear-based power-generating facilities shall completely cease operations by 2025'. The referendum found overwhelmingly that voters were against the plan to remove nuclear from the power mix target (World Nuclear News, 2018). This

[102] The Nationally Determined Contributions (NDCs) reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), or 'COP21 Paris Agreement'. Intended Nationally Determined Contributions are those submitted pre-COP21. INDCs are converted to NDCs when formally ratifying the Paris Agreement. Therefore, Chinese Taipei's INDC cannot be converted to a NDC since it is not a member of the United Nations.

result has created significant uncertainty around Chinese Taipei's energy policy, with the government yet to establish whether it will continue pursuing the nuclear-free target. The government should reassess the possibility of continuing to use nuclear beyond 2025 and enhance communication with the public with a view to revising the power generation target in response to the referendum result.

To support the transition towards a cleaner power mix, the government has announced that the construction of a coal-fired power plant in Shen Ao will cease, and has instead approved a third LNG receiving terminal. The development and completion of fourth and fifth LNG receiving terminals should be prioritised in order to continue supporting the replacement of coal with gas in the electricity sector.

In the long term, the government should continue promoting the use of renewable energy sources, both solar and wind power, biomass for industrial applications, and geothermal for electricity and direct use. For demand sectors, the government should strengthen current energy efficiency policies, especially for buildings and non-energy uses—the sectors demonstrating the lowest demand reductions in the BAU. Although Chinese Taipei has already begun drafting an Energy White Paper and set up targets and roadmaps for each demand sector, these are just the first steps. In many cases, targets are not achieved because there are not enough policies to support and enforce action; the government should therefore continue drafting supporting policies and related measures, as well as mechanisms for regular monitoring, to drive target achievement in each demand sector.

19. THAILAND

KEY FINDINGS

- **Thailand's FED increases by 76% over the Outlook period in the BAU (1.7% CAGR), reaching 171 Mtoe by 2050.** The buildings sector grows the most rapidly, at a 2.0% CAGR, followed by industry (1.8%) and transport (1.4%).

- **TPES increases almost as much—by 73%—to reach 239 Mtoe in 2050.** Fossil fuels continue to play a major role in the BAU, maintaining a 73% to 75% share through the Outlook.

- **Thailand's domestic fossil fuel supplies are being rapidly depleted—at current rates of production, oil resources last two more years and natural gas five more years.** Improving natural gas security is contingent on the success of recent tenders for offshore natural gas exploration of the Erawan and Bongkot fields.

- **Strong fuel economy standards, labelling, and efficiency standards for appliances and equipment provide significant opportunity to reduce energy intensity in all scenarios.** Energy efficiency improvements and decreasing electricity use in buildings underpin energy intensity improvement from 47% in the BAU to 59% in 2DC.

- **FED is 38 Mtoe lower in 2050 under the 2DC than in the BAU, but heavy reliance on fossil fuels in the supply energy mix continues (64% in 2050).** Additional decarbonisation is therefore required, especially in the electricity sector, to achieve Thailand's NDC to reduce GHG emissions by 20% of the 2005 level by 2030.

ECONOMY AND ENERGY OVERVIEW

Thailand is situated in central south-east Asia and is surrounded by other rapidly developing economies such as Myanmar, Laos and Cambodia to the north and east, and shares a border with Malaysia to the south. Thailand has an area of 513 120 square kilometres (km^2) and had a population of about 69 million in 2016. Its gross domestic product (GDP) in 2016 reached USD 1 154 billion, led by the services (50%) and industry (35%) sectors (World Bank, 2016). Thailand's GDP grows by 234% in the Outlook period (2016-50), at a compound annual growth rate (CAGR) of 3.6%, while population falls by 5.1% overall. GDP per capita is projected to increase from USD 16 758 to USD 58 932 over the period (Table 19.1).

Thailand is a member of the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC), formed in 2015 to boost cooperation among the 10 ASEAN member economies and to build an integrated and cohesive economy. ASEAN is currently the seventh-largest economy in the world. The AEC also seeks to enhance energy connectivity and market integration to achieve energy security, accessibility, affordability and sustainability for ASEAN.

Table 19.1 • Thailand: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	617	967	1 154	1 335	1 943	2 784	3 852
Population (million)	63	67	69	69	70	68	65
GDP per capita (2016 USD PPP)	9 805	14 390	16 758	19 237	27 899	40 736	58 932
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	73	118	138	162	193	220	240
TPES per capita (toe)	1.2	1.8	2.0	2.3	2.8	3.2	3.7
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	118	122	119	121	99	79	62
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	51	85	98	113	135	155	171
FED per capita (toe)	0.80	1.3	1.4	1.6	1.9	2.3	2.6
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	82	88	84	84	70	56	44
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	151	226	247	281	332	401	443
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	82	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

Thailand has limited domestic energy resources. At the end of 2016, the economy had proven reserves of 350 million barrels (Mbbl) of oil, 200 billion cubic metres (bcm) of natural gas, and 1 063 million tonnes (Mt) of coal (Table 19.2). Based on current rates of production, domestic supplies will be depleted in the near future—oil resources within two years and natural gas within five (EPPO, 2017). Most coal-fired power plants in Thailand use low-quality, domestically produced lignite, but the newly developed replacement project at the Mae Moh power plant is adopting ultra-supercritical technology that will reduce carbon dioxide (CO_2) and particulate emissions but require imports of bituminous coal. Thailand is highly dependent on energy imports, with 79% of its oil and 32% of its natural gas supply coming from abroad.

To improve energy security, in late 2018 Thailand invited bids for a production sharing contract (PSC) with rights for natural gas exploration in the offshore G1/61 and G2/61 blocks of the Erawan and Bongkot fields. Both fields currently produce up to 0.06 bcm per day, or 75% of Thailand's total natural gas production. The Petroleum Authority of Thailand Exploration and Production (PTTEP) company and its partner Mubadala Petroleum (from the United Arab Emirates) won the concession contract for Erawan (G1/61) starting in 2022, and PTTEP on its own won the contract for Bongkot (G2/61) starting in 2023 (ANN, 2018; Bangkok Post, 2018a).

Table 19.2 • Thailand: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt)	1 063	65	0.10	28	10
Oil (billion bbl)	0.35	2.1	0.02	47	12
Natural gas (tcm)	0.20	5.2	0.10	40	11

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions.
Source: BP (2018).

Thailand's renewable energy potential was assessed as part of the Alternative Energy Development Plan (AEDP 2015) (DEDE, 2015). Although some renewable energy resources are in plentiful supply, development may be challenging. Wind has so far reached only 7% of the 3 002-megawatt (MW) target set in the AEDP 2015, and solar 22% of the 6 000-MW target. Biomass, however, has developed at a faster pace, with 44% of the 5 570-MW target achieved. Inadequate transmission lines and other infrastructure hampers further uptake of renewables.

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

The Thailand Integrated Energy Blueprint (TIEB) was designed in 2015 to synchronise all of Thailand's major energy policy-related plans into a single comprehensive economy-wide plan aimed at balancing economic, ecological and security concerns. The TIEB consists of five long-term plans covering 2015-36 (EPPO, 2015a; Sutabutr, 2015).

The Power Development Plan (PDP 2015) aims to secure key power generating sources and diversify the energy mix to reduce natural gas dependence (from 64% of total fuel used for power generation in 2015 to 37% in 2036) (EPPO, 2015b). New-generation clean coal technology as well as renewable energy will be introduced through independent power producers (IPPs), small power producers (SPPs) and very small power producers (VSPPs). The net power generation capacity target is 70 335 MW by the end of 2036 (compared with 37 612 MW in 2015), and the reserve margin is set at 15%.

The Energy Efficiency Plan (EEP 2015) focuses on improving energy efficiency through a variety of compulsory measures such as factory energy management standards, minimum and high energy performance standards (MEPS and HEPS), and promotion of LEDs for lighting (EPPO, 2015c). The EEP targets an energy intensity reduction of 30% of the 2010 level by 2036.

The AEDP 2015 concentrates on diversifying the energy mix to promote non-fossil fuels (especially biofuels) by increasing the share of renewables to 30% of final energy demand (FED) by 2036 (DEDE, 2015; EPPO, 2015d). The target is 39 million tonnes of oil equivalent (Mtoe): power generation of 19 684 megawatt-hours (MWh) (5.6 Mtoe); thermal energy (from waste, biomass, biogas and solar power) of 25 Mtoe; and biofuels of 8.7 Mtoe. The strategic roadmap has also been designed to convert the AEDP 2015 into detailed activities such as a plan for preparing raw materials for bioenergy production, a plan for deploying alternative energy technologies such as energy storage systems, an expansion plan of alternative energy production and markets, and a public relations plan to raise awareness.

The Natural Gas Supply Plan (Gas Plan 2015) aims to improve supply security and reduce dependency on natural gas in the energy mix by promoting greater competition through third-party access (TPA) codes for shared infrastructure (such as pipelines) (DMF, 2016). A new round of bidding for natural gas exploration and production in key offshore fields, where current contracts are due to expire shortly, will also contribute to these aims. The Gas Plan 2015 also targets curtailing imports of liquefied natural gas (LNG)—which are rapidly gaining market share as domestic natural gas reserves diminish—by replacing some of the natural gas share with renewable energy and high-efficiency coal.

The goal of the Oil Supply Management Plan (Oil Plan 2015) is to create a transparent liquid fuels market with a policy framework based on fuel type, price and infrastructure investment (EPPO, 2015e). The Oil Plan 2015 is also designed to support both the AEDP 2015 in blending a significant quantity of biofuels into transport fuels and the EEP 2015 in improving transport vehicle efficiency. Moreover, Thailand is in the process of creating a strategic petroleum reserve (SPR) to secure oil supplies during disruptions.

A supplementary policy called Energy 4.0 has been designed to be part of a wider economic model—Thailand 4.0. This wider model was developed to promote economic prosperity, raise living standards and improve energy sustainability by 2032 through new energy-related innovations and value-based industry. Energy 4.0 involves the development of four modern energy technologies, including electric vehicles, energy storage, bio-economy through SPPs, and smart cities.

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for Thailand under the Asian Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 19.3). Definitions used in this Outlook may differ from government targets and goals published as part of the TIEB (in the PDP 2015, EEP 2015, AEDP 2015, Gas Plan 2015 and Oil Plan 2015). The BAU is based on existing Ministry of Energy policies, some already implemented and some recently proposed by the government.

Table 19.3 • Thailand: Key assumptions and policy drivers under the BAU

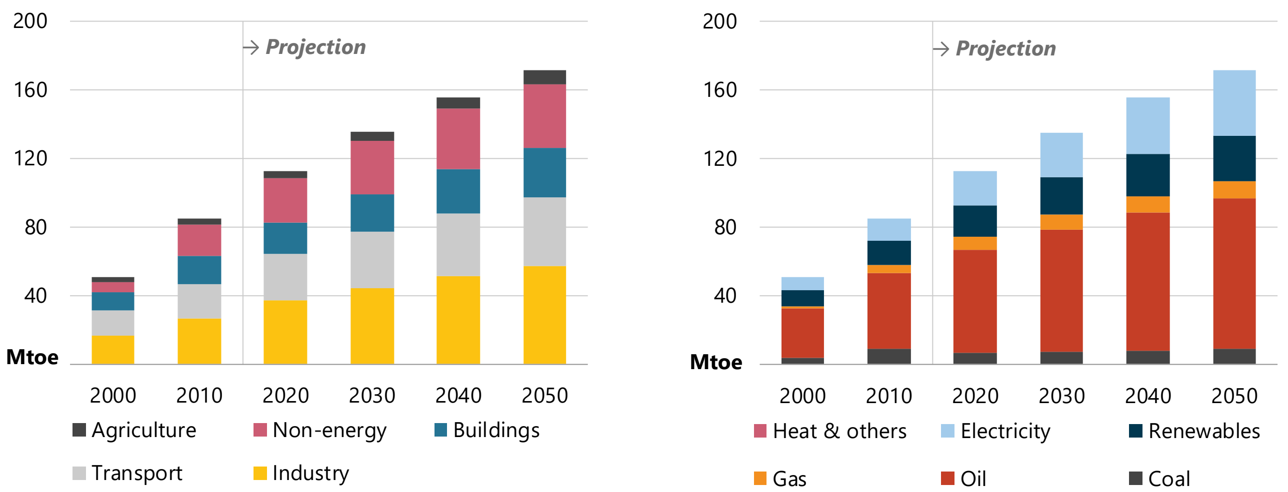
Buildings	BEC program conducted. Energy management implemented in designated buildings and factories through financial programs (soft loans and grants).
Transport	LPG and natural gas price subsidies removed. Retail oil product prices standardised. GHG emissions standards introduced. Tax incentives provided for eco-cars (discussed in the transport section of BAU).
Energy supply mix	Fuel mix diversification promoted.
Power mix	Dependence on natural gas in the power mix is reduced.
Renewables	Share of renewables in generation increased to 30% by 2036, as outlined in the AEDP 2015.
Energy security	New bidding round completed for oil and natural gas exploration. Energy efficiency policies and measures developed in EEP 2015.
Climate change	Progress made towards Thailand's NDC to reduce GHG emissions to 20% below the 2005 level by 2030.

Notes: BEC = building energy code. LPG = liquefied petroleum gas. GHG = greenhouse gas. AEDP = Alternative Energy Development Plan. EEP = Energy Efficiency Plan. NDC = Nationally Determined Contribution. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Energy demand under the BAU increases by 76% (1.7% CAGR) over the Outlook period to 171 Mtoe by 2050. The strongest growth is in agriculture (2.3% CAGR), followed by buildings (2.0%), industry (1.8%), non-energy (1.5%) and domestic transport (1.4%). Industry was the largest sector (32%) in terms of FED in 2016 and maintains approximately the same share through 2050 (33%). Non-energy use, consisting mostly of petrochemicals, also retains a significant FED share (22-24%) in 2016-50 (Figure 19.1). The EEP 2015, ratified by the National Energy Policy Council (NEPC) in 2015, stated an energy intensity reduction target of 30% of the 2010 level by 2036. This is equivalent to FED decreasing by 56 Mtoe in EEP 2015. The BAU projection is comparable to this target, achieving an energy intensity reduction of 27% from 2016 to 2036.

Figure 19.1 • Thailand: Final energy demand by sector and fuel, 2000-50

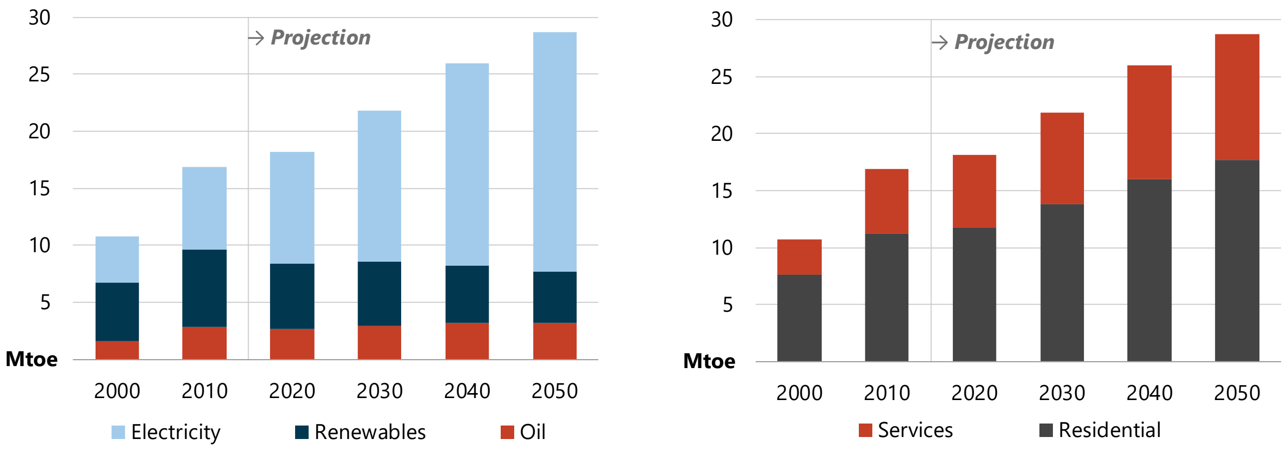


Sources: APERC analysis and IEA (2018a).

BUILDINGS: STRONG DEMAND GROWTH MET BY ELECTRICITY

The urbanisation rate in Thailand has grown significantly, from a 20% in 1990 to a 48% in 2016 (World Bank, 2019). Steady growth in buildings construction has followed, and with it an increasing electrification rate. Energy demand in buildings rises at a CAGR of 2.0% over the Outlook period, almost doubling in both the residential subsector (from 9.0 Mtoe to 18 Mtoe) and services (from 5.5 Mtoe to 11 Mtoe) (Figure 19.2). Continued growth in both subsectors results largely from improved living standards and an economic shift towards the services subsector. Space cooling is the key driver of strong energy demand in buildings, increasing more than fourfold in residential and almost twofold in services to 2050.

Figure 19.2 • Thailand: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

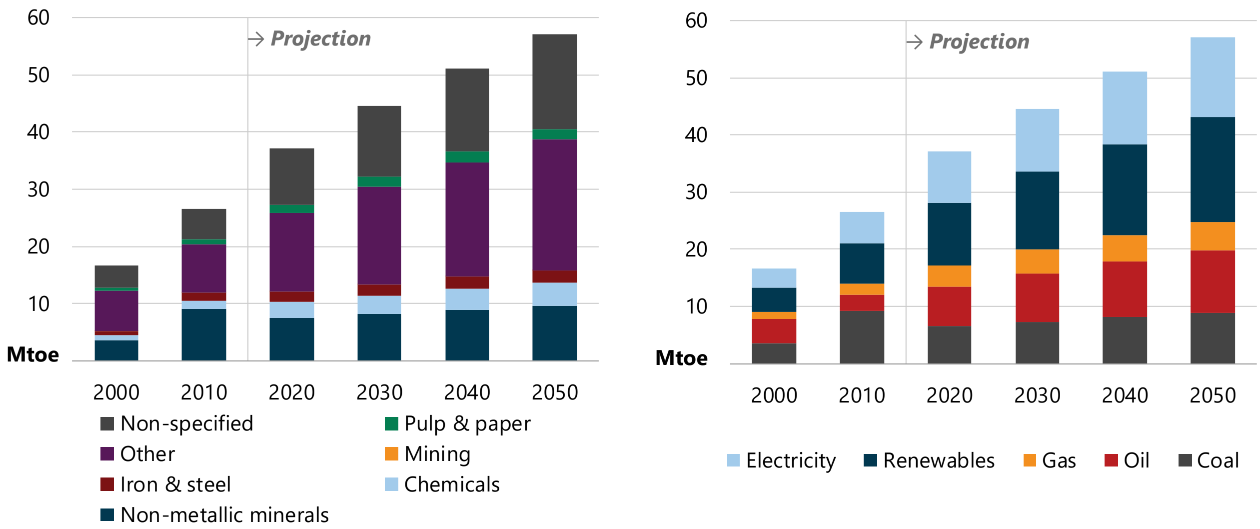
Electricity and liquefied petroleum gas (LPG) remain the major sources of energy in the residential and services subsectors throughout the Outlook period. Electricity growth is strongest (2.7% CAGR) given the high penetration of electrical appliances, while LPG use expands more slowly (1.9% CAGR) as lower pricing leads consumers to switch fuels. Traditional biomass demand shrinks over the Outlook as consumers, particularly in rural areas, prefer electricity and LPG.

Thailand has designed minimum energy performance standards (MEPS) for appliances and equipment through the Thai Industrial Standard Institute (TISI) of the Ministry of Industry. Through MEPS, the government aims to create awareness among the general public of the benefits of energy efficiency, hoping to encourage people to buy or use highly energy-efficient equipment and appliances. Some appliances, such as air conditioners and refrigerators, have mandated standards while 16 other pieces of equipment have voluntary standards. The Ministry of Energy also has regulations on HEPS for 28 appliances and pieces of equipment. Based on these regulations, the Electricity Generating Authority of Thailand (EGAT) will enforce and issue No. 5 labels for electrical appliances, while the Department of Alternate Energy Development and Efficiency (DEDE) will label them for heating or non-electrical equipment and engines. Products certified with the No. 5 label are highly efficient, meet government laboratory standards and are promoted as products of choice in public campaigns. These performance standards for appliances and equipment will help to curtail some growth, but further efforts will be essential to control rapidly rising energy demand in this sector.

INDUSTRY: STEADY GROWTH THROUGHOUT THE OUTLOOK PERIOD

Industrial growth has focused on the non-metallic mineral, 'other' (electronics, machinery and automobiles) and chemical subsectors, which have all contributed significantly to GDP growth. Industry energy demand increased by 88% during 2000-16, reaching 32% of FED by 2016. Under the BAU, energy demand in industry increases by 82% over the Outlook period, from 31 Mtoe in 2016 to 57 Mtoe in 2050. The chemical and petrochemical, 'other' (electronics, machinery and automobiles) and non-specified subsectors underpin the majority of this growth (Figure 19.3). Renewables, electricity and oil are the main energy resources for industry in 2050. Under the BAU, the fastest-growing subsectors (chemicals and petrochemicals) rely more on electricity and natural gas, the use of both of which increases by 54% (CAGR of 1.3%) by 2050.

Figure 19.3 • Thailand: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

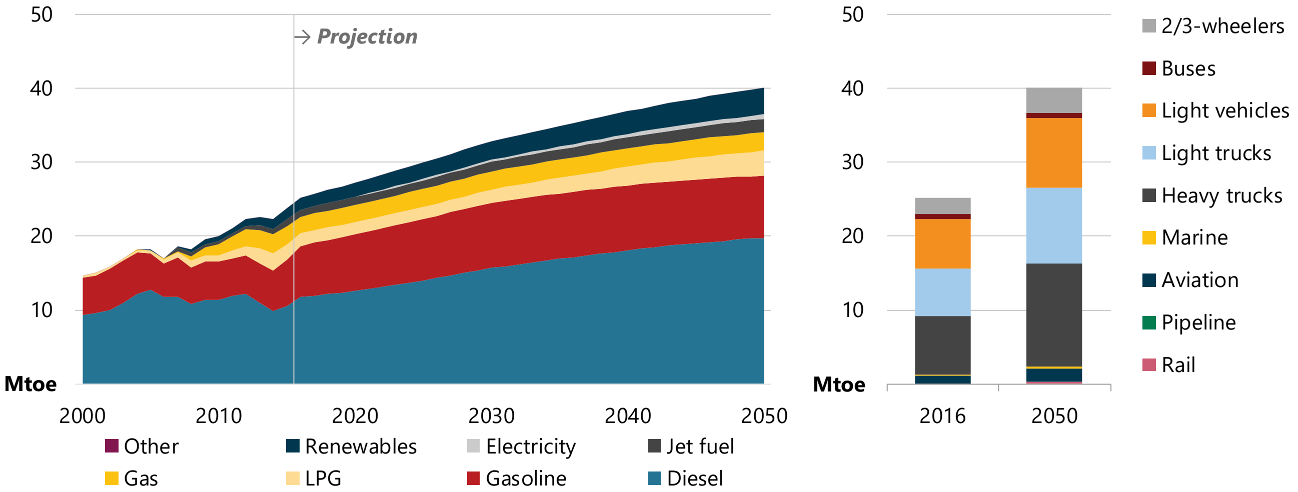
Thailand's energy efficiency policy focuses on four major economic sectors: industry, commercial and government buildings, residential buildings and transport. Five measures have been designed to reduce energy intensity by 30% in industry by 2036. In the buildings sector, the government classified 5 898 buildings and 3 088 factories as 'designated' in 2018. In accordance with the Energy Conservation and Promotion Act (1992 and 2007), buildings and factories that install electric meters or transformers with a minimum size (1 000 kilowatts [kW] for buildings and 10 000 kW for factories), or that consume more than 20 megajoules (MJ) per year (buildings) or 200 MJ per year (factories), are 'designated' and must submit energy management and consumption reports to DEDE. The organisation then provides feedback by evaluating the level of energy efficiency as a benchmark for other buildings and factories. Regulations also stipulate that designated buildings and factories must have energy management auditors responsible for monitoring energy demand and proposing energy efficiency programs.

TRANSPORT: DIESEL BEGINS TO DOMINATE THE ENERGY MIX

Under the stimulated trade program designed by Thailand's Board of Investment in the 1990s, the automobile industry has been at the forefront of a rapidly expanding transport sector. The car manufacturing sector has transformed from a production base for domestic vehicles to a production hub for export markets, with an annual output of approximately 2 million vehicles (passenger cars and pickup trucks) (Marklines, 2016).

Transport FED expanded 69% in 2000-16 and is projected to increase further from 31 Mtoe in 2016 to 52 Mtoe in 2050, predominately due to domestic road transport demand which accounts for more than 73% of transport FED over the outlook period (Figure 19.4). Stock numbers as well as passenger and freight kilometres increase with energy demand as government policies such as the eco-car[103] program improve the fuel efficiency of new vehicles. Thailand is also in the process of developing energy performance standards for vehicles, which are expected to be on a voluntary basis initially before becoming mandatory. Such standards also help achieve the EEP target of reducing energy intensity to 30% of the 2010 level by 2036.

Figure 19.4 • Thailand: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Freight continues to be transported mainly by road during the Outlook period. As a result of increasing household wealth, the number of light-duty vehicles (LDVs) rises from 10 million in 2016 to 14 million in 2050. High-efficiency vehicles such as hybrids represent 15% of the total LDV stock in 2050, compared with 10% in 2016, and battery-operated electric vehicles represent 4.7%.

Energy demand in international transport more than doubles (112%) over the Outlook, expanding more rapidly than domestic transport (59%). International aviation and marine FED amounts to 12 Mtoe in 2050, while demand in domestic transport reaches 40 Mtoe.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Rapid growth in domestic energy demand in recent years is reflected in expanding refinery and electricity generation capacity. In 2000-16, refinery capacity increased by 19% and electricity generation capacity doubled. Demand growth also led to a 90% increase in total primary energy supply (TPES) in the same period. Growth in electricity generation and TPES is projected to continue over the Outlook, although at a slower rate than the last 16 years.

ENERGY INDUSTRY OWN-USE: REFINERY OVERCAPACITY

Thailand has been highly active in developing new refining capacity to cope with growing domestic demand for petroleum products in recent decades, which has resulted in refinery overcapacity since 1998. While Thailand relies heavily on crude imports, constant changes in the oil price have resulted in fluctuating refining margins,

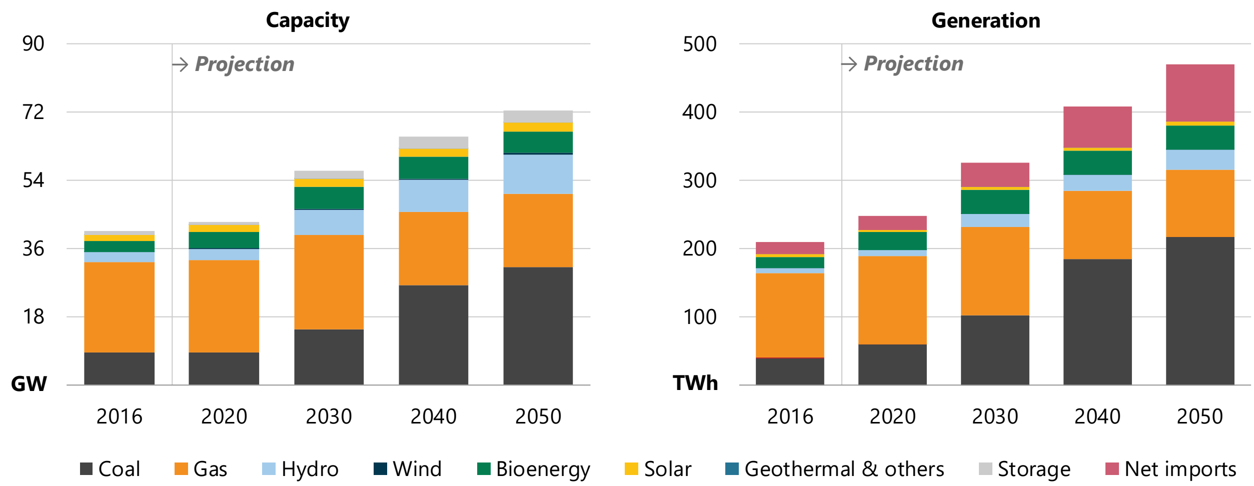
[103] The eco-car program promotes environmentally-friendly cars via tax incentives and stricter environmental standards. See UNESCAP (2019) for more information.

raising uncertainty for refiners in building future capacity. ThaiOil is the only refinery to announce major capacity expansion plans—135 000 barrels (bbl) per day (7.0 Mt per year) by 2021 (Bangkok Post, 2018b).

POWER SECTOR: FOSSIL FUELS REMAIN DOMINANT

Thailand's electricity sector has expanded rapidly over the past 15 years as demand has grown exponentially, especially in industry and buildings. Natural gas has recently become the dominant fuel as a result of incentives to tackle environmental concerns and its competitive price. Under the BAU, electricity generation (excluding imported electricity) increases at a CAGR of 2.1% during 2016-50. This growth leads to a similarly rapid increase in installed capacity, from 41 gigawatts (GW) in 2016 to 72 GW in 2050 (Figure 19.5). The capacity mix also changes significantly over the Outlook period as coal becomes dominant in 2050 (reaching 43%, up from 21% in 2016), while natural gas loses share (shrinking to 27% from 58% in 2016), non-hydro renewable energy increases slightly (to 12%, up from 11%) and hydro more than doubles (from 6.0% to 14%).

Figure 19.5 • Thailand: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

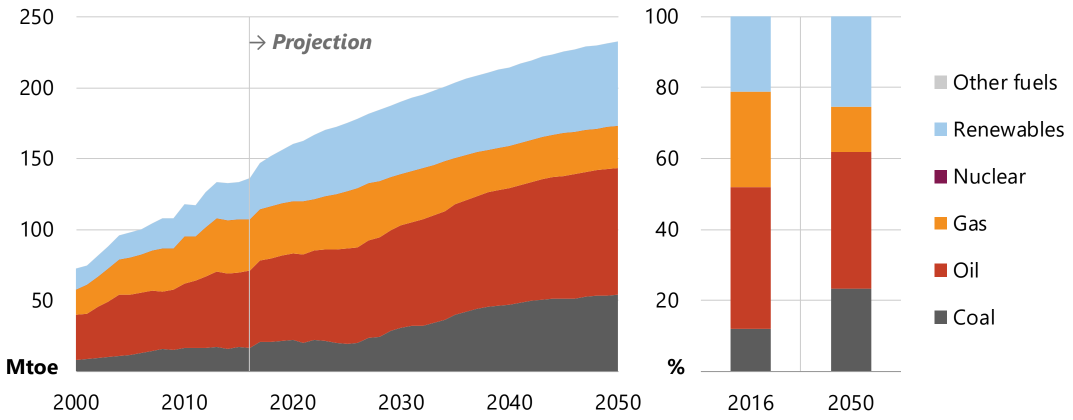
According to the PDP 2015, the share of natural gas in power generation decreases from 63% in 2015 to 58% in 2036 as the power mix shifts from natural gas to renewables (EPPO, 2015b). Petroleum-based fuels such as fuel oil and diesel continue to provide back-up electricity generation when natural gas-fired power plants undergo maintenance, which is more common in southern Thailand given the distance from the main electricity infrastructure. The share of imported hydropower from Laos also increases from 11% in 2015 to 14% by 2036.

The BAU incorporates the aims of PDP 2015 to diversify the energy mix in power generation and reduce energy security concerns. The PDP 2015 does not directly address existing and anticipated environmental concerns, as fossil fuels remain the major sources of power generation, whereas the BAU attempts to tackle these issues. Under the BAU, Thailand adopts low-carbon technologies for power plants, such as combined-cycle, bioenergy and supercritical coal. The AEDP 2015 targets 20 GW of renewable energy capacity from solar, biomass, wind, hydro and waste resources by 2036. This target will bring the share of renewables in power generation to 20% by 2036. Continued development of transmission lines and adoption of smart grid technology will be essential to maximise the use of renewables in power generation.

TOTAL PRIMARY ENERGY SUPPLY: STEADY GROWTH ACROSS FUEL TYPES

Under the BAU, Thailand's TPES increases 73% (from 138 Mtoe to 239 Mtoe). Oil still dominates with a 38% share in 2050, but it decreases from 41% in 2016. Similarly, the share of natural gas decreases from 27% in 2016 to 12% in 2050, but coal consumption increases over the projection period from 12% of TPES in 2016 to 23% in 2050 (Figure 19.6). Renewables also increase, from 21% of TPES in 2016 (29 Mtoe) to 24% by 2050 (58 Mtoe). This increase can be attributed to renewables-based electricity generation expanding to address environmental concerns.

Figure 19.6 • Thailand: Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

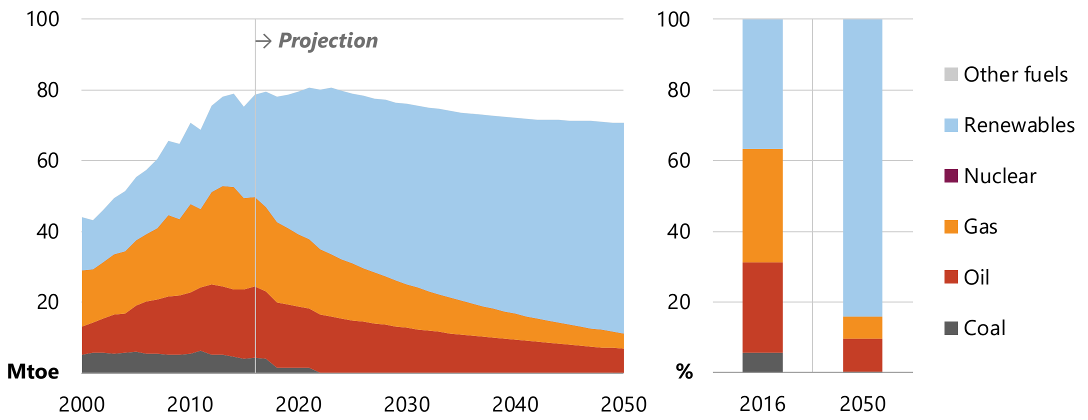
In 2050, TPES under the BAU differs from that envisaged by Thailand's energy policy, which plans to secure energy supplies and reduce oil and natural gas dependence by 2036. Original plans detailed in PDP 2015 to increase coal as a major fuel are currently being revisited and the environmental impact of local pollution is pushing Thailand away from deploying new coal-fired power plants.

ENERGY PRODUCTION AND TRADE: FOSSIL FUEL PRODUCTION FALLS, IMPORTS RISE

Thailand's domestic energy production has historically been relatively evenly split among oil, natural gas and renewables, with a smaller amount of coal production (Figure 19.7). Natural gas comes mostly from the Erawan and Bongkot fields and oil is sourced from the Banjamas, Tantawan, Sirikit, and Jasmin fields, all of which are in the Gulf of Thailand. Coal is found mostly in Lampang province in northern Thailand. Renewables-based production is mainly in the form of bioenergy used in buildings and industry.

Energy production declines 12% over the Outlook period due to fossil fuel resource depletion. Under the BAU, renewables increase significantly (mainly bioenergy), while coal production drops as a result of mounting environmental concerns. Oil and natural gas production also decline as resources are depleted. The recent round of bidding for natural gas exploration and production at Erawan and Bongkot fields in December 2018 has helped stabilise energy production sustainability.

Figure 19.7 • Thailand: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Thailand remains dependent on energy imports, which (in net terms) accounted for 48% of TPES in 2016. Crude oil makes up 65% of total net energy imports, followed by coal (22%), natural gas (18%) and electricity (2.4%). In 2050, net energy imports are mainly crude oil (33%), coal (30%) and natural gas (14%), while electricity is 4.1%. Under the BAU, the share of net imported natural gas decreases from 18% to 14%; gas imports come from Qatar and Malaysia mainly as LNG, and less natural gas is piped from Myanmar. Electricity, mainly hydropower, is imported from neighbouring economies (mostly Laos) via transmission grid interconnections. Thailand's dependence on energy imports doubles by 2050 to reach 76% of TPES.

ALTERNATIVE SCENARIOS

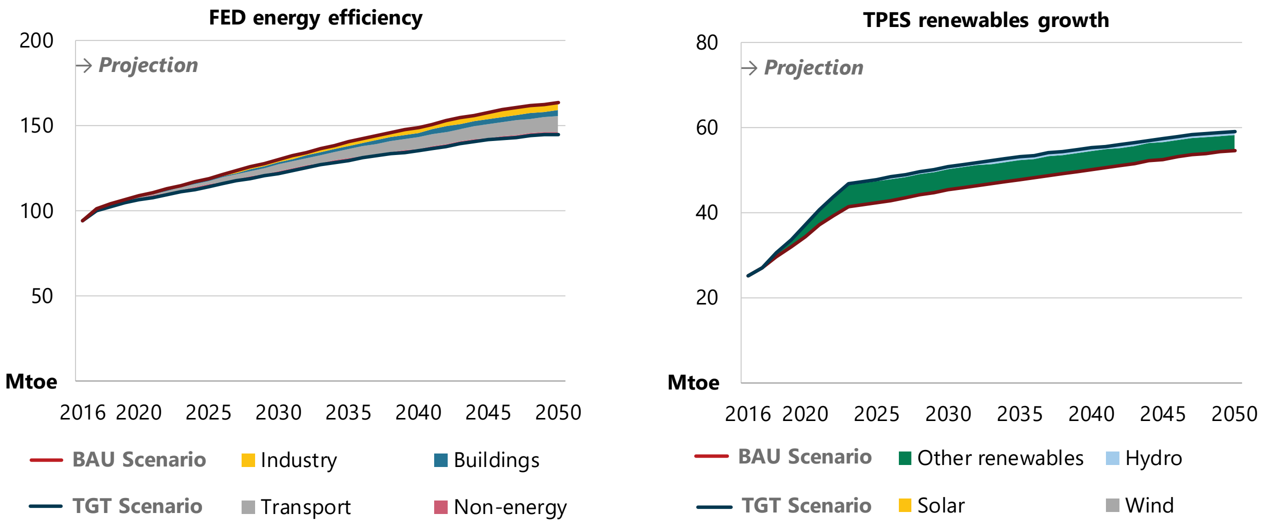
While the BAU Scenario is intended to be representative of Thailand's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, FED is 11% lower and CO_2 emissions are 19% lower in the TGT in 2050. Under the 2DC, Thailand's FED is 22% lower and CO_2 emissions are 66% lower. The share of renewables in TPES is 3.9% higher in the TGT and 11% higher in the 2DC by 2050.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. While this goal is a collective APEC target and does not include any economy-specific targets, Thailand has set its own target to reduce energy intensity by 30% of the 2010 level by 2036. To achieve this target, the Ministry of Energy has developed an energy efficiency action plan allocating targets by sector. In the updated EEP 2015, the demand reduction for electricity could reach 89 672 gigawatt-hours (GWh), and fuel and heating demand could drop by 44 Mtoe by 2036. This is equal to 30% of FED in 2036, according to EEP 2015.

Under the TGT, FED decreases 17 Mtoe by 2050 compared with the BAU, or about 13% (excluding non-energy uses). Transport contributes the most to this demand reduction (9.0 Mtoe), followed by industry (4.5 Mtoe) and buildings (3.5 Mtoe) (Figure 19.8). Stronger fuel economy standards, labelling, and efficiency standards for electrical appliances and equipment in industry and buildings provide significant opportunities to reduce demand still further. According to the EEP 2015, Thailand will implement energy efficiency resource standards (EERS) to encourage utilities to take energy demand reduction measures with their customers (EPPO, 2015c).

Figure 19.8 • Thailand: Energy efficiency and renewables growth, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

APEC's renewables goal aims to double the 2010 level of renewable energy across all sectors in the APEC region by 2030. As with the energy intensity goal, this ambition is APEC-wide and economy-specific targets have not been identified. Thailand, however, has developed the AEDP 2015, which sets out to increase the renewables contribution in FED from 12% in 2015 to 30% by 2036. This target will be implemented in conjunction with the PDP 2015 to increase renewables in the energy mix for power generation from 10% to 20% by 2036.

Under the TGT, the share of renewables in power generation increases to 24% in 2050, compared with 18% under the BAU. Among renewables, biomass (51%) and hydro (39%) are the largest sources in power generation in 2050, followed by solar (7.1%) and wind (2.7%). The AEDP 2015 aims to develop generation capacities of 5.6 GW from biomass, 6 GW from solar and 3 GW from wind by 2035, compared with the 2015 capacities of 2.5 GW (biomass), 1.3 GW (solar) and 0.2 GW (wind) (EPPO, 2015d). The goals for solar and wind are not achieved in the TGT as improved energy efficiency results in less new generation capacity. However, the ratio of renewables in power generation in the TGT increases from 14% (2016) to 24% (2036).

Under the TGT, demand for biofuels (bioethanol and biodiesel) more than doubles from 1.6 Mtoe in 2016 to 3.5 Mtoe in 2050, compared with 3.6 Mtoe in 2050 under the BAU. Biofuels, which made up 12% of total renewables demand in 2016, account for 14% in 2050. Compared with the BAU, bioethanol demand is 16% lower and biodiesel 5.8% higher in 2050 under the TGT. Bioethanol accounts for 34% of total biofuel demand, and biodiesel 66%. Under these projections, Thailand can produce enough bioethanol and biodiesel to meet demand in 2050.

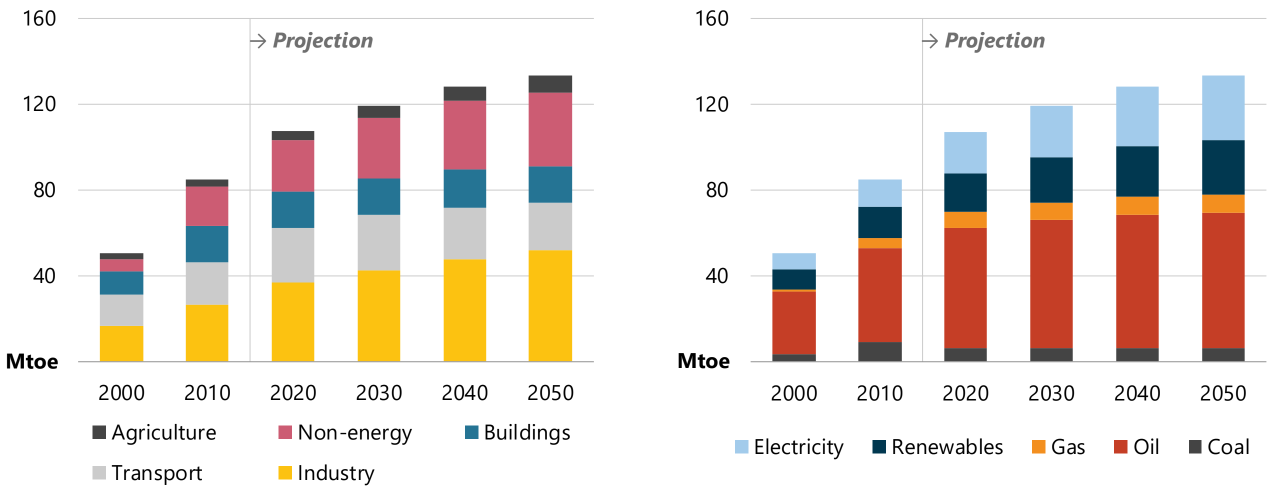
TWO-DEGREES SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Thailand will have to undergo some degree of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Under the 2DC, FED still grows strongly over the Outlook period, reaching 133 Mtoe in 2050 (from 98 Mtoe in 2016), underpinned by economic growth and increasing GDP per capita (Figure 19.9). However, FED is 38 Mtoe lower in 2050 in the 2DC compared with the BAU. Transport contributes 48% (18 Mtoe) of this energy demand reduction in 2050, followed by the residential and services subsectors (31% or 12 Mtoe) and industry (14% or 5.3 Mtoe).

Figure 19.9 • Thailand: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

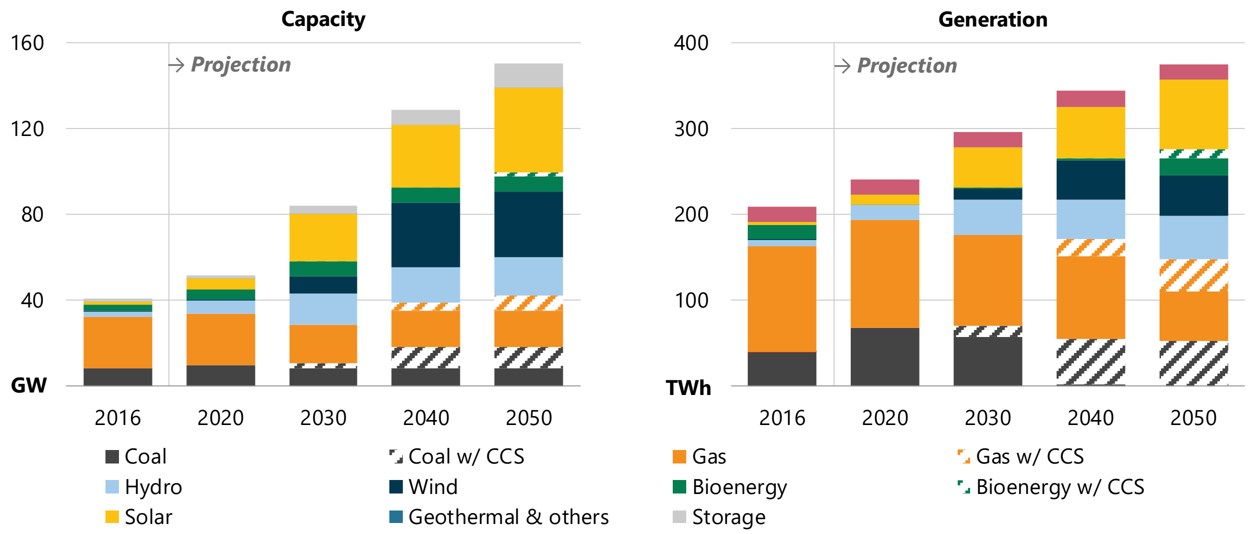
Energy efficiency improvement in domestic transport is the largest driver of reduced demand in the 2DC, decreasing from 25 Mtoe in 2016 to 22 Mtoe in 2050 (compared with 40 Mtoe in the BAU). This improvement is underpinned by significant changes in the composition and efficiency of the vehicle fleet, and decreases in tonne and passenger kilometres are instrumental. The LDV stock expands from 10 million to 12 million, including more than 7.2 million technologically advanced vehicles by 2050. The number of battery electric vehicles in particular increases rapidly, to account for 20% of LDVs in 2050. Another major change is the increasing share of biofuels by 2050 (9.0% in the BAU, compared with 14% in the 2DC). The EEP 2015 includes several policies to be implemented, but increasing their ambition, such as via higher mandated blend rates, can help to accelerate deployment.

Demand in buildings also falls significantly under the 2DC—from 29 Mtoe in the BAU to 17 Mtoe under the 2DC in 2050, shared between residential (11 Mtoe) and services (6.3 Mtoe). Decreasing electricity demand under the 2DC, resulting from improved building envelopes and electrical appliances, is the major reason for these reductions. Industrial energy demand still expands strongly in the 2DC (31 Mtoe to 52 Mtoe over the Outlook), but it is slightly more moderate than under the BAU (57 Mtoe in 2050). This improvement is driven mainly by improved recycle rates in iron and steel, and clinker-to-cement ratios in cement. There is also a slight increase in renewables deployment in industry as more advanced biomass replaces coal and natural gas.

TRANSFORMATION AND SUPPLY IN THE 2DC

The two most significant changes in the power generation mix in the 2DC are the deployment of a transformational quantity of carbon capture and storage (CCS) technology and renewables, which largely replace fossil fuels without CCS in the BAU. By 2045, all coal-based power generation includes CCS, as does a significant share of natural gas (27%) and bioenergy (12%). Coal-fired generation in the 2DC decreases from 217 terrawatt-hours (TWh) (56%) in the BAU to 53 TWh (15%) in the 2DC. Natural gas-fired power generation also decreases from 124 TWh in 2016 to 95 TWh by 2050. Renewables-based power generation increases almost eightfold over the Outlook period, from 28 TWh to 210 TWh (compared with 70 TWh in the BAU), and the share expands significantly from 14% to 59% (Figure 19.10).

Figure 19.10 • Thailand: Power capacity and electricity generation in the 2DC by fuel, 2016-50

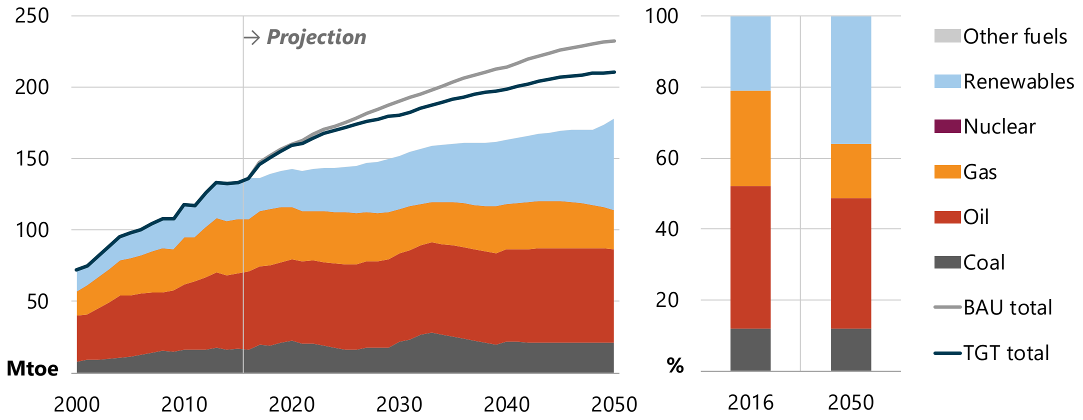


Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

The increasing share of renewables in power generation under the 2DC is aligned with the PDP 2015, which aims to increase renewables contributions from solar, biomass, wind and hydro—some of which is imported from Laos. In addition to the significant role played by renewables, CCS is essential to reduce Thailand's CO_2 emissions under the 2DC.

Fossil fuels continue to make up the majority of TPES in the 2DC, but the share increases only marginally, from 109 Mtoe in 2016 to 114 Mtoe in 2050—compared with an increase of 65 Mtoe under the BAU. The energy mix still contains a significant share of fossil fuels, although the 64% in 2050 is considerably lower than the 79% in 2016. Under the 2DC, this heavy reliance on fossil fuels continues throughout the Outlook period. Coal increases by 32% and oil by 17% owing to their importance in power generation and transport, while natural gas use declines 26% by 2050 (Figure 19.11).

Figure 19.11 • Thailand: Total primary energy supply in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

Primary energy production in the 2DC is similar to the other scenarios, as natural gas- and oil-based production drop significantly due to dwindling reserves. Likewise, renewables-based production becomes more important for Thailand's energy supply in the long term and continues to be dominated by bioenergy. However, lower demand in the 2DC results in significantly lower imports (particularly of coal) compared with the other scenarios.

SCENARIO IMPLICATIONS

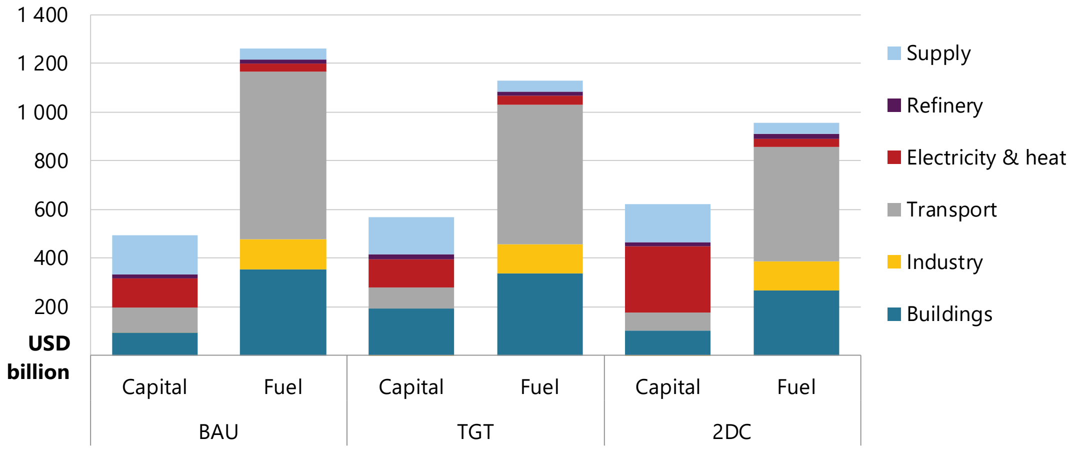
ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC Outlook 7th Edition considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[104]

Thailand's total investment and fuel costs over the Outlook period are USD 1 756 billion (Figure 19.12). Capital investments amount to USD 492 billion, of which 32% is designated for supply-side investments (upstream, downstream and energy transport). Power accounts for 24% (USD 117 billion) of capital investments, to install 31 GW of generation capacity. Demand-side investments (transport, buildings and industry) account for 40% and refinery investments claim another 3.6%. Fuel costs amount to USD 1 264 billion, with the majority going to transport (55%) and buildings (28%).

[104] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 19.12 • Thailand: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

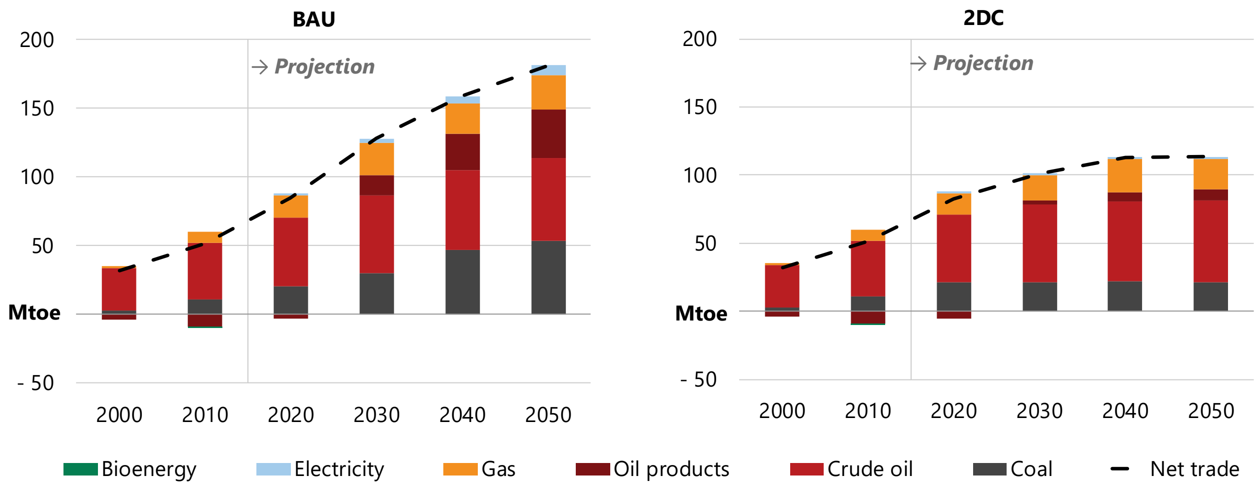
Under the TGT, total investment and fuel costs decrease to USD 1 697 billion. Although capital investments increase to USD 566 billion, they are outweighed by fuel cost savings. Fuel efficiency improvements bring fuel costs down by 11%, of which energy demand reduction in transport contributes 17% and buildings contribute -4.5%. Under the TGT, supply-side investments are 3.1% (USD 155 billion) lower than under the BAU, as energy demand expands less quickly. Electricity demand is also lower in the TGT than in the BAU, which results in 1.1 GW less installed power capacity growth (increasing by 30 GW over the Outlook), but costs are slightly higher (USD 2.2 billion) as more renewables are deployed.

Total investment and fuel costs decrease still further under the 2DC, amounting to USD 1 577 billion. Fuel costs are 24% lower at USD 958 billion, driven mainly by a 32% energy demand reduction in transport and a 25% energy demand reduction in buildings. Capital investments under the 2DC decrease by 26% from the BAU level, with total investments of USD 619 billion demonstrated. Investments in power increase from USD 117 billion in the BAU to USD 271 billion under the 2DC, as expensive natural gas-fired power plants with CCS and significantly more renewables-based power plants require financing. Total demand-side investment nevertheless decreases, from USD 198 billion in the BAU to USD 177 billion in the 2DC, amounting to 29% of total capital investment.

ENERGY TRADE AND SECURITY

Thailand's net imports almost triple during the Outlook period in the BAU as a result of surging domestic demand, particularly for fossil fuels. This growth is moderated in the 2DC (increasing by only 72%) owing to lower coal demand from the power sector and less oil product demand in transport. Natural gas net imports increase significantly from 12 Mtoe in 2016 to 25 Mtoe in 2050 under the BAU as demand surges, especially in the electricity sector, and natural gas-producing fields are depleted. Net import growth stays the same in the TGT and similar in the 2DC (reaching 23 Mtoe in 2050), resulting in significant LNG import dependency throughout the Outlook in all three scenarios—highlighting the importance of diversifying supply sources. Crude oil net imports also increase significantly (by more than 41% in all scenarios), from 43 Mtoe in 2016 to 60 Mtoe in 2050 in the BAU and 61 Mtoe in the 2DC as demand surges in all three scenarios (Figure 19.13). Dependence on Middle Eastern crude oil supplies also increases. Acquiring crude oil from other regions to diversify supplies could alleviate energy security concerns but this would need to be weighed against economic considerations.

Figure 19.13 • Thailand: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Thailand's natural gas self-sufficiency decreases drastically from 69% in 2016 to 16% in 2050 in the 2DC, emphasising the need to accelerate exploration and production or diversify power generation fuel sources (Table 19.4). Crude oil follows the downward trend of natural gas, though to a lesser degree. The reserve gap of crude oil is larger, however, prompting Thailand to seriously increase exploration of domestic crude oil while acquiring additional long-term contracts from markets. Thailand is also striving to expand the share of renewables in the energy mix to strengthen energy sustainability and self-sufficiency, and to resolve environmental concerns. Crude oil price drops since 2014 have, however, made fossil fuels more attractive, so the share of renewables in FED fell slightly from 17% to 14% in 2016.

Table 19.4 • Thailand: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	57	39	44	40	29	33	41
Coal self-sufficiency (%)	27	0.47	0.64	0.65	0.26	0.34	0.66
Gas self-sufficiency (%)	69	34	35	40	15	15	16
Crude oil self-sufficiency (%)	29	18	18	18	10	10	10
Primary energy supply diversity (HHI)	0.29	0.27	0.27	0.28	0.26	0.26	0.28
Coal reserve gap (%)	0.45	2.2	2.2	2.2	2.5	2.5	2.5
Gas reserve gap (%)	14	153	153	153	238	238	238
Crude oil reserve gap (%)	31	391	391	391	691	691	691

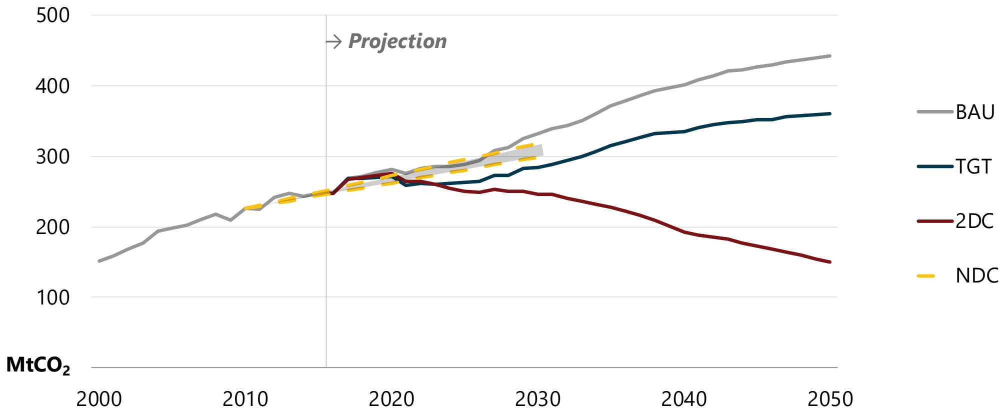
Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

In its cabinet-approved Climate Change Master Plan 2015-50, Thailand recognises that a continuous, long-term effort is needed to address climate change. The Master Plan provides a framework for long-term measures and actions to achieve climate change-resilient and low-carbon growth in line with a sustainable development pathway by 2050. Relevant agencies in various sectors are currently formulating sector-specific plans to address climate change. At the 2015 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, Thailand submitted its Intended Nationally Determined Contribution (INDC), which included policy action to support the agreement reached during COP21. Thailand's Nationally Determined Contribution (NDC), ratified in November 2016, indicates the economy's intention to reduce greenhouse gas (GHG) emissions by 20% of the BAU level (as projected in the NDC) by 2030 (ONEP, 2016). The PDP 2015, AEDP 2015 and EEP 2015 are all designed to support this target.

Energy sector CO_2 emissions (252 million tonnes of carbon dioxide [$MtCO_2$] in 2016) decrease significantly in the 2DC by 2050 (150 $MtCO_2$), which is 66% lower than in the BAU (444 $MtCO_2$) and 58% lower than in the TGT (361 $MtCO_2$) (Figure 19.14). This improvement in the 2DC compared with the other scenarios results mainly from improved energy efficiency and lifestyle changes in the demand sectors and a significant shift towards renewables and fossil fuels with CCS in the power sector. Thailand's NDC is achieved in both the TGT and 2DC, but narrowly missed in the BAU.

Figure 19.14 • Thailand: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The *7th Edition* calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

The success of the 21st round of bidding for natural gas exploration and production rights in late 2018, for the soon-to-expire Erawan and Bongkot fields, is crucial to Thailand's long-term energy supply security and sustainability. Since the fields together account for 75% of Thailand's natural gas supply, the Ministry of Energy should consider further revisions to the Gas Plan 2015 to evaluate in advance the impacts of this bid and monitor income from the release of future concessions. Income figures should be made publicly available, and the results could be used in a knowledge-sharing exercise to understand the criteria for putting future bids out to tender.

Energy 4.0 promotes the development of four modern energy technologies—electric vehicles, energy storage systems, bio-economy through SPPs, and smart cities/smart grids. Despite being developed after the TIEB, integrating Energy 4.0 into the TIEB and synchronising the objectives of both plans would avoid overlap and redundancy.

The Gas Plan 2015 focuses on the implementation of TPA and is designed to promote greater competition in the natural gas industry. Procedures allowing other energy companies access to Petroleum Authority of Thailand (PTT) pipelines and LNG terminal facilities in a fair and non-discriminatory manner is vital to eventually reduce natural gas market monopoly. Following TPA implementation (the Electricity Generating Authority of Thailand will import 1.5 Mt of LNG through the PTT system in 2019), it will be important for Thailand to monitor the market closely to ensure best practice adoption and continuing competition.

As the Ministry of Energy has organised a special ad hoc committee to introduce a new PDP in 2019, the government should clearly outline the objectives of the new plan for energy investors. Although it is sensible to revise the energy plan occasionally to reflect any changes in power generation, it would provide greater certainty to investors and market participants if there were an organised schedule for PDP updates—once every five years, for example—rather than the current ad hoc approach.

The new PDP should be synchronised with other energy plans (such as the EEP 2015, AEDP 2015, the Gas Plan and the Oil Plan) to ensure that it not only reflects recent changes in power generation but will support ongoing energy developments implemented since the last edition, as well as any recently announced projects. In addition, the scope of the new PDP should include policy support for renewables, CCS, research and development (R&D) and greater electricity trading with neighbouring economies.

20. UNITED STATES

KEY FINDINGS

- **Strong economic growth causes energy intensity (Mtoe/GDP) to fall 45% in the BAU Scenario.** With additional measures, energy intensity decreases 52% in the TGT and 62% in the 2DC.

- **Declining costs, particularly for wind and solar technologies, as well as supportive policies result in rapid renewables expansion.** The renewables share in the electricity generation mix rises from 15% in 2016 to 26% in 2050 in the BAU.

- **Coal demand decreases in all scenarios as coal-fired power plants are replaced by low-cost natural gas and renewables-based generation.**

- **Renewables fuel nearly half (47%) of electricity generated in 2050 in the 2DC.** Solar resources generate 13% of total electricity, with 41% of that through rooftop solar panels.

- **FED in the 2DC reaches 1 146 Mtoe in 2050—21% (306 Mtoe) lower than under the TGT and 32% (530 Mtoe) below the BAU projection.** The greatest energy demand reductions in the 2DC occur in domestic transport (down 50% from 2016 to 2050) and buildings (32%).

- **Energy-related CO_2 emissions fall by nearly two-thirds (63%) in the 2DC, amounting to 1 807 MtCO_2 in 2050.** The greatest emissions reductions are achieved in buildings and road transport through higher efficiency standards and switching to low-carbon fuels. Emissions from coal use drop 97%.

ECONOMY AND ENERGY OVERVIEW

Situated in North America between the Atlantic and Pacific Oceans, the United States is the world's second-largest economy. With a land area of 9.9 million square kilometres (CIA, 2019) and a population of 322 million in 2016, the US economy has accounted for more than 15% of global economic output since at least 1990 (World Bank, 2018b). Gross domestic product (GDP) was USD 18 trillion (at 2016 USD purchasing power parity) in 2016, and per-capita GDP was the fourth-highest in the Asia-Pacific Economic Cooperation (APEC) region, at USD 57 193 (the APEC average is USD 22 536) (Table 20.1). US GDP increased 1.8% annually in real terms between 2000 and 2016, and it is projected to continue rising at a compound annual growth rate (CAGR) of 2.1% between 2016 and 2050 while population increases more slowly (0.56% CAGR).

The United States is the second-largest producer and consumer of energy in APEC. With higher oil and natural gas production as a result of the shale revolution and the removal of crude oil export restrictions, crude oil and oil product exports rose by 0.15 million tonnes of oil equivalent (Mtoe) (1.1 million barrels [Mbbl]) per day in 2016-17 and the United States became a net gas exporter for the first time since 1957 (EIA, 2018a; 2018b and 2018c).

The United States has one of the highest per-capita final energy demand (FED) levels in APEC, at 4.7 tonnes of oil equivalent (toe) in 2016. On a per-GDP basis, the United States has the sixth-highest energy intensity in APEC at 84 toe of FED per GDP. This level is driven largely by high energy demand in the transport and buildings sectors, as vehicle ownership and use is greater than in other APEC economies, and residential homes are larger. Per-capita energy demand varies considerably among the 50 states, with the average person in Louisiana consuming almost five times as much as someone in New York (EIA, 2018d).

Table 20.1 · United States: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	13 845	16 296	18 427	20 387	25 833	31 554	37 161
Population (million)	282	309	322	331	355	374	390
GDP per capita (2016 USD PPP)	49 098	52 800	57 193	61 512	72 827	84 354	95 385
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	2 334	2 281	2 176	2 243	2 306	2 339	2 390
TPES per capita (toe)	8.3	7.4	6.8	6.8	6.5	6.3	6.1
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	169	140	118	110	89	74	64
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	1 546	1 513	1 515	1 552	1 601	1 632	1 676
FED per capita (toe)	5.5	4.9	4.7	4.7	4.5	4.4	4.3
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	112	93	82	76	62	52	45
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	5 773	5 542	4 911	4 945	4 927	4 875	4 893
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	100	100	100	100	100	100	100

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

ENERGY RESOURCES

The United States is a resource-rich economy with 50 billion barrels of proved oil reserves, 8.7 trillion cubic metres of natural gas reserves, 251 billion tonnes of coal reserves and 47 kilotonnes of uranium in 2016 (Table 20.2). Renewable resources include on- and offshore wind, solar, hydro, geothermal, biomass and tidal power.

In 2016, the United States held 4.5% of the world's natural gas reserves. Production takes place in 34 states but is concentrated in Texas, Louisiana, Oklahoma and Pennsylvania, which account for almost 60% of dry production (EIA, 2018e). Since the mid-2000s, horizontal drilling and hydraulic fracturing have drastically increased natural gas production from shale formations. Shale gas production rose from 8.0% in 2007 to 63% of gross withdrawals in 2017 as a result of what has been dubbed the shale revolution (EIA, 2018f).

Coal is mined throughout the United States, with major reserves in Wyoming, Illinois and West Virginia. Almost 367 Mtoe of coal were produced in 2016, 41% of it from Wyoming, where production is almost exclusively from surface mines (EIA, 2018g). Crude oil is produced mainly in Texas, North Dakota and the Gulf of Mexico. In 2016, onshore drilling in Texas alone produced 36% of US crude oil (EIA, 2018a).

Table 20.2 · United States: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	250 916	357	24	1.0	1.0
Oil (billion bbl) [a]	50	10	2.9	9.0	3.0
Natural gas (tcm) [a]	8.7	12	4.5	5.0	2.0
Uranium (tU) [b]	47 200	49	1.2	13	5.0

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. tU = tonnes of uranium. a. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions. b. Reasonably assured resources at USD 130 per kilogram of uranium (kgU).
Sources: For coal, oil and natural gas, BP (2018). For uranium, NEA (2018).

Renewable resources can be found throughout the United States. Broadly speaking, the best solar resources are in the south-western continental United States as well as in Hawaii. For wind, the highest potential extends from North Dakota through Texas as well as offshore on both coasts and the western portion of the Gulf of Mexico (NREL, 2012 and 2018). Geothermal potential is concentrated in the western half of the continental United States and biomass is available everywhere (NREL, 2005 and 2009).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

US energy policy is formulated at the federal, state and local levels, which has resulted in a multi-layered policy structure and numerous stakeholders. Since the energy crises in the 1970s, several pieces of legislation have been developed to address energy security, energy efficiency, domestic energy production and the use of renewable energy, and to reduce the impact of the energy sector on the environment and public health. Table 20.3, which presents some key policies of the past decade, does not include federal incentive programs integrated into the tax code (e.g. personal and corporate tax credits), which are discussed in the *APEC Energy Overview* (APERC, 2018).

Table 20.3 · United States: Selected energy policies, 2007-17

Energy Independence and Security Act of 2007 (EISA)	Energy security actions: raise biofuels production, improve vehicle fuel economy, implement residential building energy efficiency measures and ensure high-performance commercial and federal buildings. Targets: greater energy independence and security; increased renewable fuel production; higher energy efficiency of products, buildings and vehicles; introduction of greenhouse gas (GHG) capture and storage options.
American Recovery and Reinvestment Act of 2009 (ARRA)	Power: transmission system upgrades; carbon capture and storage (CCS); energy efficiency and renewable energy infrastructure. Transport: battery and electric vehicle (EV) development. Buildings: repairs and energy efficient modernisation. Energy efficiency and renewable energy research and development: grants, loan guarantees, research funding.
Consolidated Appropriations Act of 2016	Energy trade: 40-year-old ban on crude oil exports lifted.
Corporate Average Fuel Economy (CAFE) standards	Transport: standards to improve fuel economy of new cars and light-duty trucks. For example, fuel consumption of newly manufactured passenger cars with footprints of 3.8 square metres (m^2) and smaller to improve from 36 miles per gallon (mpg) to 54.5 mpg (6.53 litres per 100 km [L per 100 km] to 4.32 L per 100 km) from 2012 to 2025.
Strategic Petroleum Reserve Drawdown	Energy security: six laws passed by US Congress from 2015 to 2018 to reduce the Strategic Petroleum Reserve from 695 Mbbl in 2017 to 405 Mbbl by 2028 (GAO, 2018).
Energy Efficiency Resource Standards	Mandatory state-wide energy efficiency resource standards in 24 states; energy efficiency resource goal in 6 states. (EIA, 2018h)
Renewables Standards	Renewable portfolio standards in 29 states as well as the District of Columbia and 3 territories (Northern Mariana Islands, Puerto Rico and the US Virgin Islands); renewable portfolio goals in 8 states and 1 territory (Guam).
Net Metering	Mandatory net metering rules for certain utilities in 38 states as well as the District of Columbia and 3 territories (American Samoa, the US Virgin Islands and Puerto Rico). In 2 other states (Texas and Idaho), some utilities allow for net metering, while 7 states and 1 territory have distributed generation compensation rules rather than net metering.
Nationally Determined Contribution (NDC)	Economy-wide GHG emissions reduced 26% to 28% below the 2005 level by 2025, and best efforts to reduce emissions by 28%.

Sources: APERC (2018) and DSIRE (2018).

BUSINESS-AS-USUAL SCENARIO

This section summarises key energy demand and supply assumptions for the United States under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 20.4). Definitions used in this Outlook may differ from government targets and goals published elsewhere, such as in the US Nationally Determined Contribution (NDC) under the COP21 Paris Agreement.

Table 20.4 · United States: Key assumptions and policy drivers under the BAU

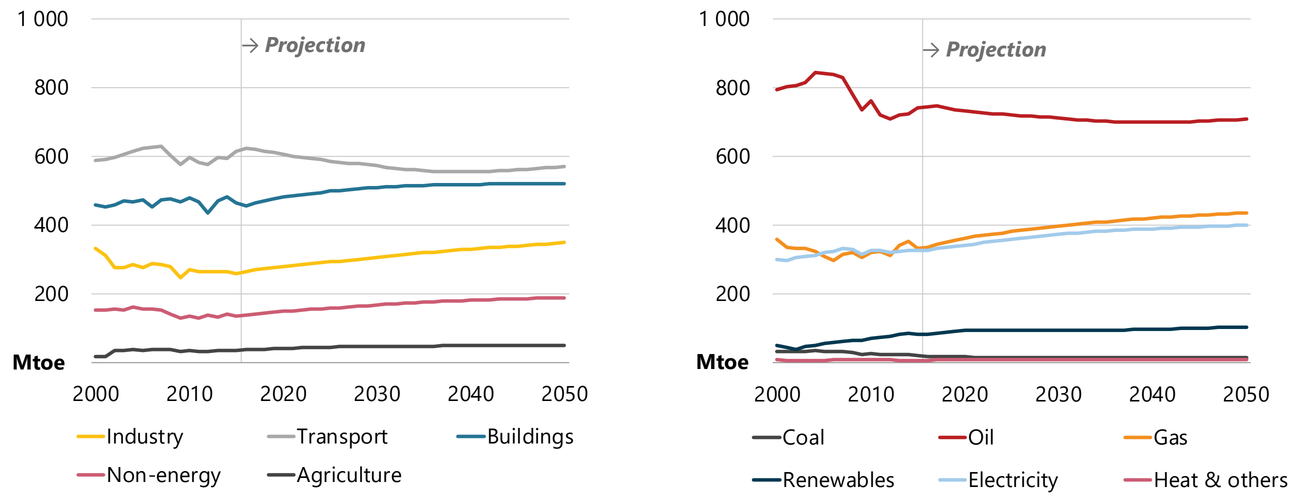
Buildings	Envelope, furnace, appliance and lighting standards improve modestly.
Transport	2021-25 Corporate Average Fuel Economy (CAFE) standards remain in place. Government support for electric vehicle (EV) charging stations continues.
Energy supply mix	Market determined. Shale development continues.
Power mix	Market determined.
Renewables	Tax credits are not renewed. Renewable portfolio standards improve modestly.
Energy security	International Energy Agency (IEA) membership continues. Self-sufficient in coal.
Climate change	NDC submitted by the United States not included in the BAU.

Notes: NDC = Nationally Determined Contribution. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

In the BAU Scenario, FED grows 11% over the Outlook period (2016-50), rising slowly at a CAGR of just 0.30%. Domestic transport had the highest share of FED in 2016 (41%), followed by buildings (30%) and industry (17%) (Figure 20.1). These shares are largely the same in 2050, with transport still demanding the most energy (34%), followed by buildings (31%) and industry (21%).

Figure 20.1 · United States: Final energy demand by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Overall sector and fuel trends correspond to an increase in FED from 1 515 Mtoe to 1 676 Mtoe over the projection period. For domestic transport, FED falls from 622 Mtoe to 570 Mtoe in the BAU, with the decline resulting in part from the Corporate Average Fuel Economy (CAFE) standards adopted to improve road vehicle efficiency. The impact of the CAFE standards is uncertain, however, as the National Highway Traffic Safety Administration (NHTSA) has proposed freezing fuel economy standards for light-duty vehicles at the 2020 levels (NHTSA, 2018).

Regarding fuel use, oil supplied almost half (49%) of FED in 2016, followed by almost equal shares of natural gas (22%) and electricity (22%). In 2050, the share of oil declines somewhat to 42% of total FED, with a corresponding increase in the use of natural gas to 26%. Demand for electricity and renewables increases over time, with electricity's share increasing 2.2% from 2016 to 2050 and renewables increasing by 0.75%.

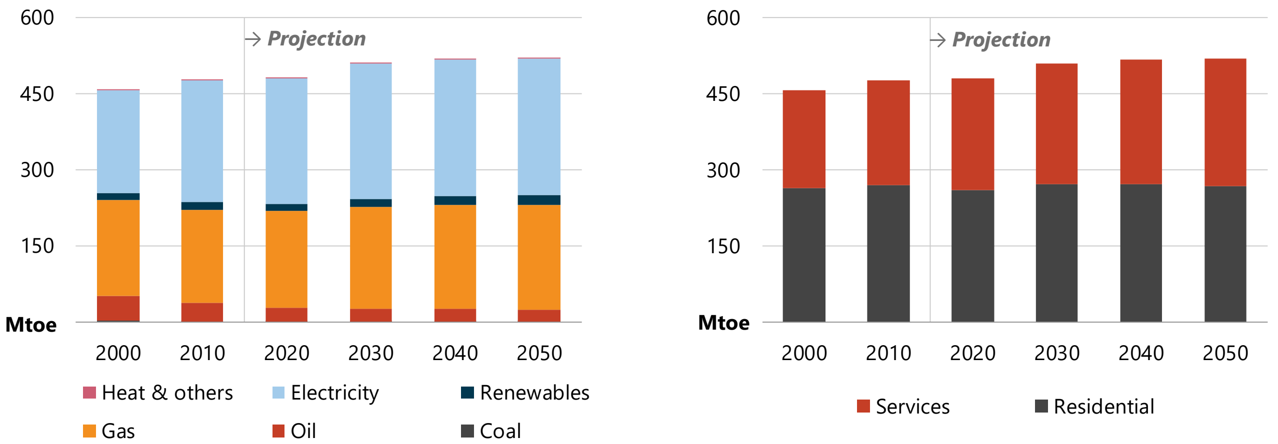
BUILDINGS: ENERGY EFFICIENCY GAINS HELP TO SLOW RESIDENTIAL DEMAND GROWTH

FED in the buildings sector rises slowly (0.38% CAGR) in the BAU, resulting in an overall increase of 14% from 456 Mtoe in 2016 to 520 Mtoe in 2050 (Figure 20.2). This increase is driven largely by the service buildings subsector, in which demand grows by 20% from 2016 to 2050, compared with 8.4% growth in residential buildings.

Overall demand in residential buildings rises from 247 Mtoe to 268 Mtoe over the projection period, as population and GDP growth slightly outpace gains in energy efficiency. For example, the average energy intensity for space heating (measured in kilowatt-hours per square metre) in residential buildings decreases 3.3% over the period. For service buildings, FED rises from 209 Mtoe to 252 Mtoe by 2050, particularly because of rising demand for other end uses (e.g. various types of office equipment and security systems). Overall energy demand for other end-uses rises nearly 40%.

Electricity supplies more energy in buildings than any other fuel over the period, rising from 238 Mtoe to 270 Mtoe, while natural gas use is second, expanding by 18% (from 175 Mtoe to 207 Mtoe). This increase results largely from higher gas demand for cooking, water heating and space heating in residential buildings, as well as for other end-uses and water heating in service buildings. Renewables demand grows more quickly than that of any other fuel (0.88% CAGR) as their range of uses broadens, including using solar resources for both electricity generation and water heating.

Figure 20.2 · United States: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

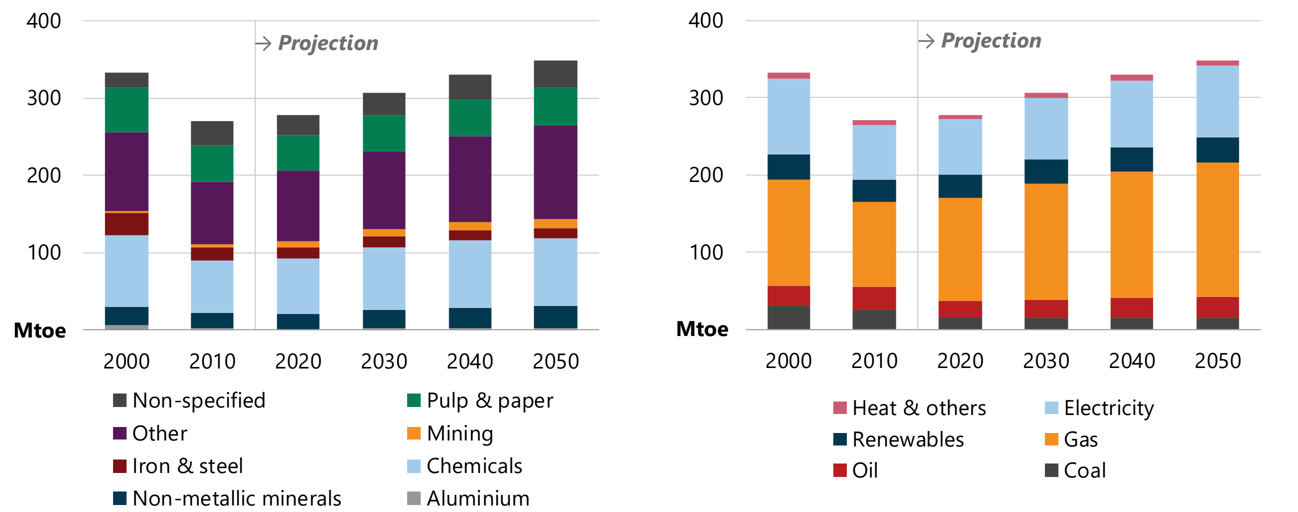
The United States has adopted federal, state and local incentive programs to support greater energy efficiency in buildings. At the federal level, the Weatherization Assistance Program (WAP) supplies grants to low-income households to increase the energy efficiency of their homes while ensuring their health and safety. According to the US Department of Energy (DOE), which oversees this program, the WAP has provided support to more than 7 million families since 1976 and has saved these households an average of USD 283 per year in energy bills (DOE, 2018a).

While the United States does not have an economy-wide building or energy code, numerous state and local governments have adopted codes aimed at gradually improving the energy efficiency of buildings. At the end of 2017, 43 of the 50 states had adopted energy codes for commercial buildings (42 had also adopted energy codes for residential buildings). These codes are projected to save US home and business owners USD 126 billion and reduce carbon dioxide (CO_2) emissions by 841 million tonnes of CO_2 ($MtCO_2$) through 2040 (DOE, 2017). Through its Appliance and Equipment Standards Program, the US DOE also sets minimum energy conservation standards for more than 60 categories of appliances and equipment used in buildings, including kitchen appliances, bathroom and plumbing equipment, clothes washers and dryers, lighting technologies, some electronics, and heating, ventilation and air conditioning equipment (DOE, 2018b and 2018c). This program also supports the voluntary ENERGY STAR energy efficiency labelling program, which is overseen by the US Environmental Protection Agency (EPA) (ENERGY STAR, 2018).

INDUSTRY: CHEMICALS AND PETROCHEMICALS CONTINUE TO LEAD GROWTH

Energy demand in industry grows more quickly than in other sectors, increasing from 264 Mtoe to 349 Mtoe (32%) over the projection period, because of rising GDP and population (Figure 20.3). Within industry, the fastest growth is in non-metallic minerals production (1.3% CAGR), although demand increases at a 1.0% rate in the aluminium, chemical and petrochemical, mining, and 'other' (e.g. machinery manufacturing) subsectors. Conversely, energy demand falls significantly for the iron and steel (-14%) subsector, in which demand is already low.

Figure 20.3 · United States: Industry final energy demand by subsector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

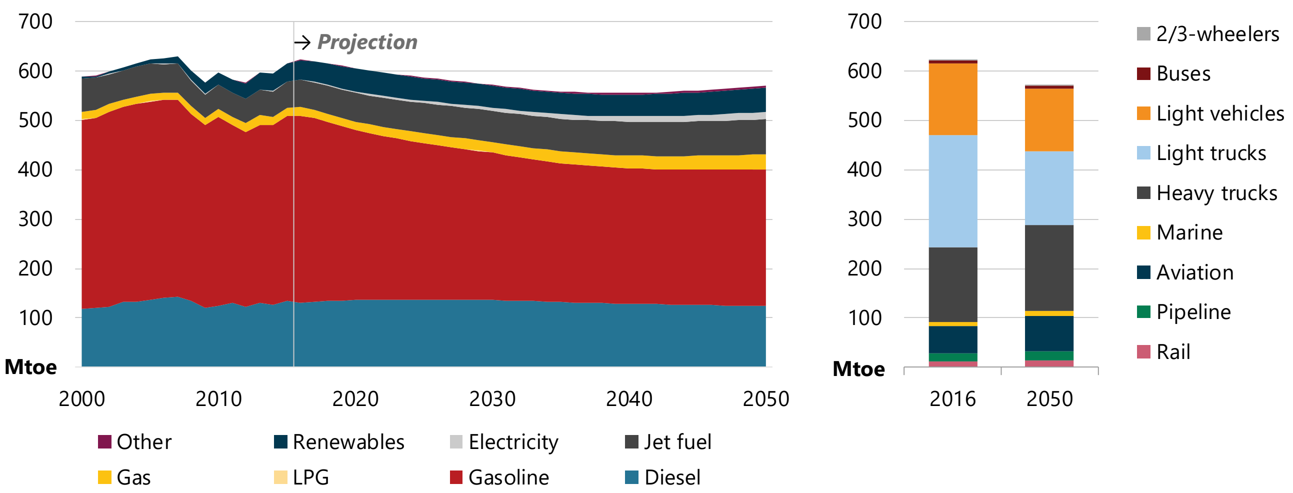
Demand for all fuels except coal rises over the projection period, with the largest increase in natural gas (41%—from 123 Mtoe in 2016 to 174 Mtoe in 2050). Oil demand increases nearly as much (40%), driven by aluminium, non-metallic minerals, chemicals and petrochemicals, mining, and the 'other' subsectors. Electricity use also expands significantly, with a 35% increase driven mostly by rising demand in the chemical and petrochemical, non-metallic minerals, and 'other' subsectors. Coal demand declines from 17 Mtoe to 14 Mtoe as its use drops in all areas of industry.

TRANSPORT: HEAVY-DUTY TRUCKS RAISE ROAD TRANSPORT ENERGY DEMAND

Energy demand for domestic transport declines from 622 Mtoe to 570 Mtoe over the projection period, at a CAGR of -0.26% (Figure 20.4). This is lower than the 0.35% CAGR of the 2000-16 period because higher consumption is counterbalanced by rising vehicle fuel economy. This trend is also similar to that projected in the 6th edition of the Outlook, in which transport FED declined slightly over the projection period. However, energy efficiency is outpaced by rising transport energy demand in the final decade of the Outlook period [2040-50], given the recent trend to adopt trucks and sport utility vehicles (SUVs), instead of passenger sedans.

Road vehicles continue to dominate energy demand for domestic transport, though demand falls only 14%, from 530 Mtoe to 455 Mtoe. Behind this decline, however, are dramatic shifts by subtype, with FED from light-duty trucks decreasing by one-third (-34%) and rising for heavy-duty trucks (13%). In 2050, heavy-duty trucks account for 38% of FED from road vehicles, versus 29% in 2016.

Figure 20.4 · United States: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

There is some uncertainty, however, regarding fuel economy trends for light-duty passenger vehicles and trucks. In August 2018, NHTSA proposed freezing the planned fuel economy standard increases for cars and light-duty trucks for model years 2022-26 at the 2020 levels. NHTSA estimates that its proposal would raise US fuel consumption by 500 000 barrels (bbl) per day (NHTSA, 2018).

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Fuel inputs for transformation have declined since 2000 because the amount of fuel used for electricity generation has fallen, although refinery inputs and energy industry own-use consumption have largely remained steady. Power sector fuel inputs peaked in 2007 and then declined as newer, more efficient natural gas generators replaced older coal- and oil-fired plants. Oil and gas production expanded, however, significantly reducing oil and gas imports and causing the United States to become a net exporter rather than net importer of petroleum products.

REFINERY CAPACITY EXPANDS WHILE PRODUCTION REMAINS STEADY

Refinery inputs and outputs rose during 2000-08, then dipped after the global financial crisis and have since surpassed 2008 levels. At the same time, refinery capacity expanded steadily from 2000 to 2015 (0.70% CAGR) as new, small refineries began operating and existing ones added capacity (BP, 2018; OGJ, 2016 and 2017; EIA, 2018i).

Like refinery inputs, energy industry own-use consumption changed very little from 2000 to 2016 (energy industry own-use covers any fuel used in refineries, oil and gas extraction, and power plants). Three-quarters of the fuel used in the energy sector during this period was oil and gas, with electricity providing much of the rest. Natural gas became the dominant fuel, rising from 35% of the total in 2000 to 47% in 2016, while oil declined.

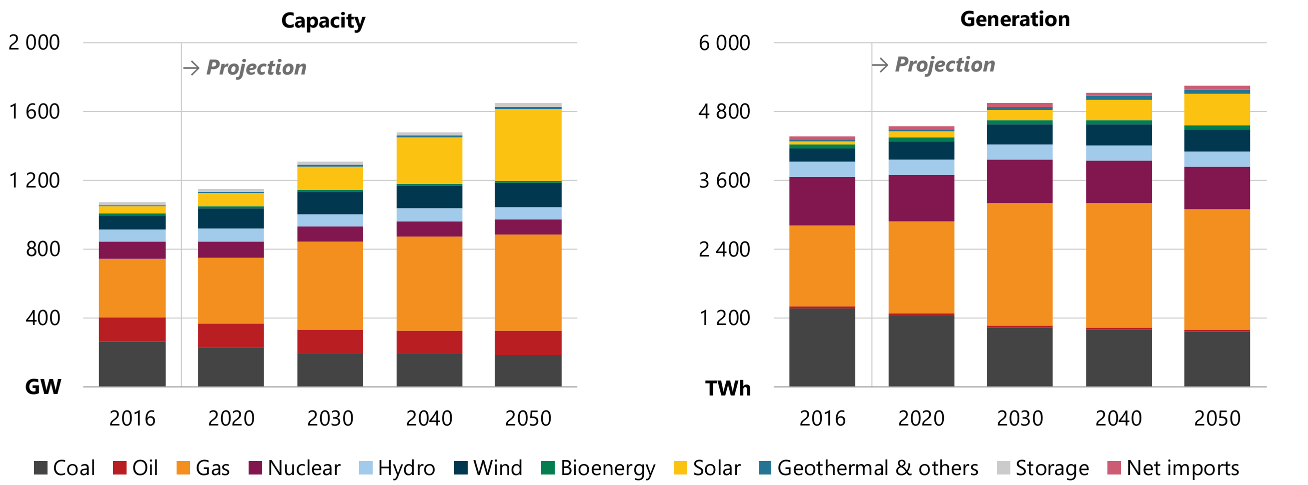
POWER SECTOR REDUCES COAL USE IN FAVOUR OF NATURAL GAS AND RENEWABLES

In the BAU Scenario, power capacity increases from 1 071 gigawatts (GW) in 2016 to 1 646 GW in 2050, a 54% overall capacity growth (1.3% CAGR) (Figure 20.5). Coal, oil and nuclear capacity all decline over the projection period, with 65 GW of low-efficiency coal-fired power plants retired by 2025. The retirement of 12 nuclear reactors by 2025 more than offsets the additions of the new Vogtle 3 and 4 plants (EIA, 2018j). Conversely, natural gas and renewables capacity expands because of lower costs.

In large part because of these capacity changes, electricity generation from coal declines (-29% from 2016 to 2050), as does that from nuclear (-11%). Natural gas-fired generation rises from 1 414 terawatt-hours (TWh) to 2 093 TWh over the projection period in the BAU, owing to continued low costs. Its share in total generation increases from 33% in 2016 to nearly 40% in 2050.

Electricity generation from renewables more than doubles to account for 26% of generation in 2050, with more than 40% from solar resources. Solar power generation grows more quickly than from any other renewable source, at a CAGR of 7.3% (from 50 TWh in 2016 to 549 TWh in 2050). Wind power generation increases from 229 TWh to 375 TWh over the projection period (1.5% CAGR), and geothermal generation rises from 19 TWh to 63 TWh.

Figure 20.5 · United States: Power capacity and electricity generation by fuel, 2016-50

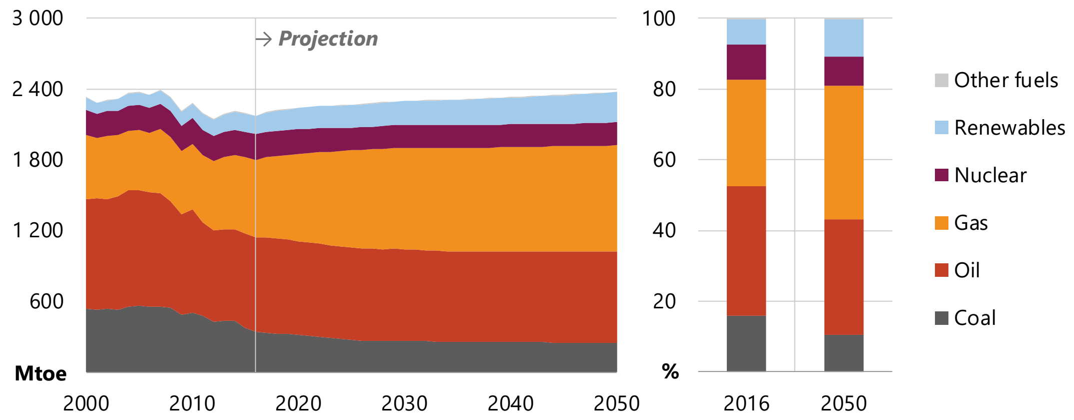


Sources: APERC analysis and IEA (2018a).

PRIMARY ENERGY SUPPLY CHANGES SLOWLY

Total primary energy supply (TPES) rises 10% (from 2 176 Mtoe in 2016 to 2 392 Mtoe in 2050) in the BAU, more than projected in the 6th edition of the Outlook. Coal supplies drop by 28% and uranium by 11%, while natural gas supplies increase 38% (Figure 20.6). Renewables expand more quickly than any other fuel, by 63% (from 156 Mtoe to 255 Mtoe).

Figure 20.6 · United States: Total primary energy supply by fuel, 2000-50



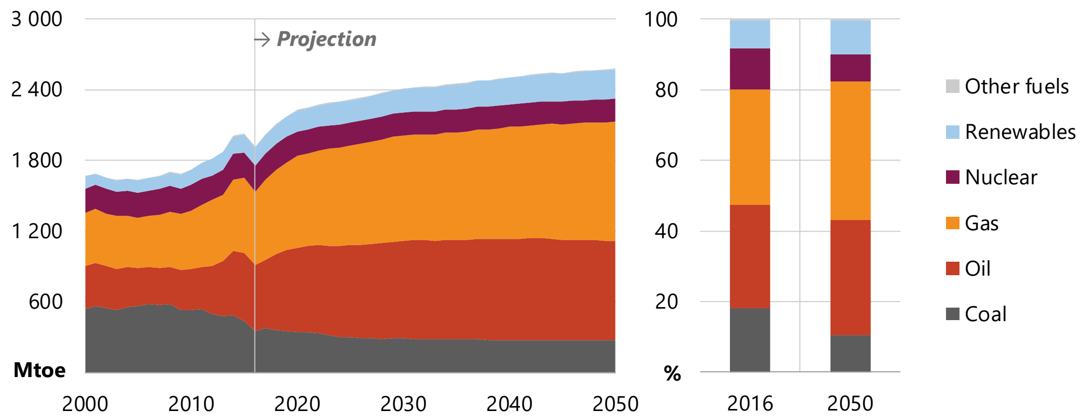
Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: THE UNITED STATES BECOMES A NET GAS EXPORTER

The United States is a major participant in global energy markets and maintains strong infrastructure ties with Canada to the north and Mexico to the south, including numerous oil and gas pipelines as well as electricity transmission interconnections. This economy has also long been a major fossil fuel producer, overtaking Russia as the largest APEC producer of gas and oil in 2015. In 2017, thanks to booming production enabled by advanced horizontal drilling techniques, the United States transitioned from being a net importer of natural gas to a net exporter (Figure 20.7). While it is still a net importer of crude oil, rising domestic production continues to reduce the need for imports.

In the BAU, coal and uranium production decline while that of oil and natural gas rises significantly. Renewables—particularly wind, solar and geothermal—expand more quickly than any other fuel, mainly owing to decreasing costs. Outputs from refineries rise slightly.

Figure 20.7 · United States: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

In 2017, the United States imported 1.4 Mtoe (10.1 Mbbl) of petroleum[105] per day and exported 6.4 Mbbl per day. Canada is by far the largest source of US crude oil imports (EIA, 2018k and 2018l). The United States exported 0.13 Mtoe (914 000 bbl) of propane per day in 2017, with approximately half shipped to Japan, China, Korea and Singapore (EIA, 2018m). Investments in petrochemical facilities in these four economies are the impetus for their high imports of US propane (EIA, 2018n). The United States also became a net natural gas exporter in 2017, as growing domestic production led not only to lower pipeline imports from western Canada, but to increased pipeline exports to eastern Canada and Mexico, as well as liquefied natural gas (LNG) to the broader global market (Box 20.1).

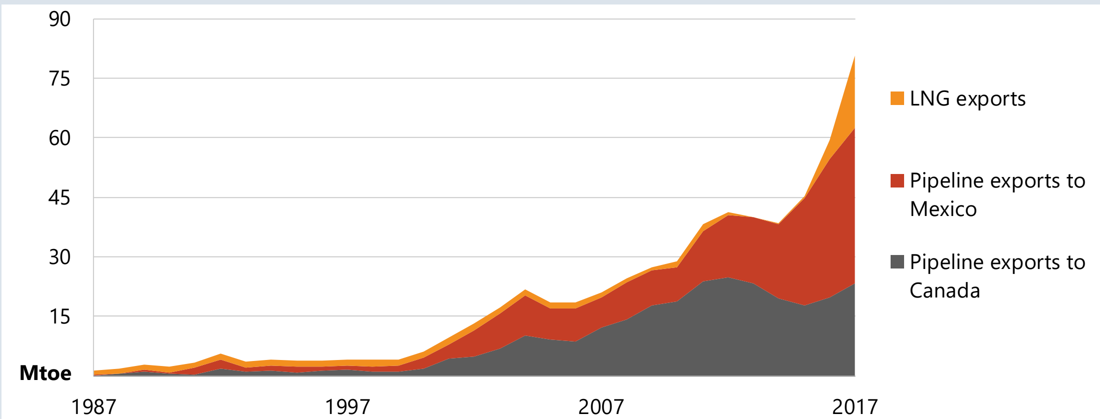
As a net exporter of coal, the United States exported 60 Mtoe in 2017 and imported 4.2 Mtoe. The majority of exports (57%) were metallurgical coal, and almost half of all coal exports went to five economies: India (12%), Korea (10%), the Netherlands (10%),[106] Japan (7.9%) and Brazil (7.8%). Most of the small amount of coal imports (78%) was thermal coal from Colombia (EIA, 2018g).

Net exports of natural gas increase almost threefold from 2020 to 2050 under the BAU, predominately through pipeline exports to neighbouring Canada and Mexico. Net imports of crude oil decline by 49% from 2016 to 2050 in response to growing production, and net coal exports fall 22% because of declining world demand.

Box 20.1 · United States: Soaring gas exports

LNG exports have risen dramatically since the Sabine Pass terminal began to ramp up operations in early 2016 (EIA 2017a). In 2017, US LNG exports nearly quadrupled from the previous year (Figure 20.8), totalling 18 Mtoe and reaching 27 economies around the world—with more than half going to three APEC members (Mexico, Korea and China) (EIA, 2018m). A record natural gas pipeline expansion in the Northeast in 2018 is slated to raise the capacity for moving natural gas out of the region to more than 210 Mtoe per year, a threefold increase from 2014 (EIA, 2018o). This additional capacity could enable more natural gas produced in the Marcellus and Utica basins in Pennsylvania, Ohio and West Virginia to be exported to new markets.

Figure 20.8 · US natural gas exports, 1987-2017



Source: EIA (2018k).

[105] Including crude oil, natural gas plant liquids, liquefied refinery gases, refined petroleum products (e.g. gasoline and diesel) and biofuels (e.g. ethanol and biodiesel). In 2017, 79% of gross petroleum imports into the United States were crude oil.
[106] Delivered to ports in the Netherlands, but may have ultimately been consumed throughout Europe.

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to represent current US energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Relative to the BAU, the United States under the TGT shows FED as 13% lower in 2050 while CO_2 emissions are 19% lower.

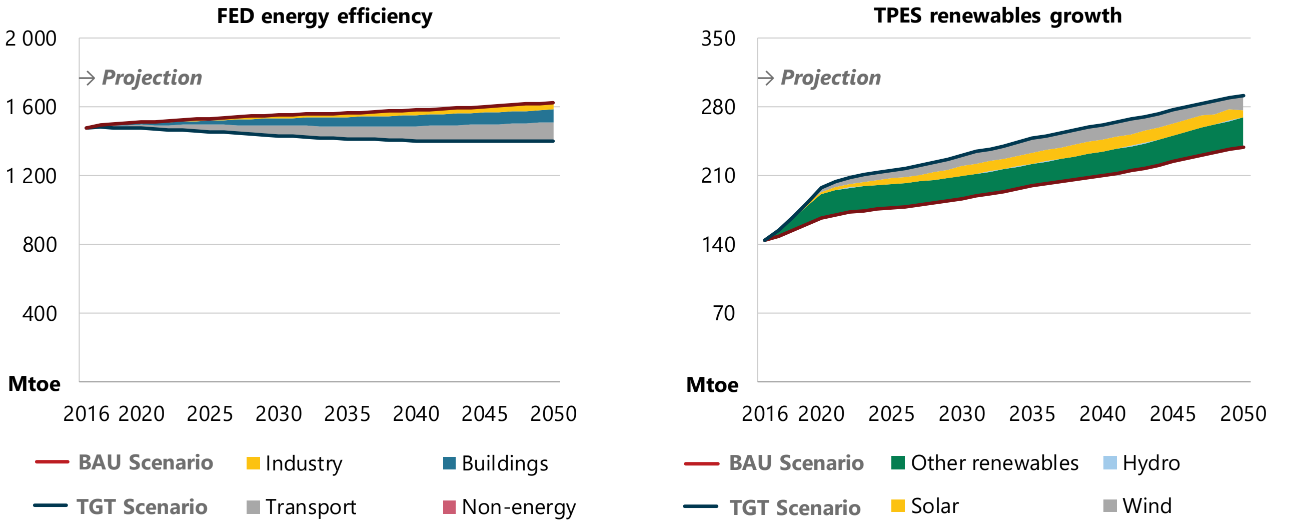
FED under the TGT is 224 Mtoe lower than in the BAU in 2050. Approximately half of this reduction (46%) results from increased efficiency in the transport sector, with the remainder achieved in buildings through the adoption of more efficient appliances and LED light bulbs, and in industry with the increased use of more efficient best available technologies. In the 2DC, FED in 2050 is 1 146 Mtoe: 21% (306 Mtoe) lower than in the TGT and 32% (530 Mtoe) below the BAU level. The transport sector accounts for 49% of the overall energy demand reduction from the BAU to the 2DC, and another 40% is in the buildings sector.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. The APEC energy intensity reduction and renewable doubling goals do not articulate specific economy-level targets, but rather emphasise greater efforts to achieve the targets across the entire APEC region. In the United States, this means making existing efforts more ambitious to raise energy efficiency and the use of renewables, for example through implementing CAFE standards. Additional details on the methodology used for the TGT Scenario can be found in Annex I.

Total FED under the TGT falls from 1 515 Mtoe in 2016 to 1 452 Mtoe in 2050 (-0.12% CAGR) (Figure 20.9). This slight downward trend in demand is primarily the result of greater fuel efficiency, which reduces energy use by 25% in domestic transport.

Figure 20.9 · United States: Energy efficiency and renewables growth, TGT versus BAU, 2016-50



Notes: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Total electricity generation in 2050 is approximately 10% (493 TWh) lower in the TGT than the BAU owing to increased energy efficiency in the end-use sectors (i.e. transport, buildings and industry). The use of renewable sources for power generation has already expanded considerably in the United States because of declining costs, particularly for wind and solar, as well as supportive policies. In the BAU, the share of renewables in the electricity generation mix increases from 15% in 2016 to 26% in 2050. In the TGT, however, the share is 33% in 2050 owing to additional wind power. Wind generation reaches 553 TWh in 2050 under the TGT (47% higher than the BAU).

TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

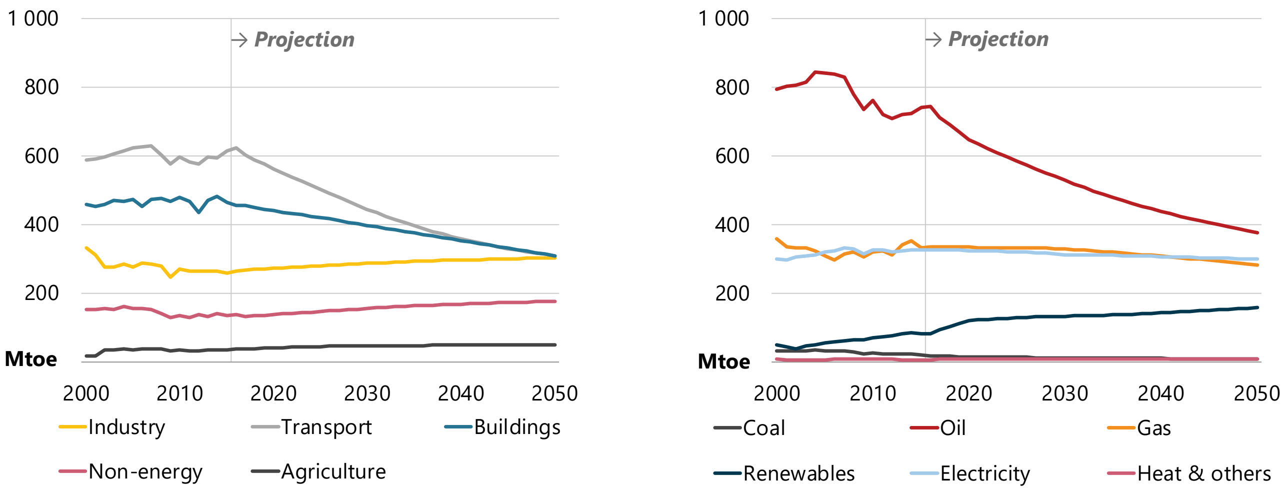
The 2DC Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in the United States will have to undergo varying levels of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Total FED falls 24% (1 515 Mtoe to 1 146 Mtoe) from 2016 to 2050 in the 2DC, primarily owing to rising energy efficiency in domestic transport (resulting from fuel economy standards) and buildings. In transportation, demand decreases 50% in the 2DC, compared with 25% in the TGT and 8.3% in the BAU (Figure 20.10). Accelerated deployment of electric vehicles (EVs) in the 2DC results in a 12% CAGR for electricity demand in domestic transport, compared with 8.5% in the BAU. For light-duty passenger cars, 22 million plug-in hybrid EVs (PHEVs) and 58 million battery EVs (BEVs) are on the road in 2050 in the 2DC—in addition to 21 million BEV light-duty trucks. In the BAU, 2.7 million PHEVs and 23 million BEVs are deployed over the same time frame, in addition to 3.5 million BEV light-duty trucks.

Buildings FED decreases by almost one-third (32%), from nearly 456 Mtoe in 2016 to 308 Mtoe in 2050. These reductions result from adopting higher-efficiency appliances and better building envelopes for new builds and retrofits. Residential building demand falls 29%, from 247 Mtoe to 177 Mtoe, while service buildings drop even more, by 37% (from 209 Mtoe to 132 Mtoe). Both sets of demand reductions are primarily the result of decreased energy demand for lighting, and for space heating and cooling.

Figure 20.10 · United States: Final energy demand in the 2DC by sector and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

TRANSFORMATION AND SUPPLY IN THE 2DC

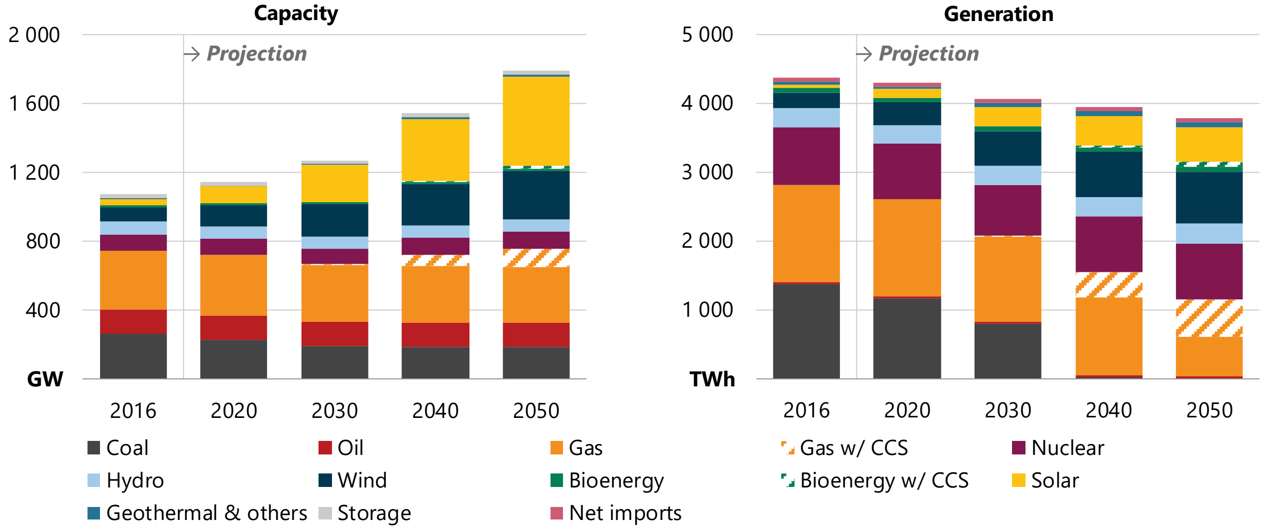
Falling FED for refined petroleum products in the 2DC results in significantly lower utilisation rates in the refining sector. Depending on individual plant economics and business decisions, this decrease could result in lower utilisation rates fleet-wide, or the closure of individual refining facilities—or a combination of the two. Analysis of individual plant economics is beyond the scope of BAU, TGT and 2DC modelling, but given the logistical constraints on moving refined products within the United States and the fact that more than half of all gasoline exports go to Mexico (EIA, 2018p), it is reasonable to conclude that lower utilisation rates would have regional impacts.

In the electricity sector, generation in the 2DC falls from 4 306 TWh in 2016 to 3 723 TWh in 2050 as greater energy efficiency offsets increasing electrification in the demand sectors (particularly transport, as discussed above) (Figure 20.11). Renewables fuel almost half (47%) of the electricity generated in 2050 in the 2DC, compared with 33% in the TGT and 26% in the BAU. In addition to the carbon constraints assumed under the 2DC, rapidly falling costs and the resulting increase in capacity additions mean that wind installations supply 20% of total electricity generation in 2050, more than any other renewable technology and more than 2.5 times the amount supplied by hydro power facilities. All of this solar electricity comes from onshore projects.

Conversely, fossil fuel-based generation drops as lower-cost renewables gain a larger share of the market. Coal-fired generation in the 2DC reaches zero—plummeting from 1 365 TWh in 2016 to zero in 2045—and natural gas-fuelled generation drops 22% (from 1 414 TWh to 1 109 TWh). Electricity generation from nuclear plants also decreases in the 2DC (by 2.6%), but far less than the 11% decrease in both the TGT and BAU scenarios.

For the first time, this 7th edition of the Outlook projects the deployment of carbon capture and storage (CCS) technologies after 2035 to reduce emissions from natural gas-fired power plants and to realise negative-emissions opportunities for biomass facilities. In 2050 under the 2DC, roughly one-third of electricity generation from biomass power plants and almost half of gas-based electricity come from facilities equipped with CCS. A total 17 GW of bioenergy and 103 GW of natural gas with CCS capacity are online in 2050.

Figure 20.11 · United States: Electricity capacity and generation in the 2DC by fuel, 2016-50

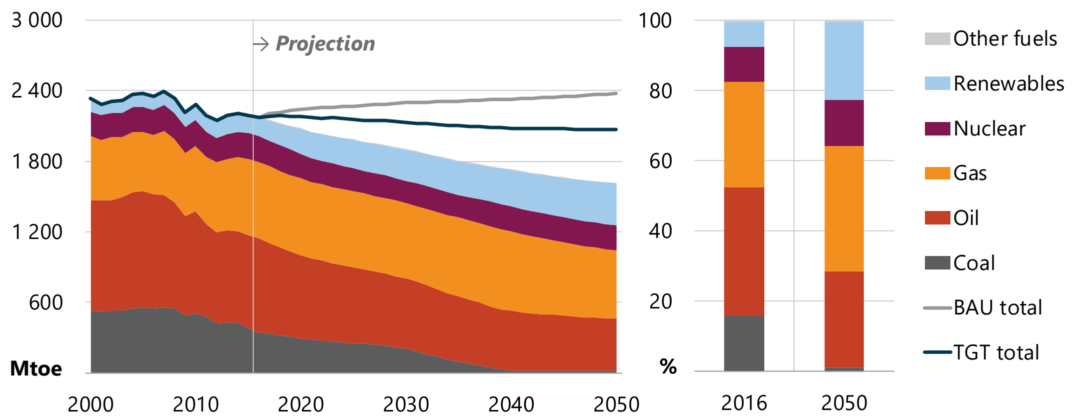


Notes: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

Demand sector changes, combined with corresponding upstream changes, lead to an overall decrease in TPES from 2 176 Mtoe in 2016 to 1 654 Mtoe in 2050 (Figure 20.12). This drop of 24% is significantly larger than the 3.5% decrease under the TGT and the 9.9% increase in the BAU.

The supply of renewables expands by 130% under the 2DC, from 156 Mtoe in 2016 to 360 Mtoe in 2050, driven by the rising renewables demand outlined above. Given the emissions reductions required in the 2DC, coal and oil shares in TPES shrink in response to falling domestic demand and decreasing production. Cuts in production are based on the assumption that demand for these fossil fuels also decreases globally over the projection period, as 2DC emissions trajectories imply that the entire globe transitions to a low-carbon economy to mitigate climate change. Coal supplies overall drop 95% (from 345 Mtoe in 2016 to 16 Mtoe in 2050) in the 2DC, as do supplies of oil (-46%) and natural gas (-11%).

Figure 20.12 · United States: Total primary energy supply in the 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

SCENARIO IMPLICATIONS

ENERGY SECTOR INVESTMENTS AND SAVINGS

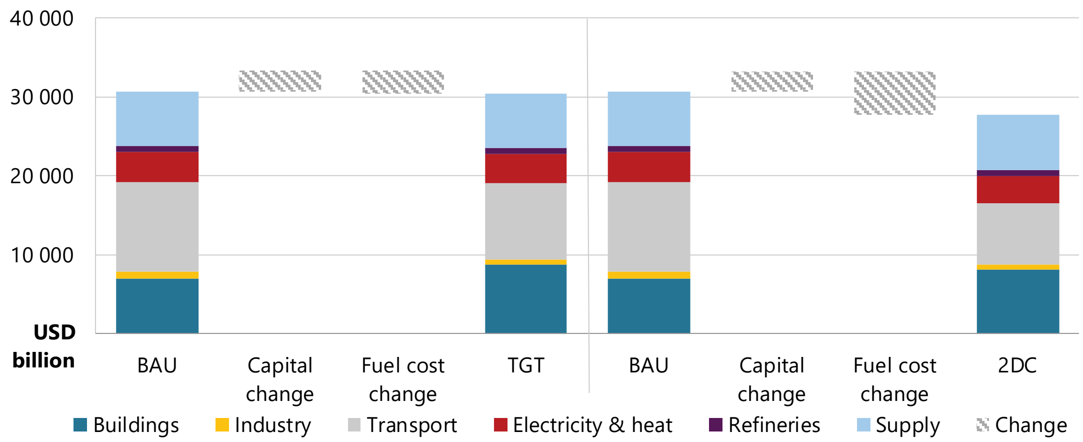
The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. These projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[107]

Total investment for 2017-50 in the BAU Scenario amounts to USD 31 trillion (in 2016 USD), with USD 15 trillion for capital investments (more than 75% of 2017 GDP) and USD 16 trillion for fuel costs (Figure 20.13) (EIA, 2018q). Of the capital investments, 42% is allotted to energy supply and 23% to electricity (i.e. power plants) and heating. The remainder is earmarked for demand-side improvements in buildings (26%) and transportation (8.4%) to meet higher energy efficiency requirements under existing policies. Spending on fuel goes overwhelmingly to the transport sector, which claims 63%, and buildings receive 20%.

Cumulative capital investments are USD 2.7 trillion higher under the TGT than in the BAU, and USD 2.6 trillion higher in the 2DC. These increases are predominately for energy efficiency investments in the buildings sector, to adopt energy efficient appliances and improve building envelopes. Conversely, less investment is directed towards the transport sector in the TGT and 2DC than in the BAU because of less need for conventional fuelling infrastructure (e.g. gasoline stations). This decrease is partially offset by increased investment in EV charging stations, however. Electricity sector investments fall slightly from USD 3.8 trillion in the BAU to USD 3.7 trillion in the TGT and USD 3.4 trillion in the 2DC, because demand is lower.

Additional capital investments in the TGT and 2DC are counterbalanced by fuel cost savings resulting from increased energy efficiency and fuel switching (e.g. from oil products to electricity). In the TGT, total fuel cost savings amount to USD 3.0 trillion, outweighing the additional USD 2.7 trillion in capital investments. Fuel cost savings in the 2DC reach USD 5.5 trillion—more than double the additional capital investment of USD 2.6 trillion. This highlights the cost-effectiveness of many energy efficiency investments.

Figure 20.13 · United States: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

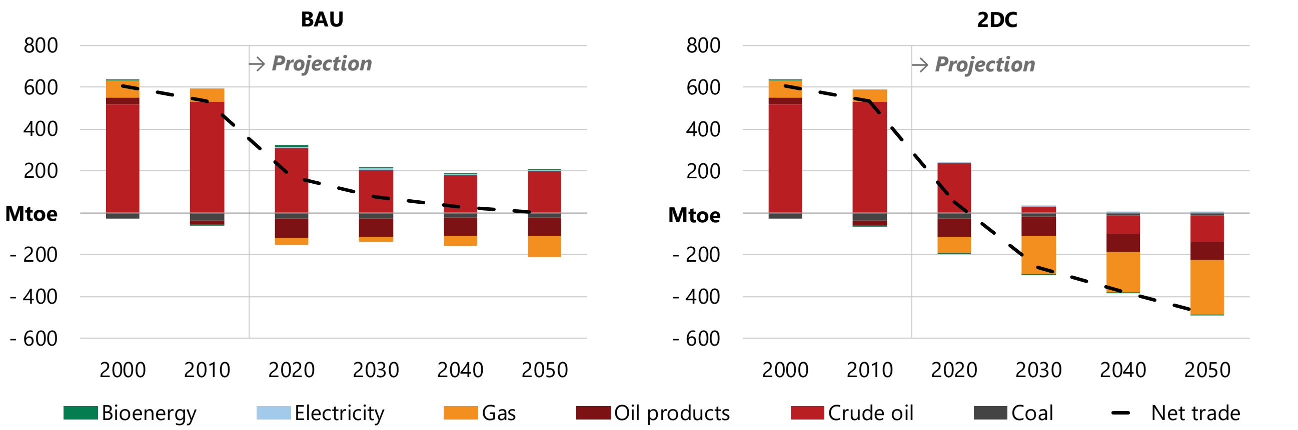
[107] A more detailed description of the investment boundaries is provided in the Annex I Investment Methodology section.

ENERGY TRADE AND SECURITY

The US energy system is highly integrated with those of its neighbours. In 2016, energy accounted for 5.2% of the value of all exports to Canada and 19% of the value of all imports from Canada (EIA, 2017b). The United States imports mostly crude oil from Canada, moving it from Alberta to the Midwest and Gulf Coast regions for subsequent refining. In 2016, the United States imported 161 Mtoe (3.3 Mbbl per day) of crude oil from Canada, and exported 29 Mtoe (576 000 bbl per day) of refined petroleum products to Canada (EIA, 2017b and 2018m). More than half of US gasoline exports are currently sent to Mexico, where fuel market changes and low refinery utilisation rates have boosted demand for imports in recent years. In 2017, exports of finished motor gasoline to Mexico were 21 Mtoe (425 000 bbl per day) (EIA, 2018m and 2018p).

The United States is currently a net exporter of both coal and natural gas, and remains so until 2050 in all three scenarios. Net crude oil imports decrease in the TGT and 2DC as domestic production rises in tandem with efficiency gains, particularly in transport. In the BAU, the United States remains a net importer of fossil fuels until 2043, but in the TGT it becomes a net exporter by 2026 and in the 2DC by 2022 (Figure 20.14).

Figure 20.14 · United States: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Although the United States is self-sufficient in coal and natural gas, it does not produce enough oil to meet its own needs in the BAU (Table 20.5). Oil self-sufficiency improves over time, however, as production expands and demand declines in all three scenarios. As a result, the United States has decided to reduce its crude oil reserve by nearly 40% by 2028 (see Volume 1, Box 8.1). Some of the sales revenue will be used to modernise the oil reserve. Even after this cut, the Strategic Petroleum Reserve is projected to hold more than 100 days' worth of net crude and oil product imports in 2028.

As might be expected from the world's largest coal reserve holder, in 2016 the United States had enough coal reserves to meet all its needs in all three scenarios. Gas reserves are almost sufficient, but more oil reserves need to be discovered to reduce the reserve gap in the BAU Scenario. Even though the United States has only 11 or 12 years of oil and gas reserves at current levels of production, resources are constantly being converted into reserves. If all known oil and gas resources were converted into reserves, the United States would have more than 50 additional years of oil production at the 2016 level, and more than 80 of natural gas (EIA, 2018f).

Table 20.5 · United States: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	87	100	100	100	100	100	100
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Gas self-sufficiency (%)	96	100	100	100	100	100	100
Crude oil self-sufficiency (%)	59	90	100	100	97	100	100
Primary energy supply diversity (HHI)	0.26	0.27	0.26	0.24	0.27	0.24	0.25
Coal reserve gap (%)	4	42	41	39	90	87	51
Gas reserve gap (%)	8	152	148	144	395	379	367
Crude oil reserve gap (%)	11	198	198	198	511	511	511

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (i.e. greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.
Sources: APERC analysis and IEA (2018a).

SUSTAINABLE ENERGY PATHWAY

At the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement', in 2015, the United States submitted its Intended Nationally Determined Contribution (INDC) and Mid-Century Strategy outlining the economy's intended actions to meet its commitments. The INDC, which reflects policy action to support agreement reached during COP21 was subsequently converted into the economy's first NDC in September 2016.[108] The US NDC, which pledges to reduce greenhouse gas (GHG) emissions 26% to 28% below the 2005 level by 2025, would cut emissions from fossil fuel combustion to between 4 109 $MtCO_2$ and 4 223 $MtCO_2$ in 2025.

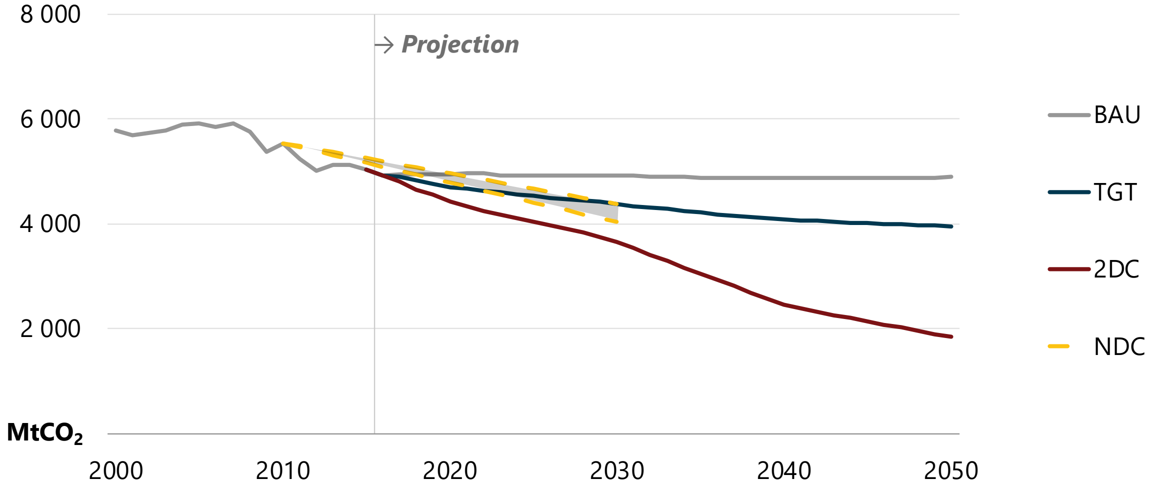
The 2DC models one of the pathways the United States could follow to support a global energy transition and mitigate climate change by reducing GHG emissions; it well exceeds the economy's non-binding NDC commitments. The 2DC pathway for the United States is part of APEC-wide efforts to reduce total emissions in line with the cost-optimised emissions reduction pathway charted in the IEA's global 2°C Scenario (IEA, 2017a).

Emphasising early action to reduce the overall cost of transitioning to low-carbon energy resources, the primary goal of the 2DC is to reduce GHG emissions. Deeper CO_2 emissions reductions can be achieved in transport, buildings and industry through improved energy efficiency and greater electrification in all demand sectors, as well as wider use of low-carbon resources to generate electricity. Some behavioural changes in the transport sector and service buildings subsector,[109] and the use of CCS technologies after 2035 in industry, electricity generation and refining, also significantly reduce emissions. More details on the 2DC methodology are included in Annex I.

To help APEC meet its emissions reduction goals, total US CO_2 emissions drop 63% under the 2DC, from 4 903 $MtCO_2$ in 2016 to 1 807 $MtCO_2$ in 2050 (Figure 20.15). Emissions from coal use decrease significantly (by 96%), as do those from oil (-64%) and natural gas (-26%). The deepest reductions result from changes in buildings and domestic transport.

[108] On 1 June 2017, however, President Donald Trump announced his intention to withdraw from the COP21 Paris Agreement and begin negotiations to re-enter the Agreement under a set of 'terms that are fair to the United States, its businesses, its workers, its people, [and] its taxpayers' (The White House, 2018). The United States is eligible to withdraw from the Agreement on 5 November 2020.
[109] In the service buildings subsector, the 2DC assumes a 0.82% increase in total floor area (compared with 25% expansion in the BAU and TGT). In transport, total passenger-kilometres travelled grows more slowly with shifts in travel modes and more people teleworking. See Annex I for more details.

Figure 20.15 · United States: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Notes: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

OPPORTUNITIES FOR POLICY ACTION

Differences in the BAU and TGT GHG emissions profiles illustrate the value in increasing support for energy efficiency and renewables throughout the energy system. Although the United States has already taken significant measures to support greater energy efficiency (e.g. through energy efficiency standards for buildings and labelling programs for appliances) and the use of renewables (e.g. through biofuels mandates and renewable portfolio standards), these programs could be expanded and strengthened.

Scenario results indicate considerable opportunities to continue developing and expanding efficiency standards for building appliances and transport, including the CAFE standards already in place. Efforts should particularly emphasise fuel economy standards for heavy-duty trucks, given that they account for 38% of road vehicle FED in 2050 in the BAU (up from 29% in 2016). For passenger transport, consumer trends favouring light-duty trucks (e.g. crossover vehicles and SUVs) suggest that early action should be taken to increase fuel economy in these vehicles.

In the TGT, the United States achieves its NDC commitments but does not meet its mid-century goals, indicating that greater focus should be placed on opportunities to reduce GHG emissions. As shown in the 2DC, numerous options exist to support decarbonisation through energy efficiency measures, fuel switching (including increased electrification) and further decarbonisation of the electricity system. Given the abundance of renewable energy resources in the United States, coupled with the availability of inexpensive natural gas and a highly interconnected transmission grid system, this economy has all the tools it needs to hasten electricity sector decarbonisation. Faster decarbonisation would also boost the economy's energy self-sufficiency and make more resources available for export, as demonstrated under the TGT and 2DC Scenarios—both of which model the United States becoming a net exporter of fossil fuel resources.

21. VIET NAM

KEY FINDINGS

- **FED per capita is similar to other south-east Asian economies but lower than the APEC average.** Viet Nam's FED doubles over the Outlook period in the BAU. Industry remains the largest sector, but domestic transport expands the most, demonstrating the second-largest FED by 2050.

- **Viet Nam became a net energy importer in 2015.** Energy production remains at 69 Mtoe to 80 Mtoe per year but demand surges, causing net imports to continue expanding (to 94 Mtoe in 2050 in the BAU, 64 Mtoe in the TGT and 31 Mtoe in the 2DC).

- **The power sector expands rapidly in the medium term, but capacity remains quite flat after 2035.** Cost-effective coal-fired generation is the first choice for long-term power supply under the BAU.

- **Renewable energy, especially solar and hydropower, contributes greatly to a greener economy when coal is phased out.** In the 2DC, renewables account for 63% of electricity generation capacity in 2050.

- **Investment costs are lowest in the 2DC owing to significantly lower fuel expenditures.** The 2DC investment of USD 1 363 billion is only 87% of the TGT investment requirement and 82% of the BAU.

- **Greater effort to achieve CO_2 emissions reduction targets is needed, including to secure international support.** In the BAU, CO_2 emissions increase by 2.5 times. The TGT scenario realises the NDC's highest reduction rate of 25% although emissions keep growing, while the 2DC achieves a slight decrease over the Outlook period.

ECONOMY AND ENERGY OVERVIEW

Viet Nam is an S-shaped economy located in the centre of south-east Asia, sharing borders with China, Laos, and Cambodia, and waters with Chinese Taipei, the Philippines, Malaysia, Indonesia and Thailand. Viet Nam covers 331 231 square kilometres (km^2) and has a population of 95 million, making it the 8th most populous economy in the Asia-Pacific Economic Cooperation (APEC) region. Located in a tropical monsoon zone and profoundly affected by the East Sea (Bien Dong), Viet Nam has warm weather, abundant solar radiation, high humidity and generous seasonal rainfall.

As a dynamic emerging economy, Viet Nam's gross domestic product (GDP) reached USD 589 billion in 2016, with growth rates ranging from 5% to 7% per year since 2000. Over the past 30 years, Viet Nam has transformed from the centrally planned economy of 1986 to its current open, socialist-oriented market economy with active international integration. In 2050, GDP per capita increases to USD 24 599, nearly half of the APEC average (Table 21.1). Major exports include electronics, machinery, textiles, garments and footwear. Crude oil has been an important but decreasing export in the past few years. Viet Nam has been importing most of its petroleum since 2009 (Viet Nam Customs, 2017). Because energy demand has risen along with GDP, population and income growth, Viet Nam became a net energy importer in 2015.

Table 21.1 • Viet Nam: Macroeconomic drivers and projections, 2000-50

	2000	2010	2016	2020	2030	2040	2050
GDP (2016 USD billion PPP)	219	416	589	741	1 218	1 923	2 820
Population (million)	80	88	95	98	106	111	115
GDP per capita (2016 USD PPP)	2 734	4 703	6 229	7 537	11 456	17 292	24 599
APEC GDP per capita (2016 USD PPP)	13 548	18 615	22 536	25 659	34 200	44 787	56 218
Total primary energy supply (Mtoe)	29	59	79	93	121	143	169
TPES per capita (toe)	0.36	0.66	0.84	1.0	1.1	1.3	1.5
APEC TPES per capita (toe)	2.3	2.7	2.8	2.8	2.9	3.0	3.2
TPES per GDP (toe per 2016 USD million PPP)	131	141	135	126	100	75	60
APEC TPES per GDP (toe per 2016 USD million PPP)	168	147	123	111	85	67	56
Final energy demand (Mtoe)	25	48	65	73	92	110	128
FED per capita (toe)	0.31	0.55	0.69	0.75	0.87	1.0	1.1
APEC FED per capita (toe)	1.5	1.8	1.9	1.9	1.9	2.0	2.1
FED per GDP (toe per 2016 USD million PPP)	114	116	110	99	76	57	45
APEC FED per GDP (toe per 2016 USD million PPP)	112	95	83	74	57	45	38
Energy-related CO_2 emissions ($MtCO_2$)	43	127	189	226	302	365	459
APEC energy-related CO_2 emissions ($MtCO_2$)	14 421	20 033	20 694	20 891	21 152	21 586	21 917
Electrification rate (%)	86	98	98	99	99	99	99

Notes: PPP = purchasing power parity. TPES = total primary energy supply. toe = tonnes of oil equivalent. FED = final energy demand. Mtoe = million tonnes of oil equivalent. $MtCO_2$ = million tonnes of carbon dioxide. Energy projections are for the BAU; identical GDP and population projections are used across all three scenarios. GDP is measured in USD billion at the 2016 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2016 USD PPP. GDP projections in this Outlook are made by APERC (see Methodology in Annex I) and are lower than the domestic results of the General Statistics Office of Viet Nam.
Sources: APERC analysis, IEA (2018a), IPCC (2018), OECD (2018), UN DESA (2018) and World Bank (2018a and 2018b).

The energy sector is important for attracting foreign investment, boosting industry growth and export earnings, and developing science and technology. However, in recent years, priority has shifted to meeting domestic demand, particularly for electricity, due to rising demand and the increasing electrification rate. Any developments in the sector should be in line with the green growth strategy of following the emission reduction and environment protection goals (PMVN, 2012a).

Viet Nam's first Nationally Determined Contribution (NDC) to the COP21 Paris Agreement (adopted in 2016)[110] aims to reduce greenhouse gas (GHG) emissions in 2030 by 8%, compared with a business-as-usual projection of 787 million tonnes of carbon dioxide ($MtCO_2$) for the same year from sectors including energy, agriculture, waste, and LULUCF (land use, land use change and forestry).[111] Conditional on receiving international support, Viet Nam has also set a more ambitious 25% reduction target (GOVVN, 2016a). With energy-related emissions of 187 $MtCO_2$ in 2016, Viet Nam accounted for only 0.91% of total APEC CO_2 emissions.

ENERGY RESOURCES

Viet Nam is endowed with diverse energy resources, including oil, natural gas, coal and renewables. Although a thorough assessment of resources is yet to be carried out across the entire economy (especially in deep layers and deep-sea areas), proved fossil energy reserves at the end of 2016 included 4.4 billion barrels (bbl) of oil, 650 billion cubic metres (bcm) of natural gas and 3 360 million tonnes (Mt) of coal (Table 21.2). Given its significant proved resources, Viet Nam's coal industry and export activities have a long history. Since 2011, however, exports have been declining because the government has been prioritising long-term domestic use of coal. Domestic production of oil and natural gas is also decelerating, while natural gas and liquefied natural gas (LNG) imports are now being promoted (PMVN, 2017a). Several thousand tonnes of identified recoverable uranium resources also exist in Viet Nam, but they have yet to be developed (NEA, 2018).

Table 21.2 • Viet Nam: Energy reserves and years of production, 2017

	Proved reserves	Years of production	Share of world reserves (%)	Global ranking reserves	APEC ranking reserves
Coal (Mt) [a]	3 360	88	0.32	19	8.0
Oil (billion bbl) [a]	4.4	36	0.26	25	6.0
Natural gas (tcm) [a]	0.65	68	0.33	29	8.0

Notes: Mt = million tonnes. bbl = barrels. tcm = trillion cubic metres. Reserves are classified as proved, which refers to amounts that can be recovered with reasonable certainty from known reservoirs under existing economic and operating conditions.
Source: BP (2018).

Viet Nam's economic and technical potential for hydropower is estimated at 95 terawatt-hours (TWh) to 100 TWh per year, or 25 gigawatts (GW) (APERC, 2016) to 31 GW (domestic estimate). The government is strongly promoting the development and deployment of other renewables within the next 15 years, including wind, solar, biomass and municipal solid waste (MSW). Potential capacity for solar power is 12 GW, followed by wind (6 GW) and biomass (2 GW), while MSW potential is 320 megawatts (MW) (PMVN, 2016b).

ENERGY POLICY CONTEXT AND RECENT DEVELOPMENTS

The Ministry of Industry and Trade (MOIT), formed in 2007, oversees the entire energy sector. Three bodies in charge of formulating law, policy and planning for each energy industry fall under its remit: the Authority of Electricity and Renewable Energy; the Department of Energy Efficiency and Sustainable Development; and the Department of Oil, Gas and Coal.[112] The Electricity Regulatory Authority of Viet Nam (ERAV) administers

[110] NDCs reflect policy action to support the agreement reached during the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), referred to as the 'COP21 Paris Agreement'.
[111] The NDC is being revised by the Ministry of Natural Resources and Environment (MONRE) in May 2019, with emissions likely to increase due to the inclusion of industrial processes (according to the first draft released in August 2018). The Ministry of Industry and Trade (MOIT) is also developing an NDC specifically for the energy sector.
[112] Prior to the formation of these three departments, from 2011-17 the General Directorate of Energy (GDE, also under MOIT) was responsible for all energy issues. The GDE was disbanded following MOIT restructuring in August 2017.

regulatory activities for electricity to ensure its safe and high-quality supply. The Institute of Energy is responsible for carrying out energy research, forecasting activities, and power and development plans.

The 2007 *National Energy Development Strategy to 2020, with a Vision to 2050* (PMVN, 2007) is still up to date and guides energy policy. Another energy development plan for 2016-25, which will update many of the specific goals and present newer sectoral planning, is currently under review but is unlikely to change the key objectives already established. The key areas earmarked for development in Viet Nam's energy sector are summarised in Table 21.3 • .

Viet Nam's most recent five-year socioeconomic development plan sets a GDP growth target of around 6.5% per year to 2020 (NAVN, 2016), similar to recent growth of 6.2% in 2016 and 6.8% in 2017. As well as boosting imports beyond 2020, Viet Nam will continue to develop domestic fossil fuel resources to meet increasing domestic energy demand driven by economic growth. As oil production continues to decline, domestic demand remains a priority, particularly in the power sector. In the *Revised Power Development Master Plan for 2011-2020* (Revised PDP7) published in 2016, coal is important in the power sector, accounting for 43% of capacity and a 53% share of power generation in 2030. In November 2016, the government decided to halt construction of two nuclear power plants (GOVVN, 2016b), meaning that by 2030 nuclear energy makes no contribution to generation even though a target was set in the Revised PDP7.

Table 21.3 • Viet Nam: Key energy policy sector targets

Economic plan (NAVN, 2016)	6.5% to 7% CAGR during 2016-20. GDP in 2020: USD 3 200 to USD 3 500 per capita. Urbanisation rate: 38% to 40%. Energy intensity reduction: 1.0% to 1.5% per year.
Oil (PMVN, 2015a)	Increase annual petroleum reserves to 25-30 Mtoe during 2016-20 and to 20-28 Mtoe during 2021-30. Annual crude oil production: 10-15 Mt in 2016-20 and 5-12 Mt in the 2021-35 period.
Natural Gas (PMVN, 2017a)	Natural gas: produce 11-15 bcm per year by 2020, 13-27 bcm per year by 2025 and 23-31 bcm per year by 2030. LNG: import 1-4 bcm per year in 2020-25 and 6-10 bcm per year by 2035.
Coal (PMVN, 2016a)	Production capacity to reach 47-50 Mt per year by 2020, 51-54 Mt per year by 2025 and 55-57 Mt per year by 2030. Reduce coal losses to 20% (underground) and 5% (open-cut) by 2020 and maintain at these levels or below thereafter.
Electricity (PMVN, 2016b)	Combined electricity production and imports: 265-278 TWh in 2020, 400-431 TWh in 2025 and 572-632 TWh in 2030. Power capacity share in 2030: 21% renewables, 43% coal, 17% hydropower including pumped storage, 15% gas including LNG, 3.6% nuclear[113] and 1.2% imports. Electrification in rural areas approaches 100%.
Renewables (PMVN, 2015b)	Renewables supply: 37 Mtoe by 2020, 62 Mtoe by 2030 and 138 Mtoe by 2050. Renewables share in power generation mix: 38% by 2020, 32% by 2030 and 43% by 2050.
Energy security (PMVN, 2017b)	Oil stockpiling (including crude oil and petroleum products) adequate for 90 net-import days by 2020.
Climate change (GOVVN, 2016a)	GHG emissions: 8% reduction compared with business-as-usual, i.e. 474 $MtCO_2$ by 2020 and 787 $MtCO_2$ by 2030. Sectors involved: energy, agriculture, waste and LULUCF sectors (not including industrial processes).

Notes: CAGR = compound annual growth rate. Mtoe = million tonnes of oil equivalent. bcm = billion cubic metres. LNG = liquefied natural gas. Mt = million tonnes. TWh = terawatt-hours. GHG = greenhouse gas. $MtCO_2$ = million tonnes of carbon dioxide. Mtoe = million tonnes of oil equivalent. LULUCF = land use, land use change and forestry.

[113] All nuclear power development plans were halted in 2016, but the official amendment on this share is not yet available. Primarily coal, natural gas and renewables are expected to fill the 3.6% gap by 2030.

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy demand and supply assumptions for Viet Nam under the Asia Pacific Energy Research Centre (APERC) Business-as-Usual (BAU) Scenario, which reflects current trends and relevant policies already in place or planned (Table 21.). Definitions used in this Outlook may differ from government targets and goals published elsewhere, including those covered in Table 21.4.

Table 21.4 • Viet Nam: Key assumptions and policy drivers under the BAU

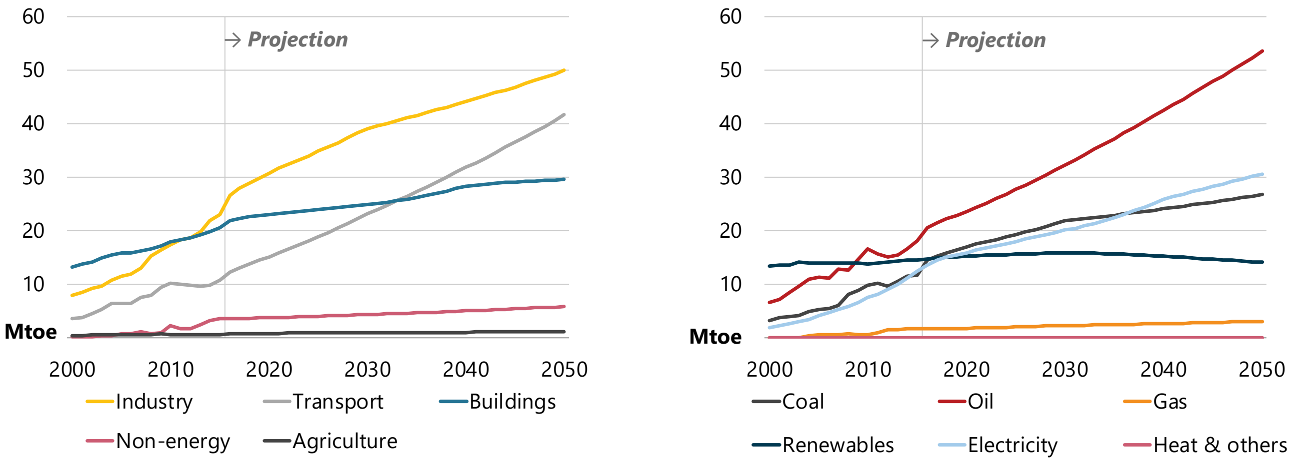
Buildings	Economic growth and urbanisation stimulate demand for appliances and electricity use in buildings.
Industry	Industry remains the backbone of the economy and continues to be dominated by iron and steel as well as cement.
Transport	Energy elasticity linked to GDP is consistent with the base year's fuel mix. Biodiesel not yet introduced. Vehicle stock continues to rise.
Energy supply mix	Coal and natural gas production targets follow sectoral development plans. Projects for LNG terminals come to fruition. Oil production is based on historical and available reserves.
Power mix	Power mix based on optimisation and capacity, with data from the Revised PDP7.
Renewables	Less use of biomass, which is burnt in an inefficient way but remains the main renewable resource in power.
Energy security	Extra energy imported when domestic demand cannot be met.
Climate change	The NDC, which aims to reduce GHG emissions by 8% to 25% compared with domestic business-as-usual projections, is not achieved.

Notes: Revised PDP7 = Revised Power Development Master Plan for 2011-2020. NDC = Nationally Determined Contribution. LNG = liquefied natural gas. GHG = greenhouse gas. This table summarises the main policies of the BAU Scenario; it is not intended to be a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Viet Nam's final energy demand (FED) increased at a compound annual growth rate (CAGR) of 6.1% in the period 2000-16 to reach 65 Mtoe. In the BAU, it rises to 128 Mtoe in 2050 at a CAGR of 2.0%. Energy efficiency measures, coupled with lower population and GDP growth, help curb energy demand growth over the Outlook period (2016-50). Industry is the highest-consuming sector through the Outlook, accounting for 41% of FED in 2016 and 39% in 2050 (Figure 21.1Figure 21.1). Energy consumption in buildings, including residential and services, accounts for the second-largest share in 2016 (34%) but is overtaken by fast-growing transport consumption in 2050 (23%). At a CAGR of 3.7%, demand for domestic transport rises twice as quickly as for industry and quadruples that of buildings, for a 33% share in 2050 (from 19% in 2016). Final energy intensity per GDP steadily decreases year on year, from 110 tonnes of oil equivalent (toe) per million USD in 2016 to 45 toe per million USD in 2050, much closer to the APEC average (38 toe per million USD).

Figure 21.1 • Viet Nam: Final energy demand by sector and fuel, 2000-50

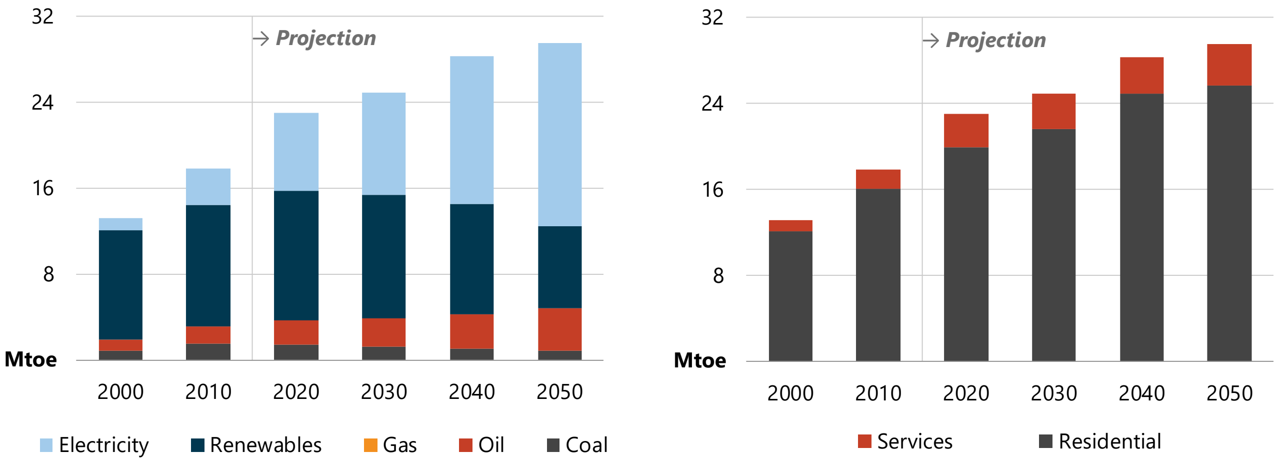


Sources: APERC analysis and IEA (2018a).

BUILDINGS AND AGRICULTURE: ELECTRICITY TO REPLACE TRADITIONAL BIOMASS

Energy demand in Viet Nam's buildings sector has increased rapidly over the past decade, in line with rising GDP per capita. A number of energy efficiency policies, such as the two phases of the Viet Nam National Energy Efficiency Program (VNEEP), have sought to curtail the rise. In the BAU, the share of electricity increases significantly (3.1% CAGR) from 28% in 2016 to 58% in 2050 (Figure 21.2). Viet Nam shifts from traditional fuels (such as coal and biomass) to electricity thanks to a high economy-wide electrification rate of 99%, which is driven by continued urbanisation. In the residential sector, 4.4 Mtoe of renewables—mostly traditional biomass—gradually disappear from the fuel mix, especially after 2025, as consumers move away from burning wood, straw, husks and bagasse for cooking and heating. The use of solar water heaters increases slightly by 2020 but does not keep pace to the end of the period because of limited roof space and demand.

Figure 21.2 • Viet Nam: Buildings final energy demand by fuel and subsector, 2000-50



Sources: APERC analysis and IEA (2018a).

In the residential sector, cooking accounts for the largest share of energy demand (45% in 2016), but the share decreases towards 2050 (29%) as more energy-efficient devices come onto the market (e.g. electric and liquefied petroleum gas [LPG] stoves) in rural areas. Energy demand for space cooling rises sharply towards the end of the Outlook period (CAGR of 5.2% during 2030-50), due partly to the climate and to rising incomes. The use of residential appliances such as televisions, refrigerators and washing machines remains stable, with electricity the only source of power.

In services, replacing fluorescent light bulbs with LED lamps in public areas curbs demand by 0.26% per year to 2050. Other end-uses, including a wide range of appliances such as elevators, freezers and equipment used in diverse facilities (e.g. cinemas, hospitals, restaurants), continue to grow in quantity and hence consume increasing amounts of energy, keeping pace with economic development. Of the 2.2 Mtoe used in 2050, 70% comes from electricity and the rest from petroleum products (mainly LPG).

The VNEEP Phase Two 2012-15 (PMVN, 2012b) mandates energy saving standards in large new builds and renovations. Energy saving solutions (e.g. technology, equipment and materials) and efficient public lighting are particularly promoted, and competitions for green energy-saving buildings are also organised under the VNEEP. The National Technical Regulation on Energy Efficiency Buildings, or the Energy Efficiency Building Code (MOC, 2017), sets out mandatory technical standards for energy efficiency in the design, construction and renovation of public buildings with a surface area of 2 500 square metres or larger (e.g. offices, hotels, hospitals, schools, commercial services buildings and apartment blocks). According to the draft of VNEEP Phase Three for 2019-2030, all new and renovated buildings must conform to the Building Code. If Phase Three had been brought forward and the Building Code issued earlier, energy demand reductions in buildings would be greater over the Outlook period. [114]

Energy demand in agriculture and non-specified sector was quite modest in 2016, at only 0.72 Mtoe after having increased steadily in the preceding decades. Under government agricultural and rural industrialisation goals (PMVN, 2014), it rises at a CAGR of 1.2% over the Outlook period. Oil (68% in 2050) and electricity (22%) continue to be the most widely consumed sources, largely due to accelerated mechanisation and automation in rural areas.

INDUSTRY: COAL STILL DOMINATES FUEL DEMAND IN THE LONG TERM

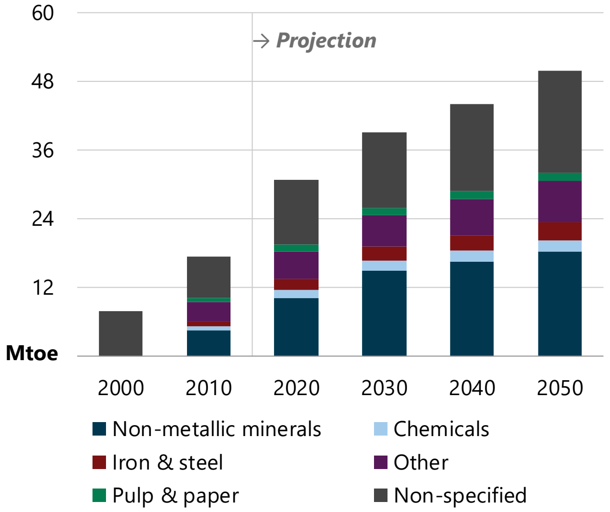
During the Economic Reforms of 1986 (Doi Moi), the year 2020 was set as the initial milestone for Viet Nam to become an industrialised and modernised economy. This target was reaffirmed in 2016, but without a specific year for completion (CPV, 2016). Industry becomes a key driver of GDP growth to 2035, led by the processing and manufacturing, electronics and telecommunications, and renewable energy subsectors (PMVN, 2014).

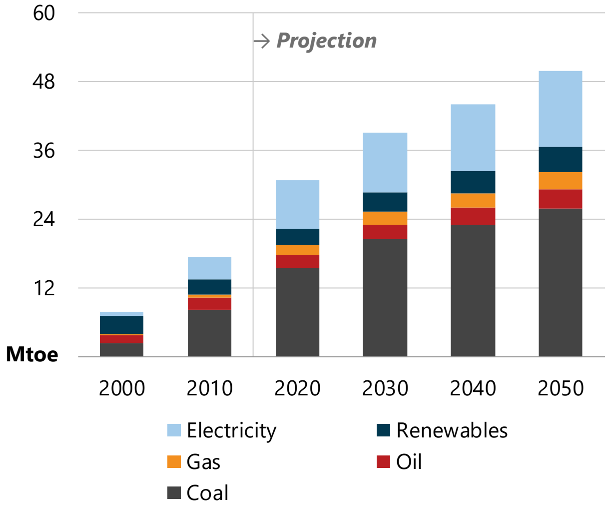
In the BAU, energy demand in industry rises 88% from 27 Mtoe in 2016 to 50 Mtoe in 2050 (Figure 21.3). Coal demand increases the fastest at a 2.1% CAGR, as it is the primary fuel used for the most energy-intensive and fastest-growing industries: non-metallic minerals[115] (77% in 2016), and iron and steel (40% in 2016). The share of coal remains stable during the Outlook period, accounting for roughly half of industry FED. Available technologies and cost implications constrain Viet Nam's capacity to shift away from coal, making the sector very difficult to decarbonise.

Electricity is the second most important fuel in industry both by share (28% in 2016) and growth rate (1.8% CAGR). It is used in all subsectors in 2050, but mostly in non-metallic minerals (3.8 Mtoe), iron and steel (1.4 Mtoe), and pulp and paper (0.87 Mtoe). The processing and textile industries, categorised within 'others' subsector, contribute significantly to Viet Nam's economy and also consume high volumes of electricity. The share of oil decreases over time (from 7.6% to 6.8%), as does that of natural gas (6.0% to 5.8%), although their combined volume increases slightly to 6.3 Mtoe in 2050 (from 3.6 Mtoe in 2016). The share of renewable energy in industry also shrinks slightly (from 10% in 2016 to 9.0% in 2050) despite also growing modestly.

[114] On 13 March 2019, Decision No. 280/QD-TTg approved VNEEP 3. While this development and related circulars (such as 52/2018/TT-BCT) affect energy efficiency in many sectors, it occurred after the completion of drafting and model runs for the Outlook.
[115] Including the cement, ceramic and glass industries.

Figure 21.3 • Viet Nam: Industry final energy demand by subsector and fuel, 2000-50





Sources: APERC analysis and IEA (2018a).

The government has been working to promote energy efficiency improvements in industry. The VNEEP Phase Two (2012-15) stipulated that energy-intensive industries (such as steel, cement, and textiles and apparel) should reduce energy consumption by 10% (PMVN, 2012b). Mandatory energy labelling, a program of standardisation and other technical assistance will also help phase out low-performance equipment. The Clean Production and Energy Efficiency Project 2011-17 (CPEE), funded by the Global Environment Facility (GEF) and the World Bank, helped issue four circulars providing instructions and energy saving measures that can be applied in industrial production, including in some specific subsectors such as chemicals, beverages, plastics, and pulp and paper.[116] Since the CPEE, Viet Nam has continued to invest significantly in energy-efficient industrial processes, even launching a USD 158-million follow-up program, two-thirds of which is funded by the World Bank (World Bank, 2018c).

TRANSPORT: DEMAND FOR FOSSIL FUELS RISES QUICKLY

Viet Nam's transport FED is dominated by domestic demand (88% in 2016 and 85% in 2050); the rest is oil used in international aviation and maritime transport. Domestic transport demand was a moderate 12 Mtoe in 2016—not even half the volume used in industry. During the Outlook period, however, domestic transport demand increases sharply (3.7% CAGR), which is double the rate of industry and four times that of the buildings sector. Road transport accounts for almost all (97%) of domestic transport energy demand throughout the period. Aviation grows rapidly (CAGR of 4.5% for international and 3.7% for domestic demand) as Viet Nam aims to position itself among the top four Association of Southeast Asian Nations (ASEAN) economies in terms of aviation activities by 2030. The government forecasts a 16% growth in passenger services in the 2015-20 period, and a further 8% rise in 2020-30 (PMVN, 2018). Rail and pipeline transport exist in Viet Nam but have not been included in this Outlook as fuel consumption data are not available. Diesel is currently the main fuel used in rail transport, but Viet Nam plans to introduce electric trains (PMVN, 2015c).

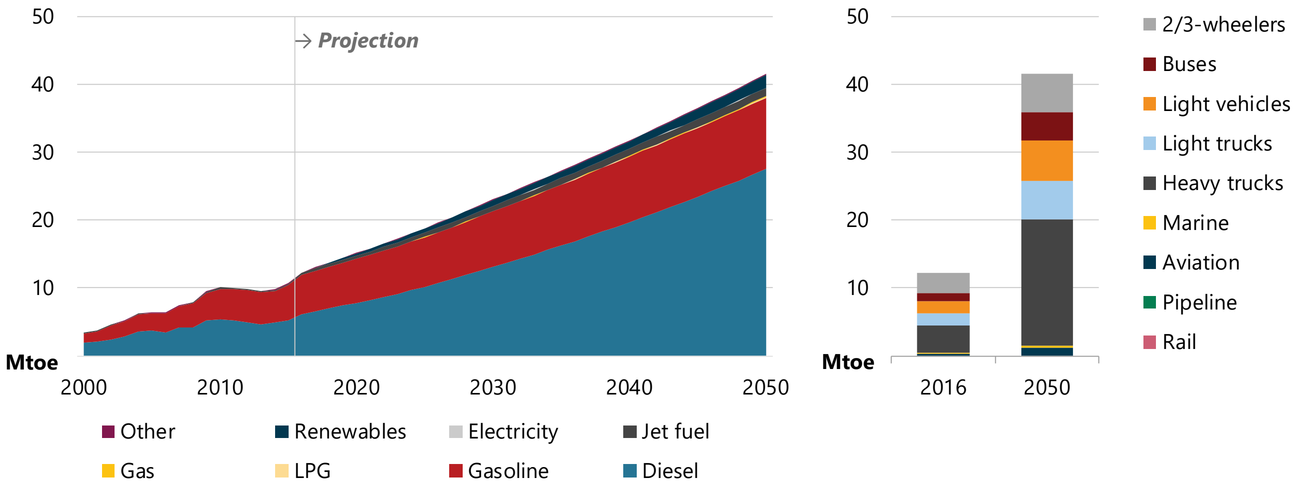
Energy demand in road transport increases 2.4 times (3.6% CAGR) over the Outlook period, reaching 40 Mtoe (Figure 21.4). Demand for domestic freight transportation increases rapidly, resulting in heavy-duty truck (HDT)

[116] Circular Nos. 02/2014/TT-BCT, 19/2016/TT-BCT, 38/2016/TT-BCT and 24/2017/TT-BCT.

energy demand growing fastest (4.6% CAGR), followed by buses (3.7% CAGR). Passenger cars of four to seven seats (light-duty vehicles [LDVs]) become the second-largest energy consumer after HDTs by 2050 (at 6.0 Mtoe).

Motorcycles and tricycles (2/3-wheelers) are currently the most widely used form of domestic road transport (91% of all vehicles) and are the second-largest energy consumers after HDTs (25% of road transport in 2016), but they are overtaken by LDVs after 2040. Roughly one in two people currently owns a motorcycle, meaning the economy's major cities (Ha Noi and Ho Chi Minh City) suffer from heavy traffic, a high risk of accidents and high levels of air pollution. Energy inefficiency and pollution are further exacerbated by an unreported number of outdated engines that should no longer be in operation.

Figure 21.4 • Viet Nam: Domestic transport final energy demand by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

According to the latest plans for road transport, Viet Nam is trying to control the rise of personal modes of transport by limiting motorcycles to 36 million and small passenger cars to 2 million (PMVN, 2013).[117] Realistically, this is not feasible under the BAU. The number of 2/3-wheelers already reached 60 million in 2016 and is set to double over the Outlook period. Strong growth in GDP per capita, better infrastructure and rising demand for enclosed vehicles to protect against frequently changing weather lead to more family-sized cars on the roads (up to 9.2 million) by 2050. To ease traffic congestion from private vehicles, government policy seeks to improve public transport and quickly develop the bus network (PMVN, 2013). The number of buses increases at a CAGR of 4.7% to reach 1.3 million units in 2050.

Fossil fuels remain dominant in road transport to 2050 (95%). The government roadmap to mandate the fuel mix of A92 gasoline and at least 5% bioethanol (PMVN, 2012c),[118] coupled with the compulsory energy labelling program for LDVs and motorcycles (PMVN, 2017c), stimulates the use of a small amount of renewables (4.6%) and electricity (minor) in the transport fuel mix by 2050.

RECENT TRENDS AND OUTLOOK FOR ENERGY TRANSFORMATION AND SUPPLY

Viet Nam's transformation sectors have traditionally been dominated by plentiful domestically available hydro and coal resources. As the economy grows, this is projected to change with increasing liquid fuel demand resulting in greater refinery capacity and hence higher crude oil use. Gas is also being promoted to diversify the

[117] Many of the targets in this development plan are already obsolete.
[118] Regular unleaded gasoline with Research Octane Number (RON) 92.

electricity supply mix. These changes are reflected in total primary energy supply (TPES) and trade, but not in primary energy production, for which coal and renewables remain dominant.

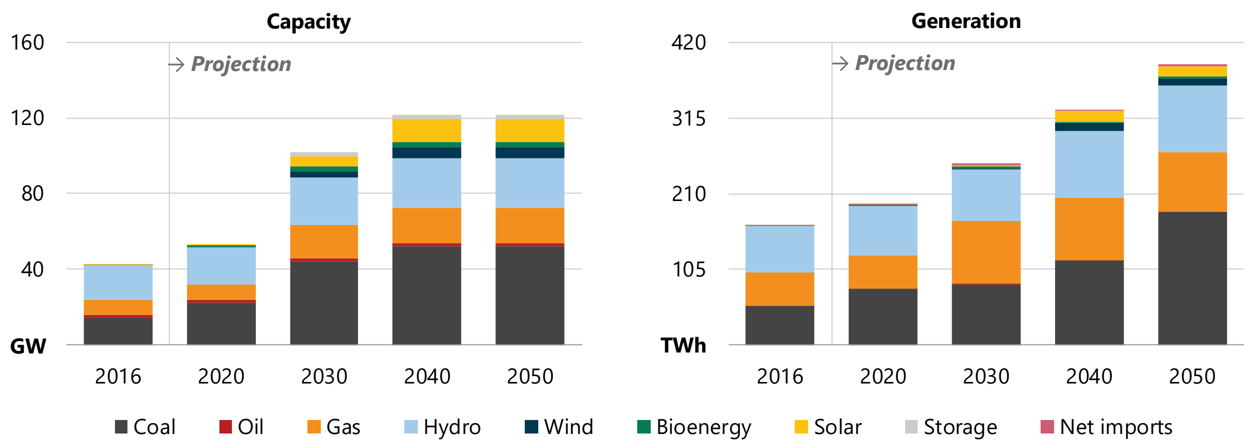
POWER SECTOR TRENDS: OVERCAPACITY AFTER 2030

Although the electricity grid is interconnected across the economy, it is mainly centred on supplying Hanoi in the north and Ho Chi Minh City in the south. Electricity Viet nam (EVN) is the state-owned corporation responsible for most power generation, transmission, distribution and supply activities (up to 61% in 2016). Hydropower generated from numerous dams, particularly in the north and central highlands, has traditionally been the main source of electricity. Coal reserves in the north, and oil and natural gas fields in the south, also provide significant energy resources.

Electricity generation more than doubles in 2016-50 under the BAU, from 165 TWh to 388 TWh (2.5% CAGR). By 2050, 80 GW of new power capacity are added, bringing the total to 122 GW. Affordable coal-fired power is the first choice in the long term, reflecting the construction of additional coal-fired plants with an extra 38 GW of capacity by 2035. The dominance of coal in the power mix will further exacerbate local air pollution and energy-related carbon dioxide (CO_2) emissions problems. To help mitigate environmental and efficiency issues, only modern supercritical (SC) or ultra-supercritical (USC) plants will be built. Electricity produced from gas-fired plants helps supply baseload generation when generation from subcritical coal power plants is in decline and newer plants are not yet operational before 2030.

Renewable energy is projected to be a major source of additional capacity, growing at a CAGR of 2.8% to make up 39% of the power capacity in 2050 (Figure 21.5). To take advantage of abundant hydro, high-quality wind and solar resources (CIEMAT et al., 2015) while moving away from nuclear power, the government is stimulating renewables use through a number of incentive mechanisms.[119] These policies increase solar, wind and bioenergy deployment rapidly in the near term, but from a very low base. By 2050, however, solar power capacity (rooftop photovoltaic [PV] and utility PV) reaches 9.9%; wind reaches 5.0%; and bioenergy (including solid biomass, biofuel and biogas without carbon capture and storage [CCS]) is 2.1%.

Figure 21.5 • Viet Nam: Power capacity and electricity generation by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

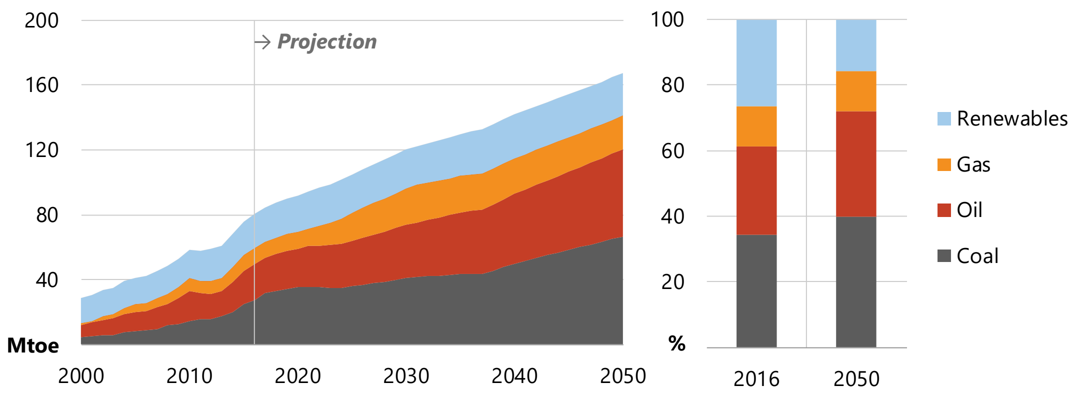
[119] The most recent are Decision No. 39/2018 on Wind Power and Decision No.11/2017 on Solar Power (PMVN, 2017d). Older regulations include Decision No. 24/2014 on Biomass and Decision No. 31/2014 on MSW.

Under the BAU, new capacity is installed mostly in the medium term (by 2030), but utilisation is expected to be higher in the latter part of the Outlook period (after 2035). Hydropower capacity in renewables-based generation is assumed to remain high, ranking second (24%) in terms of power generation in 2050, after coal (48%). Solar, wind and biomass power generation rises sharply later in the Outlook, for 7% of power generation in 2050.

TOTAL PRIMARY ENERGY SUPPLY CONTINUES TO GROW STRONGLY

Viet Nam's energy supply system has grown rapidly in the past 16 years (6.6% CAGR), supported by domestic fossil fuels and low-cost hydropower (Figure 21.6). In the BAU, TPES doubles to 169 Mtoe by 2050. Per-capita primary energy supply reaches 1.5 toe in 2050, from 0.84 toe in 2016 (1.7% CAGR). Owing to the high demand for electricity, as well as to government priorities (PMVN, 2016b), coal use rises to 67 Mtoe in 2050 (2.6% CAGR). With plenty of affordable lignite and anthracite resources available, coal makes up the largest share of TPES (40%) in 2050. Crude oil and petroleum products are the second most important (33%), driven by demand from end-users, especially in transport. Renewable energy expands and diversifies to include more wind and solar power, but its share in the fuel mix declines from 27% in 2016 to 15% by 2050.

Figure 21.6 • Viet Nam: Total primary energy supply by fuel, 2000-50



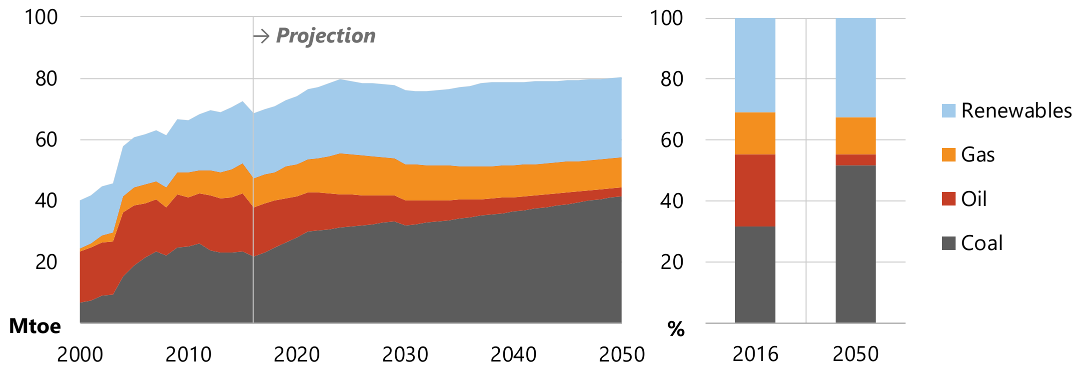
Sources: APERC analysis and IEA (2018a).

ENERGY PRODUCTION AND TRADE: DEMAND INCREASINGLY EXCEEDS PRODUCTION

Viet Nam has historically relied on its rich coal, hydro and oil resources to meet growing domestic energy demand. Production grew at a CAGR of 3.4% in the 2000-16 period; however, this is below growth rates for demand (6.1%) and TPES (6.6%). In 2015, for the first time, production was lower than TPES—an imbalance that remains throughout the Outlook period under the BAU. In 2050, Viet Nam's energy production reaches 80 Mtoe, comprising just 48% of TPES. Annual increases in domestic production of coal (1.9%) are insufficient to meet demand, especially with oil production diminishing (-5.0% CAGR).

Domestic coal has traditionally been produced and supplied mainly from open–cut and underground mines in the Quang Ninh province of northern Viet Nam. The sub-bituminous rich Red River Delta coal basin (also in the north), which is believed to hold 81% of total resources, will be developed after 2020 (PMVN, 2016a). Oil reserves are mainly offshore and in southern Viet Nam. Crude oil has been a major energy export and contributed greatly to GDP, although its importance has been diminishing in recent years, from 12% of GDP in 2014 to 7.1% in 2015, and just 3.7% in 2016 (GSO, 2016). Falling global oil prices and maturing of the Cuu Long Basin around 2020 lead to a steady decline in oil production over the Outlook period (Figure 21.7). With plans for nuclear power plants on hold, Viet Nam is instead boosting production of renewables and trading of natural gas.

Figure 21.7 • Viet Nam: Primary energy production by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

ALTERNATIVE SCENARIOS

While the BAU Scenario is intended to be representative of Viet Nam's current energy demand and supply trends as well as policy commitments, the *Outlook 7th Edition* explores two alternatives to analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of increasing renewables deployment while pursuing efforts to reduce both energy intensity and CO_2 emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050.

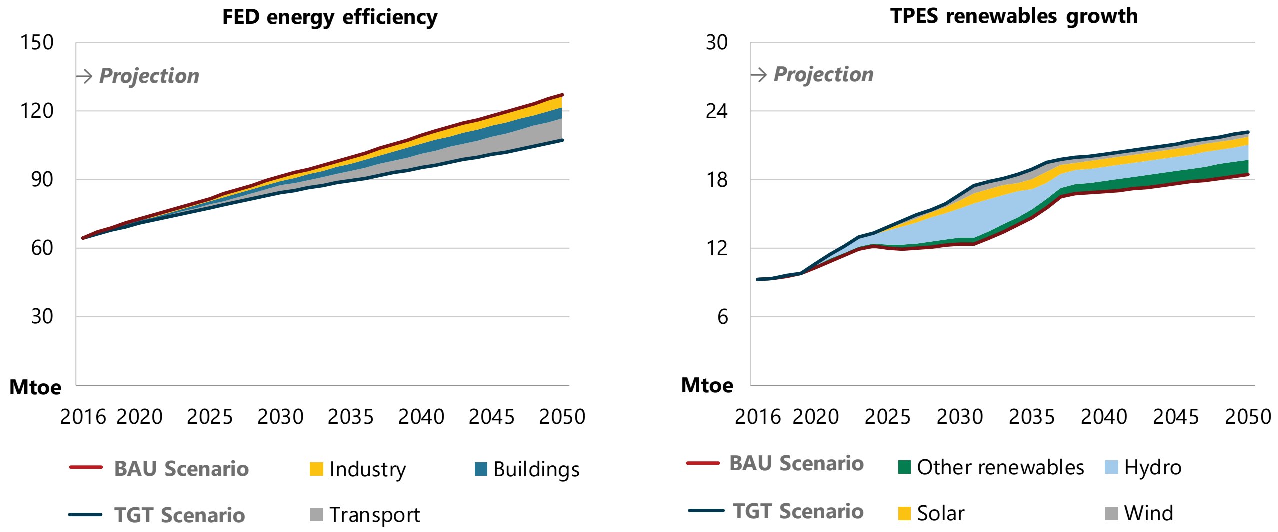
Relative to the BAU, FED is 10% lower and CO_2 emissions are 17% lower in the TGT by 2050. Under the 2DC, Viet Nam's FED is 19% lower and CO_2 emissions are 38% lower. The share of renewables in TPES is 4.4% higher in the TGT and 20% higher in the 2DC.

APEC TARGET SCENARIO: IMPROVED ENERGY INTENSITY, HIGHER RENEWABLES

The TGT Scenario is aligned with APEC's aspirational goals to reduce energy intensity and increase the deployment of renewables. Under the TGT, Viet Nam's FED is 108 Mtoe in 2050—20 Mtoe (15%) lower than under the BAU (Figure 21.8). Cumulative demand in the TGT is 330 Mtoe lower over the Outlook period, with transport contributing the most to savings (142 Mtoe), followed by buildings (95 Mtoe) and industry (93 Mtoe).

Viet Nam is currently an energy-intensive economy compared with the APEC average. In 2016, final energy intensity (measured as final energy in tonnes of oil equivalent [toe] per unit of GDP) was 1.4 times higher than the APEC average. Under the TGT, it remains 1.2 times higher in 2050, almost identical to the BAU. The latest *Energy Outlook Report* (MOIT and DEA, 2017) highlighted energy efficiency as the lowest-cost way to reduce GHG emissions while improving energy security. Energy efficiency policy is underpinned by the National Target Program for Energy Efficiency and Conservation Phase One (2006) and Phase Two (2012), strengthened by the Energy Efficiency Law of 2010. These two programs reduced energy demand in 2012-15 by 5.6% (11 Mtoe), with marked reductions in energy-intensive sectors such as steel (8%), textiles and apparel (7%) and cement (6%) (VNEEP, 2018). Phase Three of the VNEEP, proposed in 2018 for the 2019-30 period, aims to reduce energy demand by 8% to 10% (50 Mtoe to 60 Mtoe). Additionally, this phase seeks to introduce the ISO 50001 standard in industry; employ new technical codes (MOC, 2017) in all new builds; and apply energy saving standards for all vehicles.

Figure 21.8 • Viet Nam: Energy efficiency and renewables, TGT versus BAU, 2016-50



Note: FED energy efficiency shows the energy demand reduction by FED sector in the TGT compared with the BAU. TPES renewables growth shows the additional renewables in TPES by type in the TGT compared with the BAU but excludes solid bioenergy in the buildings sector.
Sources: APERC analysis and IEA (2018a).

Viet Nam has identified industry as a strategic sector in which to improve energy efficiency. With funding from the World Bank, it has launched a new USD 100-million project covering 2017-22 (World Bank, 2018c). In addition, the TGT shows that industry could reduce energy demand from fossil fuels (coal, oil and natural gas) by at least 88 Mtoe compared with the BAU, which is roughly the 2016 TPES. This is achieved through measures such as higher scrap steel recycle rates of 10% to 15%, lower clinker-to-cement ratios, greater energy efficiency and a transition to best available technologies; as production remains the same in all three scenarios.

Increasing end-use of renewables in the industry sector is driven by the replacement of coal and coal-based products with advanced biomass at various rates in non-metallic minerals (7%) and chemical and petrochemical (5%). Under the TGT, renewables demand in buildings and transport changes significantly compared with the BAU. In buildings, demand decreases more quickly as traditional biomass, used in cooking and heating, is phased out more aggressively. In transport, deploying more biofuels (bioethanol) is practical, as Viet Nam already has a clear near-term plan to implement a mandatory E10 blend rate.[120] More effort is needed, however, to improve the quality of the gasoline-bioethanol blend and enhance its image among commuters as a new, environmentally friendly fuel.

TWO-DEGREES CELSIUS SCENARIO: TOWARDS A LOW-CARBON PATHWAY

The 2DC Scenario represents an ambitious effort to move APERC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050. To meet the aims of this scenario, most energy sectors in Viet Nam will have to undergo some degree of decarbonisation. The relative amount of decarbonisation required by each sector is based on the cost-optimised modelling developed for the *Energy Technology Perspectives* publication by the International Energy

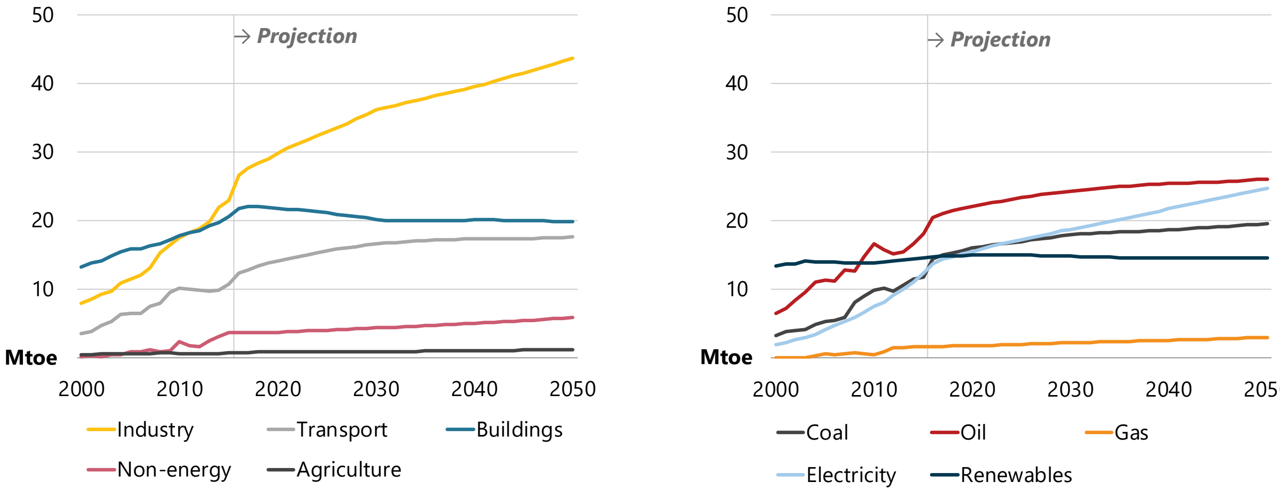
[120] A fuel mixture of 10% ethanol and 90% gasoline.

Agency (IEA, 2017a). Under this modelling, some sectors (such as electricity) are required to decarbonise much more heavily than others (such as industry) because it is more cost-effective.

SECTORAL DEMAND DEVELOPMENT IN THE 2DC

Assumptions in each demand sector for the 2DC Scenario are similar to the TGT, but with more ambitious goals. For example, the 2DC assumes a higher share of renewable energy in industry, more efficient envelopes and appliances in buildings, and in transport, higher sales of technologically advanced vehicles (e.g. electric, fuel cell and hybrid), improved fuel efficiency and faster retirement of the existing car fleet. As a result, FED in the 2DC is 31% lower in 2050 than in the BAU, a reduction of 40 Mtoe. Overall energy demand declines by 649 Mtoe from 2016 to 2050, with the largest reduction occurring in domestic transport (53% or 343 Mtoe). Although oil maintains the largest share (30%) in 2050, renewables climb to 17% (compared with 11% under the BAU) (Figure 21.9).

Figure 21.9 • Viet Nam: Final energy demand in the 2DC by sector and fuel, 2000-50



Source: APERC analysis and IEA (2018a).

Improvements in the energy performance of buildings leads to huge energy demand reductions in the services subsector, despite floor area (one of the main drivers of energy demand) increasing by 34% over the Outlook period. Such improvements include more efficient water heating and space cooling systems. In the residential subsector, similar improvements are joined by a quicker phaseout of biomass and coal. Cumulatively, renewables demand in the buildings sector decreases 56 Mtoe compared with the BAU as traditional biomass is phased out. Electricity demand declines the most (by 74 Mtoe).

Domestic transport energy demand increases significantly in the 2DC (43%), but this is a massive improvement from the more than tripling in the BAU. The introduction of new, advanced technology in the vehicle fleet helps to flatten demand: around one million hybrid and battery-powered electric minivans and half a million advanced heavy-duty trucks (mostly hybrid) are deployed by 2050, while the number of advanced small- and medium-sized passenger cars and motorcycles also escalates at more than 20% of CAGR (albeit from a very low base). Additionally, Viet Nam introduces higher bioethanol blend rates so that oil demand increases by only 0.53% per year, compared with the 3.5% CAGR under the BAU. The 2DC is feasible if Viet Nam follows the bioenergy roadmap released in 2007.

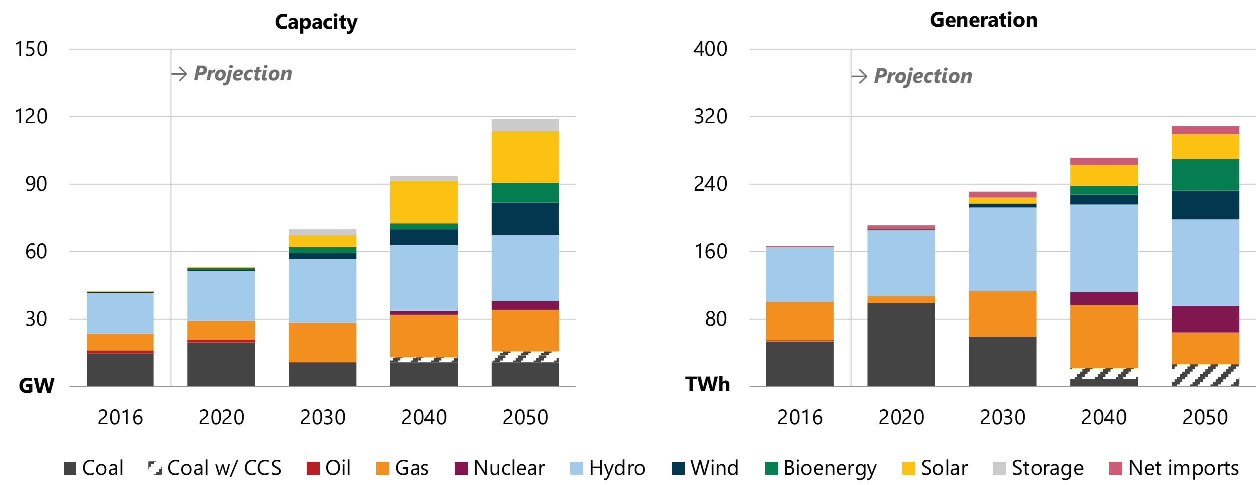
A 2DC future also requires effort by industry (particularly chemical and petrochemical, and iron and steel) to reduce energy demand while maintaining the same level of production. This is achieved by deploying a greater proportion of electric arc furnaces, relative to blast furnaces-basic oxygen furnaces, and using more processed biomass (such as wood pellets). Under the 2DC, industry energy demand is 44 Mtoe (50% of FED) in 2050, compared with 50 Mtoe in the BAU.

TRANSFORMATION AND SUPPLY IN THE 2DC

Electricity generation in the 2DC increases at a CAGR of only 1.8%, compared with 2.5% in the BAU, with output reaching 299 TWh in 2050 (Figure 21.10). In the latter part of the Outlook period (2040-50), Viet Nam's electricity is sourced dominantly from renewables (reaching 68% in 2050), which consists of large hydropower, bioenergy and other variable renewables.

By 2020, 7.9 GW of new SC and USC coal-fired plant capacity is added, as subcritical technology is phased out by 2027. After 2021, no new coal-fired plants are built (except those with CCS technology), and existing plants begin operating at reduced rates towards the end of the Outlook period. Coal with CCS is deployed from 2040, reaching 5.1 GW capacity by 2050. In response to falling demand and a need to reduce CO_2 emissions, additional oil capacity is no longer required. This overhaul of Viet Nam's generation sector may be challenging to achieve while electricity demand and GDP continue to grow strongly. Moderating energy demand growth will be essential to achieve the 2DC and to reduce CO_2 emissions in line with the NDC. To reach the 2DC pathway at least cost, nuclear power is deployed from 2035, with 4.0 GW of capacity registered in 2050.

Figure 21.10 • Viet Nam: Power capacity and electricity generation in the 2DC by fuel, 2016-50



Note: CCS = carbon capture and storage.
Sources: APERC analysis and IEA (2018a).

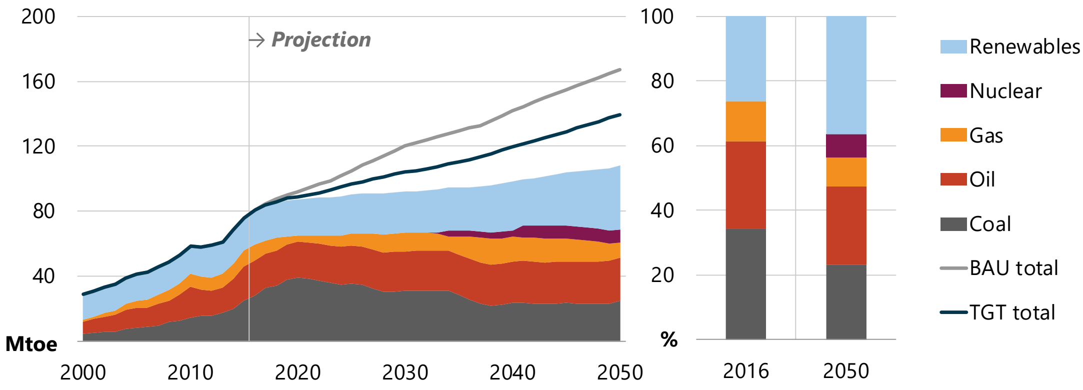
Capacity growth for all renewable energy resources increases at much higher rates in the 2DC than in the BAU. Bioenergy, for example, expands at a CAGR of 21% in the 2DC, compared with 11% in the BAU. An extra 126 GW of power from solar PV and 87 GW from hydropower is deployed cumulatively over the Outlook period. In 2050, hydropower (mostly large-scale) contributes 51% of the electricity generated from renewables. Solar irradiation is high in Viet Nam, at up to 1 825 kilowatt-hours per square metre per year (kWh/m^2 per year) (CIEMAT et al., 2015). Such volumes are in line with most economies in the region; the highest (2 600 kWh/m^2 per year) is in Australia's Great Sandy Desert (WEC, 2016). By July 2017, a total of 17 GW of solar power projects had been registered for construction[121] (VNCPC, 2018). If the government continues to promote solar power by providing land and tax exemptions, and by reinforcing grid support, electricity generation from solar PV could match

[121] Registering is only part of the development process; not all of these projects will reach construction.

projections for the 2DC. Achieving an extra 11 GW for hydropower is more challenging, although total estimated potential is 35 GW (VEO, 2017).

TPES in 2050 under the 2DC is only 111 Mtoe, a 58-Mtoe decrease from the BAU (Figure 21.11). The phase-out of coal-fired electricity generation is responsible for about 71% of this energy demand reduction; reduced demand for oil in transport also plays a significant role. Bioenergy, which transitions from solid biomass to liquid biofuel and biogas, is flat throughout most of the period before increasing from 2035, mainly in the electricity sector. Under the 2DC, production output falls to only 84 Mtoe in 2050, although net imports are also lower at 31 Mtoe compared with 94 Mtoe in the BAU.

Figure 21.11 • Viet Nam: Total primary energy supply in the 2DC versus BAU and TGT, 2000-50



Sources: APERC analysis and IEA (2018a).

SCENARIO IMPLICATIONS

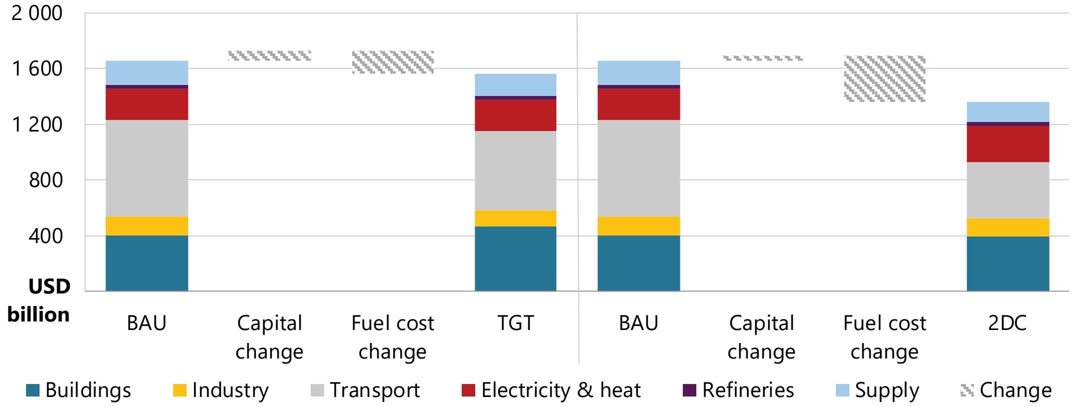
ENERGY SECTOR INVESTMENTS AND SAVINGS

The APERC *Outlook 7th Edition* considers, for the first time, demand-side energy investments, which makes it possible to assess different methods to achieve the key goals of improving energy intensity, boosting deployment of renewable energy and reducing CO_2 emissions. With the exception of refuelling infrastructure, these projections are cumulative over the entire Outlook period and are calculated in relation to a baseline scenario in which the 2016 technology mix is held constant and only additional energy investments are included in the projections.[122]

Total energy investments over the Outlook period are projected at USD 1 656 billion in the BAU. Capital costs amount to USD 557 billion, split fairly evenly across transformation (USD 208 billion, mostly for additional electricity capacity), demand (USD 190 billion) and energy supply (USD 160 billion). Within demand investment, USD 99 billion is needed in transport to deploy more advanced and efficient vehicles, and for refuelling stations. USD 90 billion allotted for buildings is mostly to invest in higher-performing residential facilities. In the BAU, fuel costs (USD 1 099 cumulatively) almost double the capital investment, with half of total expenditures in transport (USD 592 billion) (Figure 21.12).

[122] A more detailed description of the investment boundaries is provided in the Annex II Investment Methodology section.

Figure 21.12 • Viet Nam: Energy sector capital and fuel costs, 2016-50



Sources: APERC analysis and IEA (2018a).

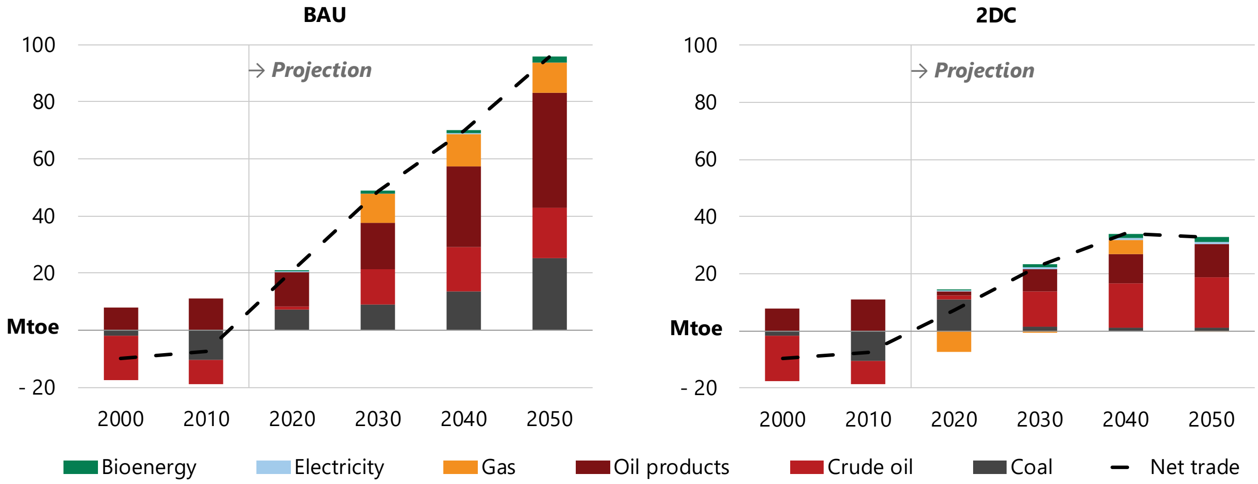
Total capital investments and fuel costs decrease slightly to USD 1 565 billion in the TGT. While capital investments increase to USD 630 billion, fuel efficiency measures help to bring fuel costs down by 15% (to USD 935 billion). Most of these savings (USD 108 billion) are in transport as a result of greater efficiency and improved public transport. Electrification, better envelopes and more efficient appliances result in an additional USD 100 billion investment in buildings, especially in the residential subsector, under the TGT. Supply-side investment under the TGT (USD 144 billion) also decreases by 10% compared with the BAU. On the other hand, the power sector requires an additional USD 13 billion to invest in more advanced coal technology (SC and USC) and more renewables for the grid.

Under the 2DC, total investments decrease still further to USD 1 363 billion (87% of the amount under the TGT); USD 327 billion is saved in fuel costs compared with the BAU. The savings result from a significant lifestyle shift towards more technologically advanced vehicles (mostly electric), stricter fuel economy standards and limiting the construction of new commercial buildings. As a result of curbed development, total capital investments are even less than in the TGT, increasing by only USD 34 billion from the BAU. The 2DC also involves large-scale housing stock improvements, more efficient and smarter transport systems, and the installation of CCS in the industry and power sectors. The 2DC proves to be even more economical given the phase-out of coal-fired power plants and lower demand, which reduce energy supply investments by USD 25 billion. Investment in renewables rises year on year across all three scenarios but is largest in the 2DC (USD 3.5 billion per year on average). The additional fuel savings achieved under the 2DC result in the lowest costs and CO_2 emissions of all three scenarios.

ENERGY TRADE AND SECURITY

Viet Nam is a net crude oil exporter but a net importer of petroleum products, mostly from the ASEAN (especially Singapore and Malaysia), Korea, China and Chinese Taipei (Vietnam Customs, 2017). In the period 2009-13, imports of petroleum products showed a slight downward trend as the first refinery began operations (the Dung Quat refinery, at 140 000 bbl per day). Imports rose again after 2013, keeping pace with economic growth. In 2016, oil products amounted to 17 Mtoe, accounting for the majority (80%) of Viet Nam's total primary oil supply. Oil product imports grow strongly over the Outlook period in the BAU (2.7% CAGR), but decrease in the 2DC (-1.1% CAGR) owing to lower demand growth (Figure 21.13).

Figure 21.13 • Viet Nam: Net energy imports and exports in the BAU and 2DC, 2000-50



Sources: APERC analysis and IEA (2018a).

Despite significant reserves, energy policy changes that prioritised coal for domestic use, coupled with falling global coal prices, shifted the trade balance more towards imports in 2016. Australia, Indonesia and Russia are the three major providers of coal to Viet Nam. Coal imports continue to expand in the BAU, reaching 25 Mtoe in 2050, but shrink to 1.2 Mtoe in the 2DC. LNG terminals and additional infrastructure will also be built to meet domestic electricity demand, particularly in southern Viet Nam (PMVN, 2017a). In the BAU, LNG imports account for half of the total natural gas supply in 2050.

Viet Nam is also a net importer of electricity and has interconnections with the neighbouring economies of Cambodia, China and Laos. Additional grid interconnections mean that the level of trade, especially with Laos, increases significantly during the Outlook period, particularly under the 2DC (cumulative 25 Mtoe, compared with 8.2 Mtoe in the BAU).

Despite significant domestic energy reserves, exploration and production are dependent on the global markets; when imports are inexpensive, they are preferred over domestic production. In all three scenarios, production is less than TPES and Viet Nam is reliant on imported coal, oil, gas and electricity. Owing to lower demand, the gap is less under the 2DC, which means that energy security, as measured by primary energy supply self-sufficiency, is higher under the 2DC than in the other two scenarios (Table 21.5).

Table 21.5 • Viet Nam: Energy security indicators under the BAU, TGT and 2DC

	2016	2030			2050		
	BAU	BAU	TGT	2DC	BAU	TGT	2DC
Primary energy supply self-sufficiency (%)	78	63	75	79	47	58	76
Coal self-sufficiency (%)	78	78	95	95	62	78	95
Gas self-sufficiency (%)	96	54	84	100	48	63	100
Crude oil self-sufficiency (%)	100	38	38	38	14	14	14
Primary energy supply diversity (HHI)	0.24	0.25	0.25	0.24	0.29	0.27	0.20
Coal reserve gap (%)	1.3	25	25	25	67	67	53
Gas reserve gap (%)	5.1	91	88	92	206	201	206
Crude oil reserve gap (%)	3.2	32	32	32	48	48	48

Notes: HHI refers to the Herfindahl-Hirschman Index, a measure of market concentration. The Index ranges from 0 to 1, with values closer to zero representing greater supply diversity (greater energy security) than numbers approaching one (i.e. energy insecurity). Reserve gaps show cumulative production of a fuel type over the Outlook as a percentage of current proved reserves within the economy.

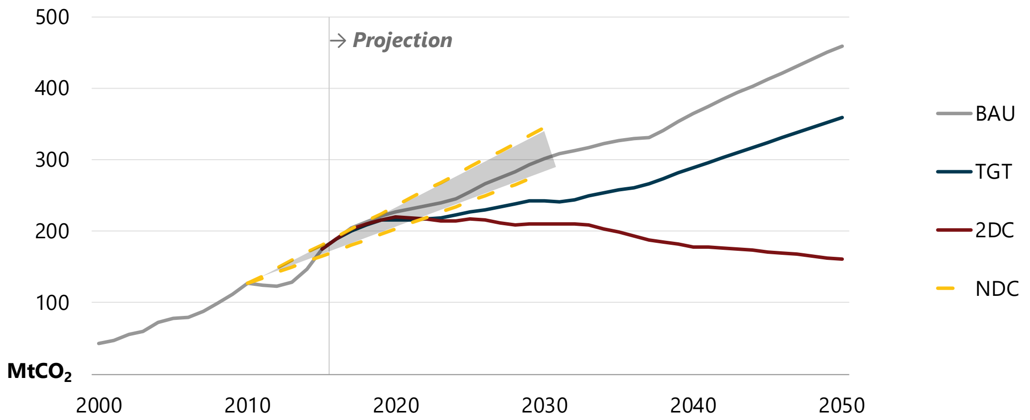
Sources: APERC analysis and IEA (2018a).

While Viet Nam is not an IEA member, it complies with the IEA treaty obligation of ensuring that emergency oil stocks equal 90 net-import days by 2020 (Government Decision No. 1030 of 2017). The economy also stockpiles enough petroleum products to meet energy demand for 30 days, with volumes amounting to 1.6 Mt by 2020 and 2.0 Mt by 2025.

SUSTAINABLE ENERGY PATHWAY

Energy-related CO_2 emissions are lowest in the 2DC, but all three scenarios achieve the goals set out in Viet Nam's NDC, first submitted in 2015 and approved in 2016: a voluntary reduction target of 8% (in which emission intensity per unit of GDP will be reduced by 20%) by 2030 (GOVVN, 2016a).[123] In the BAU, emissions amount to 230 $MtCO_2$ in 2020, 306 $MtCO_2$ in 2030 and 464 $MtCO_2$ in 2050 (an overall CAGR of 2.7%). In the TGT, CO_2 emissions are lower, growing at a CAGR of 2.0%, while in the 2DC, Viet Nam cumulatively reduces CO_2 emissions by 4.3 gigatonnes (Gt) over the Outlook period (-0.4% CAGR). In the BAU, CO_2 emissions increase by 2.5 times, while in the 2DC emissions in 2050 are even 12% less than the 2016 level (Figure 21.14).

Figure 21.14 • Viet Nam: CO_2 emissions pathways under the BAU, TGT and 2DC, 2000-50



Note: NDC = Nationally Determined Contribution (to the COP21 Paris Agreement). The 7th Edition calculates CO_2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis, IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

According to the current NDC, with more international support and a greater domestic push, Viet Nam could reduce GHG emissions by up to 25% below the business-as-usual level. Under this 25% target, energy-related emissions in 2030 will be 230 $MtCO_2$—well below the TGT projection. However, Viet Nam is now working on an updated version of its NDC (first draft released in August 2018), with the 2030 emissions level increased to include industrial processes. The new calculation methodology is expected to better reflect the main sources of emissions and facilitate the implementation of more effective measures.

Although the intended NDC was ratified and revised in a timely manner, ministries have so far not issued sufficient guidelines or specific action plans to support implementation. Despite efforts to improve energy efficiency, government departments managing energy admit that more could be done (MOIT, 2017; EVN, 2017). Stricter public administration and monitoring of energy-intensive sectors, greater awareness within companies

[123] Starting from 2010 as a base year, and including the energy, agriculture, waste and LULUCF sectors, taking all GHGs such as CO_2, methane (CH_4) and nitrous oxide (N_2O) into consideration.

of energy efficiency benefits, and access to more advanced technologies through a financial support mechanism, would enable Viet Nam to follow the 2DC low-carbon trajectory.

OPPORTUNITIES FOR POLICY ACTION

Viet Nam is rich in natural resources and yet, despite recent government efforts to reduce demand and prioritise domestic needs, the economy still imports a significant amount of energy under the BAU, particularly petroleum products and coal. To meet demand for power generation, LNG imports also begin around 2020. Nuclear power, while not included in current government planning, is another option to improve energy security and limit CO_2 emissions; it therefore plays a decisive role in the 2DC Scenario.

As a developing economy, Viet Nam contributes little to overall APEC CO_2 emissions. It is, however, in a position to be strongly affected by climate change and global warming, so it is important that it take mitigation measures. Viet Nam's NDC, which testifies to the economy's determination to take action, is in line with the BAU Scenario. If, however, international assistance can be secured, Viet Nam could achieve the TGT or even the 2DC Scenario. This would also prompt greater energy efficiency in buildings and reduce the number of gasoline-powered vehicles, boosting energy self-sufficiency and delivering significant environmental benefits. As an emerging economy, Viet Nam has access to international support, including technical assistance and funding from, for example, the World Bank. Obtaining the necessary financial support for energy efficiency programs is therefore not an issue. The challenge is to ensure that support is used in the most beneficial areas, that ministries and local government issue the appropriate guidelines to aid implementation.

Viet Nam currently promotes renewable energy projects through mechanisms such as a solar power feed-in-tariff (FiT) of USD 0.094 per kWh (as of 2017) and wind power FiTs of USD 0.078 to USD 0.085 per kWh (onshore wind) and USD 0.098 per kWh (offshore wind) as of 2018. Although such incentives have prompted numerous investment applications, few projects have been implemented for various reasons, including lack of investor implementation experience and instability of funding or human resources. Some conditions, such as the selling price for solar power, are valid for only two years from ratification of the decision (i.e. up to June 2019), while others, such as power purchase agreements, remain in force for up to 20 years. More transparent project approval procedures are needed to prevent project cancellation after several years of operation, as has occurred with some small-scale hydropower projects (MOIT, 2016). The government should also prioritise grid development to ensure the safe integration of all new, variable renewable energy resources. Furthermore, long-term tax assurances and competitive land use fees are necessary to attract foreign investment, as capital expenditures are high and payback periods lengthy.

Despite having made significant progress, Viet Nam is not able to attain full electrification during the Outlook period. Rural electrification is particularly challenging, as the grid cannot reach all mountainous and remote areas. Renewable energy projects such as small-scale hydro and solar PV can make a considerable difference in providing electricity access in these areas, bringing Viet Nam closer to its goal of full electrification.

ANNEX I: MODELLING KEY ASSUMPTIONS & METHODOLOGIES

The *APEC Energy Demand and Supply Outlook, 7th Edition* projections stem from a series of energy models, which are applied to all 21 APEC economies. There are eleven main models, which are connected via an integration module, and run sequentially: macroeconomic, industry, transport, buildings (including residential and services), agriculture and non-specified, hydrogen, electricity, heat, refineries, and production and trade. The methodology for calculating renewables supply potential, investment and security are also described. The Annex I contents are as follows:

1. Introduction
2. Common assumptions
   - GDP and population
   - Energy prices
3. Modelling methodologies
   - Integration
   - Transport
   - Industry
   - Residential buildings
   - Service buildings
   - Agriculture and non-specified
   - Hydrogen
   - Electricity
   - Heat
   - Refineries
   - Production and trade
   - Bioenergy potential
   - Rooftop solar potential
   - Investment
   - Security
4. References

To find out more about the modelling assumptions and methodologies, please either visit APERC's website (http://aperc.ieej.or.jp) or access the Annex I file on the USB version of the Outlook.

ANNEX II: DATA PROJECTION TABLES

The *APEC Energy Demand and Supply Outlook, 7th Edition* data tables show projections for energy production, trade, total primary energy supply, final energy demand, electricity generation and capacity, and carbon-dioxide (CO_2) emissions from fossil-fuel combustion under the Business-as-Usual (BAU), Target and 2-Degrees Celsius Scenarios for each economy and by regional and sub-regional totals.

To access the tables, please either visit APERC's website (http://aperc.ieej.or.jp) or access the Annex II file on the USB version of the Outlook.

REGIONAL GROUPINGS

China	
Oceania	Australia; New Zealand; Papua New Guinea
Other Americas	Canada; Chile; Mexico; Peru
North-east Asia	Hong Kong, China; Japan; Korea; Chinese Taipei
Russia	
South-east Asia	Brunei Darussalam; Indonesia; Malaysia; The Philippines; Singapore; Thailand; Viet Nam
United States	

COMMONLY USED ABBREVIATIONS AND TERMS

2016 USD PPP	2016 USD purchasing power parity
2DC	2-Degrees Celsius Scenario
ADB	Asian Development Bank
AFTA	ASEAN Free Trade Agreement
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of south-east Asian Nations
BATs	best available technologies
BAU	Business-as-Usual Scenario
bbl	barrels
bcm	billion cubic metre
CAGR	Compound annual growth rate
CAFE	Corporate Average Fuel Economy
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
COP21	21st Conference of the Parties
CSP	concentrated solar power
CTL	coal-to-liquid
EGEDA	APEC Expert Group on Energy and Data Analysis
EIA	U. S. Energy Information Administration
EPA	Environmental Protection Authority (US)
ESCOs	energy service companies
ETP	Energy Technology Perspectives
EU	European Union
EV	electric vehicle
EWG	Energy Working Group
FED	final energy demand
EWG	APEC Energy Working Group
FDI	foreign direct investment
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gases
$GtCO_2$	gigatonnes of carbon dioxide
GTL	gas-to-liquid
GW	gigawatt
GWh	gigawatt-hour
HDV	heavy-duty vehicle
HHI	Herfindahl-Hirschman Index
HVAC	heating, ventilation and air conditioning

IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IGCC	integrated coal gasification combined cycle
INDC	Intended Nationally Determined Contribution
IRENA	International Renewable Energy Agency
kWh	kilowatt-hour
LCMT	Low Carbon Model Town
LDV	light-duty vehicle
LED	light-emitting diode
LNG	liquefied natural gas
LPG	liquefied petroleum gas
Mbbl	million barrels
MEEPS	minimum energy efficiency performance standards
MEPS	minimum energy performance standard
Mt	million tonnes
$MtCO_2$	million tonnes of carbon dioxide
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt-hour
NDC	Nationally Determined Contribution
NAFTA	North American Free Trade Agreement
NEA	Nuclear Energy Agency
NREL	National Renewable Energy Laboratory
O&M	operating and maintenance
OECD	Organisation for Economic Cooperation and Development
PHEV	plug-in hybrid electric vehicle
PISE	percentage of household income spent on electricity
PJ	petajoule
PPP	purchasing power parity
PREE	APEC Peer Reviews on Energy Efficiency
PV	photovoltaic
R&D	research and development
SAIDI	system average interruption duration index
SWH	solar water heaters
T&D	transmission and distribution
Tcm	trillion cubic metres
TGT	APEC Target Scenario
toe	tonnes of oil equivalent
toe per unit of GDP	tonnes of oil equivalent per unit of GDP, energy intensity unit
TPES	total primary energy supply
TFED	total final energy demand
tU	tonnes of Uranium
TW	terawatt
TWh	terawatt-hour
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
USD	US dollar
WB	World Bank

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