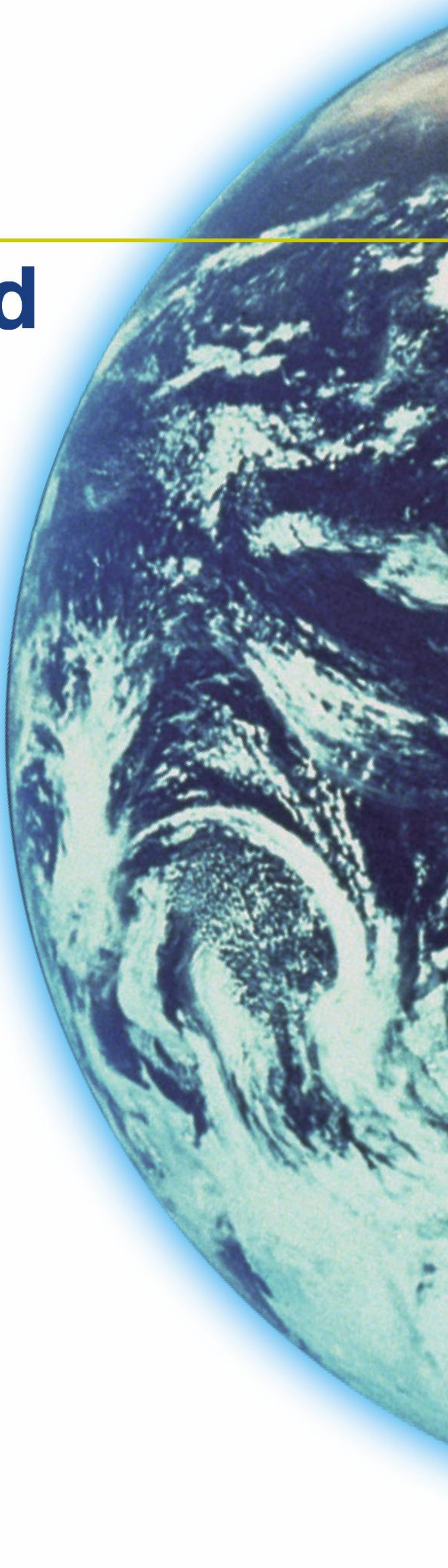
Asia-Pacific
Economic Cooperation

APEC

Energy Demand and Supply Outlook 5th Edition

February 2013



APERC

Asia Pacific Energy Research Centre

APEC ENERGY DEMAND AND SUPPLY OUTLOOK

5TH EDITION

ASIA PACIFIC ENERGY RESEARCH CENTRE

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FOREWORD

We are pleased to present the *APEC Energy Demand and Supply Outlook – 5th Edition*. This Outlook is designed to provide a basic point of reference for anyone wishing to become more informed about the energy choices facing the APEC region.

Concerns about energy security, the impacts of energy on the economy, and environmental sustainability are becoming increasingly important drivers of policy in every APEC economy. The business-as-usual projections presented here illustrate the risks of the development path the APEC region is currently on. A new feature of this Outlook is the alternative scenarios, which examine options for increasing natural gas use and reducing energy demand in transportation.

Readers who desire a quick overview of our most important findings should read Chapter 1, "Summary of Key Trends". Readers who desire a quick overview of our business-as-usual projections should read Chapter 2, "APEC Energy Demand and Supply Overview". Because of the summaries provided in these two chapters, an Executive Summary would be redundant and is not included. Detailed tables of the model results are available on the APERC website http://aperc.ieej.or.jp/.

This report is the work of the Asia Pacific Energy Research Centre (the 'we' used throughout this report). It is an independent study, and does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. But we hope that it will serve as a useful basis for discussion and analysis of energy issues both within and among APEC member economies.

I would like to express a special thanks to the many people outside APERC who have assisted us in preparing this report, as well as to the entire team here at APERC. We at APERC are, of course, responsible for any errors that remain.

I would especially like to acknowledge the contributions of my predecessor as APERC President, Kenji Kobayashi. Under Mr. Kobayashi's leadership, the *Outlook – 5th Edition* project was already well organized and underway when I joined APERC in July 2012.

Takato Ojimi
President
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The development of the *APEC Energy Demand and Supply Outlook – 5th Edition* could not have been accomplished without the contributions of many individuals and organizations. We would like to thank all those whose efforts made this Outlook possible, in particular those named below.

We are very grateful to our sponsors. The Ministry of Economy, Trade and Industry, Japan, provided the primary funding for this project. The Petroleum Institute of Thailand funded the participation of Charothon Ung-Jinda and Nontaphorn Udomwadhanaphorn. The United States Department of Energy funded the participation of Monterey R. Gardiner.

We wish to express our appreciation to the APERC Annual Conference and Workshop participants who met with us and provided invaluable insights into the issues raised in the draft report.

We also would like to thank members of the APEC Energy Working Group (EWG), the APEC Expert Group on Energy Data and Analysis (EGEDA), and the APERC Advisory Board, along with numerous government officials, for their helpful information and comments.

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LIST OF ABBREVIATIONS

APEC ECONOMIES

AUS	Australia
BD	Brunei Darussalam
CDA	Canada
CHL	Chile
CT	Chinese Taipei
HKC	Hong Kong, China
INA	Indonesia
JPN	Japan
MAS	Malaysia
MEX	Mexico
NZ	New Zealand
PE	Peru
PNG	Papua New Guinea
PRC	People's Republic of China
ROK	Republic of Korea
RP	the Republic of the Philippines
RUS	the Russian Federation
SIN	Singapore
THA	Thailand
US or USA	United States of America
VN	Viet Nam

ORGANIZATIONS AND INSTITUTIONS

ADB	Asian Development Bank
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of South-East Asian Nations
CIA	Central Intelligence Agency (USA)
EDMC	Energy Data and Modelling Center (of IEEJ)
EIA	Energy Information Administration (USA)
EWG	Energy Working Group (of APEC)
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of the Petroleum Exporting Countries
WTO	World Trade Organisation
UN	United Nations

TECHNICAL TERMS

BAU	business-as-usual
bcf	billion cubic feet
bcm	billion cubic metres
bpd	barrels per day
BRT	bus rapid transit
BTU	British thermal unit
CBM	coal bed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and sequestration
CDM	Clean Development Mechanism
CNG	compressed natural gas
CO_2	carbon dioxide
CSP	concentrated solar power
DSM	demand-side management
EOR	enhanced oil recovery
EV	electric vehicles
FCV	fuel cell vehicles
FED	final energy demand
FDI	foreign direct investment
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gases
g/kWh	grams per kilowatt-hour (used to measure the emissions caused by the generation of one unit of electricity)
GNP	gross national product
GTL	gas-to-liquids
GW	gigawatt
GWh	gigawatt-hour
IGCC	integrated coal gasification combined cycle
IGFC	integrated coal gasification fuel cell
IOC	international oil companies
IPP	independent power producers
kgoe	kilogram of oil equivalent
km	kilometre
ktoe	thousand tonnes of oil equivalent
kW	kilowatt
kWh	kilowatt-hour
LEAP	Long-range Energy Alternatives Planning System
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
mbd	million barrels per day
mcm	million cubic metres
MEPS	minimum energy performance standards

Mmbls	million barrels
mmscf	million standard cubic feet
MBTU	million British thermal units
MOU	memorandum of understanding
MPa	megapascals
MRT	mass rapid transit
MSW	municipal solid waste
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWp	megawatts peak
NAFTA	North American Free Trade Agreement
NGV	natural gas vehicle
NRE	new renewable energy
NYMEX	New York Mercantile Exchange
NO_x	nitrogen oxides
PHV	plug-in hybrid vehicles
PJ	petajoules
PPP	purchasing power parity
PSC	production sharing contract
PV	(solar) photo-voltaic
R&D	research and development
R/P	reserves-to-production ratio
SO_x	sulphur oxides
SUVs	Sports Utility Vehicles
T&D	transmission and distribution
tcf	trillion cubic feet
tcm	trillion cubic metre
toe	tonnes of oil equivalent
TPES	total primary energy supply
TWh	terawatt-hours
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical (coal power generation technology)
USD	US Dollar

Tables of Approximate Conversion Factors

Crude Oil*

From	To: tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US gallons	0.00325	0.0038	0.0238	1	–
Barrels per day	–	–	–	–	49.8

* Based on worldwide average gravity

Products

	To convert: barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
Liquefied natural gas (LPG)	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.240
Gas oil/diesel	0.133	7.5	0.839	1.192
Fuel oil	0.149	6.7	0.939	1.065

Natural Gas (NG) and Liquefied Natural Gas (LNG)

	To: billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

Units

1 metric tonne	= 2204.62 lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187 kJ = 3.968 Btu
1 kilojoule (kJ)	= 0.239 kcal = 0.948 Btu
1 British thermal	= 0.252 kcal unit (Btu) = 1.055 kJ
1 kilowatt-hour (kWh)	= 860 kcal = 3 600 kJ = 3 412 Btu

Calorific Equivalents

One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural Gas (NG) and Liquefied Natural Gas (LNG) table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil
1 barrel of biodiesel = 0.88 barrel of oil

Reproduced from the *BP Statistical Review of World Energy June 2012* with the kind permission of BP p.l.c.

1 SUMMARY OF KEY TRENDS

The *APEC Energy Demand and Supply Outlook – 5th Edition* is designed to present policymakers with an understanding of the energy trends and issues facing the APEC region to the year 2035. With this goal in mind, this first chapter presents an overview of the most important trends that deserve the attention of policymakers. This chapter appears in place of the Executive Summary that would normally appear at the beginning of a report of this size.

KEY ASSUMPTIONS

The trends discussed in this chapter and throughout this report are shaped by some specific assumptions about the future. This section explains those assumptions and why we make them.

Business-As-Usual

As this report is being written, the energy policies of APEC governments continue to change rapidly. These changes are driven by at least six factors.

1. *Volatility in the oil market.* The first decade of this century saw a dramatic rise in world oil prices, followed by a precipitous drop in late 2008, followed by another rapid rise (see Chapter 3, Figure 3.2). Oil's price volatility has been damaging to businesses and consumers throughout the APEC region. Perhaps even more worrying, however, is that much of the price volatility has reflected tensions in the Middle East, which, if not resolved peacefully, could pose serious threats to oil supply security. Governments are, therefore, increasingly seeking policies that will reduce dependence on oil in general and imported oil in particular.
2. *Climate change.* Governments are seeking policies that will reduce greenhouse gas emissions in order to limit the damage from climate change. Since the production and use of energy accounted for more than two-thirds of greenhouse gas emissions on a world scale in 2010 (IEA, 2011a, p. III.47), these policies are likely to have a profound effect on the energy sector.
3. *Rapid growth of developing economies.* Developing economies, especially in the APEC region, have been remarkably successful in their pursuit of economic growth. While this growth has lifted hundreds of millions of people out of poverty and improved the lives of additional hundreds of millions in other ways, it has had the downside of turning these economies into major world-scale energy consumers and, in some cases, energy importers. Their governments are increasingly recognizing that their own policies will have a significant impact on world energy markets and world greenhouse gas emissions, which could have damaging impacts on their own economies along with others.
4. *The continuing economic crisis.* Despite the continuing growth in the developing economies, most of the developed economies of the APEC region continue to suffer from slow growth and high unemployment. When the last *APEC Energy Demand and Supply Outlook* was published in 2009, governments were attempting to address the problem partly through stimulus programs involving increasing government spending. However, because of increasing concern over the sustainability of the deficit spending involved, governments have been shifting their policies for combating the economic crisis. In addition to monetary policies, the new focus has been on finding ways to do more with less. In the energy sector, this has meant promotion of innovation, economic liberalization and reform, and reduction of taxpayer subsidies for both fossil fuels and renewables. Developing economies have also been attempting to secure their economic future by promoting many of these same policies.
5. *The Fukushima Nuclear Accident.* The tragic events at Japan's Fukushima Daiichi Nuclear Power Plant have provoked a review of policies on nuclear power throughout the APEC region.
6. *Advances in technology.* As detailed in various chapters of this report, energy technology continues to advance in nearly every area, including fossil fuel supplies, renewable supplies, 'smart grids', and more efficient vehicles and other energy-consuming devices. Each innovation requires appropriate policy responses if its full benefits are to be realized.

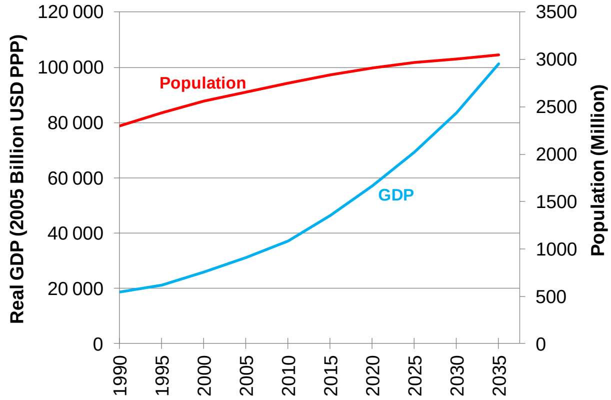
Clearly the policies of the future will not be business-as-usual. Yet what will they be? Given the uncertainties, the safe course would appear to be to assume 'business-as-usual' in our projections. Any other approach has a very real risk of 'counting our chickens before they are hatched'—that is, assuming policymakers do the right thing—resulting in an overly optimistic view of the current situation. Also, policymakers need an independent standard of comparison. Any projection that has built into it assumptions about what policymakers themselves are going to do in the future fails to provide this standard, and is likely to cause confusion.

So, except for the alternative scenarios that are considered, we assume business-as-usual throughout this report. The definition of business-as-usual includes existing policies. It also includes policies that are already being implemented; that is, any necessary legislation has already been passed and there is little uncertainty that the policy is really going to happen. On the other hand, the definition does not include 'targets', 'goals', or policy proposals that governments may have announced, but whose implementation is not yet certain or well defined.

GDP and Population

We assume that the APEC region will continue to enjoy economic growth and progress over the long term, especially in the developing economies. In developing economies, this will include increasing use of commercial fuels, increasing access to electricity, and increasing use of motorized vehicles for transportation. Figure 1.1 shows our specific assumptions about GDP and population for the APEC region as a whole.

Figure 1.1: Assumed APEC GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Table 1.1 shows the assumed APEC GDP and population growth rates. Reflecting the growing GDP share of fast-growing developing economies, and recent demographic trends, it can be seen that GDP growth rates over the 25-year outlook period are assumed to be slightly higher than recent history, while the population growth rate is a bit lower.

Table 1.1: Assumed APEC GDP and Population Growth Rates

Growth	GDP (%)	Population (%)
1990—2005	3.4	1.0
2005—2010	3.6	0.7
2005—2030	4.0	0.5
2005—2035	4.0	0.5
2010—2035	4.1	0.4

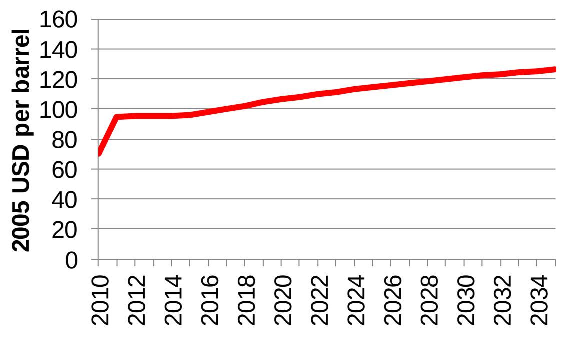
Sources: Global Insight (2012) and APERC Analysis (2012)

Oil Prices

Oil prices have been highly volatile since the oil shocks of the 1970s, and there is no reason to think that the future will be any different. There are many diverse opinions about the future of oil prices offered by well-informed people. Probably the most thorough, publicly available analysis of the long-term future of the oil market is that of the International Energy Agency (IEA) in their *World Energy Outlook 2011*. Their 'Current Policies Scenario' is based on assumptions similar to our business-as-usual assumptions. In this scenario, they assumed that the average IEA member crude oil import price would rise to USD 126/barrel in 2005 USD by 2035 (IEA, 2011b).

As discussed in Chapter 3, we have adopted the IEA's oil price projection in this report. Figure 1.2 shows our oil price assumptions.

Figure 1.2: Assumed Oil Prices



Note: Actual data for 2010 and 2011.
Historical Data: *Energy Prices and Taxes* © OECD/IEA 2012b

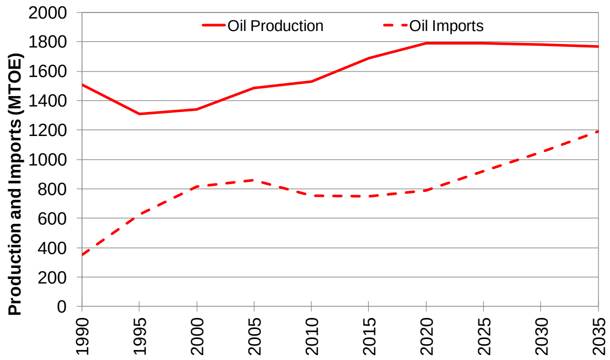
Having explained our key assumptions, the remainder of this chapter examines some expected key trends in the energy sector between now and 2035 that should be of concern to policymakers.

KEY TREND #1

Oil security remains a major threat to the economy of the APEC region

Since 1990, oil production in the APEC region has increased only slightly, while oil demand has risen significantly. As a result, oil imports into the APEC region have grown faster than production. Our business-as-usual projections, as shown in Figure 1.3, indicate that these trends will continue to 2035. Despite some significant increases in APEC's own oil production, the APEC region will become more dependent upon oil imported from outside the region.

Figure 1.3: APEC Total Oil Production and Net Oil Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

This increasing dependency on oil imported from outside the region means that APEC economies may face at least four kinds of risks to their economies:

1. The availability of oil supplies could be threatened by political events in other regions, such as the Middle East and Africa.
2. The availability of oil supplies will depend upon the ability of national oil companies and multi-national oil companies in these other regions to make adequate investments.
3. As oil production becomes more concentrated in a few countries, oil prices will be increasingly influenced by the market power of the producing countries.
4. Increasing amounts of oil will need to be shipped over long distances, typically from the Middle East or Africa, which poses additional security risks.

The likely outcomes of APEC's import dependency are that:

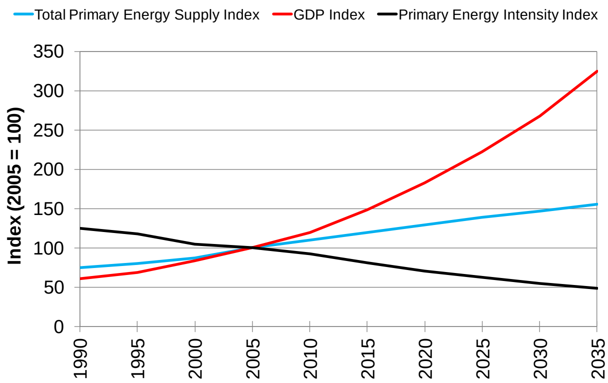
- Continued oil price volatility will be a near certainty.
- There will be significant risks of supply disruptions.
- Both of the above threaten the economic stability of APEC economies and the world.

KEY TREND #2

APEC's energy intensity goals will probably be met under business-as-usual

At their meeting in Sydney in September 2007, APEC leaders called for APEC economies to work toward achieving an APEC-wide regional aspirational goal of a reduction in energy intensity of at least 25% by 2030 (with 2005 as the base year) (APEC, 2007). The goal was revised upward in 2011 at the APEC Leaders' meeting in Honolulu, Hawaii to an improvement of 45% by 2035 (APEC, 2011) since it was becoming apparent that the APEC economies would easily surpass the original goal.

Figure 1.4: Change in APEC Primary Energy, GDP, and Energy Intensity



Source: APERC Analysis (2012)

By 2035, we would expect the APEC region primary energy supply to increase by about 53% compared to 2005, while GDP will increase by about 225%. As shown in Figure 1.4, the net impact will be a decrease in primary energy intensity of about 53%.

This improvement in energy intensity is significantly higher than past trends. Between 1990 and 2009, energy intensity declined at a rate of about 1.4% per year. Under our business-as-usual assumptions, between 2005 and 2035 it will decline at a rate of about 2.5% per year. This decline primarily reflects improvements in technology driven by market forces (including rising energy prices) and the impacts of existing government policies promoting energy efficiency.

KEY TREND #3

Business-as-usual is still environmentally unsustainable

The expected improvement in energy intensity is, unfortunately, not sufficient to put the APEC region on a path toward environmental sustainability. In fact, the best science suggests that the path we are on has a great probability of disastrous climate change consequences.

To understand why this is, we must first understand what science says needs to happen to greenhouse gas emissions to mitigate the risks of climate change. In fact, managing greenhouse gas emissions is a problem very different from managing other types of air pollution. With most air pollution, if the emissions can be stabilized, the impacts can be stabilized, and if the emissions can be reduced, the impacts will be reduced. This is not true of greenhouse gas emissions, since they build up cumulatively in the atmosphere and break down only over extremely long time periods (typically decades or centuries). Hence, only very large reductions in greenhouse gas emissions can stabilize the impacts.

Table 1.2 summarizes the challenges posed by climate change. It is taken from the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* (the Fifth Assessment Report is due for release in 2014). The IPCC is the scientific body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP) to provide objective information about climate change (IPCC, 2012).

Table 1.2: Climate Change Stabilization Scenarios

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005=375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes (from IPCC):

a) The emission reductions to meet a particular stabilization level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379 ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455 ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375 ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure 2.1).

d) The best estimate of climate sensitivity is 3°C.

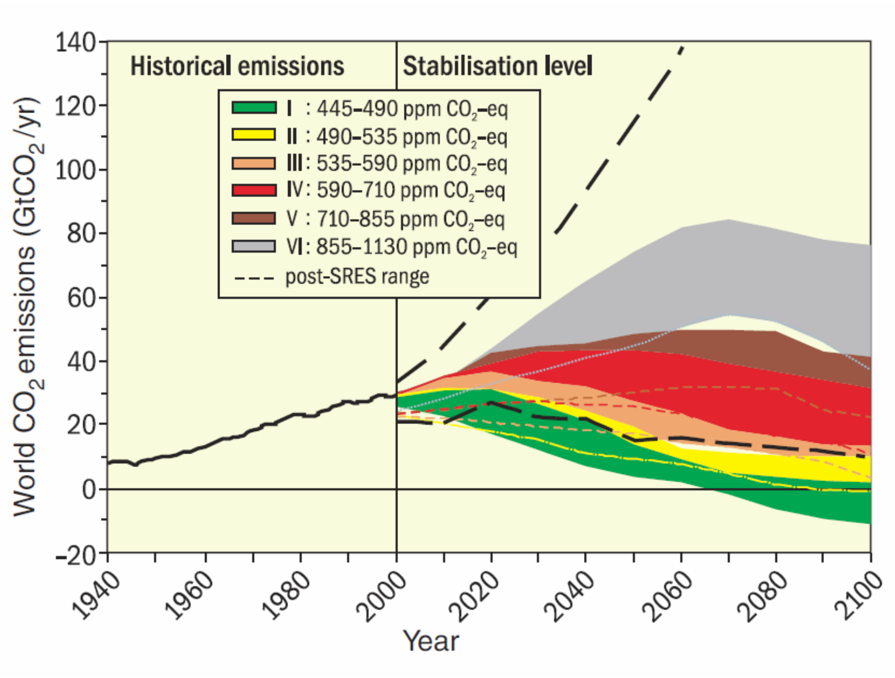
e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilization of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilization of GHG concentrations occurs between 2100 and 2150 (see also Footnote 30).

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6 m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

Source: IPCC (2007), Table 5.1, p. 67

The table shows five possible scenarios for greenhouse gas emissions. Category I, which limits the average global temperature increase to 2.0–2.4 degrees Celsius, requires concentrations of greenhouse gases in the atmosphere to stabilize at a level of 445–490 ppm of CO_2-equivalent. To achieve stabilization at this level would require global CO_2 emissions in the year 2050 to be reduced by 50–85% compared to the year 2000, with global CO_2 emissions peaking between the years 2000 and 2015. The green range in Figure 1.5 illustrates the path of emissions under such a scenario.

Figure 1.5: CO_2 Emissions for a Range of Stabilization Levels



Source: IPCC (2007), Figure 5.1, p. 66

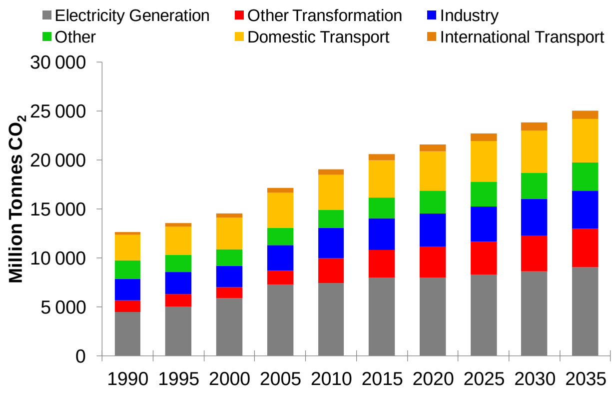
The impacts of climate change are wide-ranging, complex, and vary by location. A fair summary of the IPCC's assessment of the impacts of climate change is that there is a mixture of beneficial and damaging impacts in the 2.0–2.4 degrees Celsius range of warming. Beyond this, most impacts turn out to be damaging, some significantly so. These include:

- rising sea levels—by the 2080s many millions more people are likely to experience coastal flooding each year, especially in the low-lying mega deltas of Asia (IPCC, 2007, p. 48)
- declines in global food production potential (IPCC, 2007, p. 48)
- future tropical cyclones (typhoons and hurricanes) becoming more intense (IPCC, 2007, p. 46 and Table 3.2, p. 53)
- widespread loss of glaciers and snow cover, reducing water availability, hydro potential, and changing the seasonality of water flows in regions supplied by melt water from major mountain ranges (Hindu–Kush, Himalaya, Andes), where one-sixth of the world population currently lives (IPCC, 2007, p. 49)
- adverse health impacts, including increased diarrhoeal, cardio-respiratory, and infectious diseases (IPCC, 2007, p. 51)
- increases in rainfall in some wet, tropical areas, including East and South–East Asia, accompanied by decreases in rainfall in many semi-arid areas including the western United States; drought-affected areas are expected to increase in extent (IPCC, 2007, p. 49)
- widespread damage to coral reefs and their dependent species, including Australia's Great Barrier Reef, due to ocean acidification (IPCC, 2007, pp. 50–51)
- greater frequency of extreme weather events, including heat waves and heavy precipitation (IPCC, 2007, Table 3.2, p. 54).
- widespread extinctions of wildlife: 20–30% of species assessed so far are at risk of extinction if global average warming exceeds 1.5 to 2.5 degrees Celsius relative to 1980–1999 levels; as global average warming exceeds 3.5 degrees Celsius, this rises to 40–70% of species assessed (IPCC, 2007, p. 54).

Cooperative efforts to reduce emissions at the global level remain a work in progress. There does, however, appear to be a consensus that climate warming should be limited to 2 degrees Celsius. This consensus was reflected in the Cancun Agreements adopted at the United Nations Framework Convention for Climate Change (UNFCCC) Conference of Parties in Cancun, Mexico in December 2010, which called for holding "the increase in global temperature below 2 degrees Celsius" (UNFCCC, 2010, p. 3). The UNFCCC enjoys near universal membership, with 194 member countries plus the European Union (UNFCCC, 2012).

This need to dramatically reduce emissions may be contrasted with the business-as-usual projection of APEC region CO_2 emissions from fuel combustion, shown in Figure 1.6. CO_2 emissions from fuel combustion accounted for about 89% of greenhouse gas emissions from energy and for over 60% of greenhouse gas emissions from all sources worldwide on a CO_2-equivalent basis in 2010 (IEA, 2012a, p. III.47).

Figure 1.6: APEC CO_2 Emissions from Fuel Combustion



Source: APERC Analysis (2012)

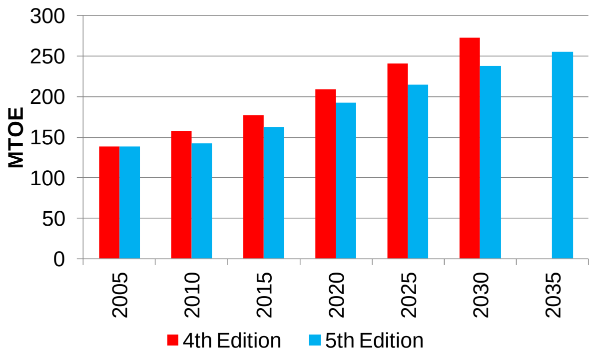
The figure shows that APEC region CO_2 emissions from fuel combustion are expected to rise by about 32% between 2010 and 2035. The threat these emissions pose to humanity, to the environment, and to the economies of the APEC region and the world certainly make it one of the greatest challenges facing the region.

KEY TREND #4

Nuclear development slows down, but not by much

As noted above, the Fukushima Nuclear Accident in Japan has caused the APEC economies that use nuclear power, or are considering using nuclear power, to reassess their policies. Nuclear safety regulation is being reviewed and upgraded in all APEC economies with nuclear power. These safety reviews will necessarily cause some delays and slow-downs in nuclear power development. However, except in Japan itself and Chinese Taipei, all the evidence suggests that the outcome over the long term will not be a lot different from what would have happened if the accident had not happened. Figure 1.7 shows a comparison of APERC's projection of nuclear electricity output in our previous *APEC Energy Demand and Supply Outlook – 4th edition* and this *Outlook– 5th Edition*. It can be seen that the differences are not large.

Figure 1.7: APEC Nuclear Output



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

Why is this the case? Based on the information available to APERC, all APEC economies with existing nuclear power plants plan to continue to operate them as originally planned, with the possible exceptions of Japan and Chinese Taipei. All APEC economies that were planning new nuclear plants, again with the possible exception of Japan and Chinese Taipei, also appear to be proceeding with their plans, subject only to the safety reviews mentioned above.

In Chinese Taipei and especially in Japan, there is a great deal of uncertainty regarding the future of nuclear power. At the time of writing this report, most nuclear power plants in Japan have been shut down pending a comprehensive nuclear safety review. When and whether they will resume operation is not clear. It will be up to the Japanese government that was newly elected in December 2012, to sort out Japan's nuclear policy going forward. In this report, we have assumed that the existing nuclear plants will resume operation, but there will be no new nuclear plants in Japan and no life extensions for existing plants beyond their 40-year life. So nuclear will effectively be slowly phased out in Japan over the outlook period.

In Chinese Taipei, the existing nuclear plants continue to operate, and work continues on two units currently under construction. However, the government has announced a policy of not granting life extensions for the existing units and of shutting down the oldest two units once the two units currently under construction are completed. As a result, we assume that nuclear output in Chinese Taipei will drop to about half of its 2009 level by 2035.

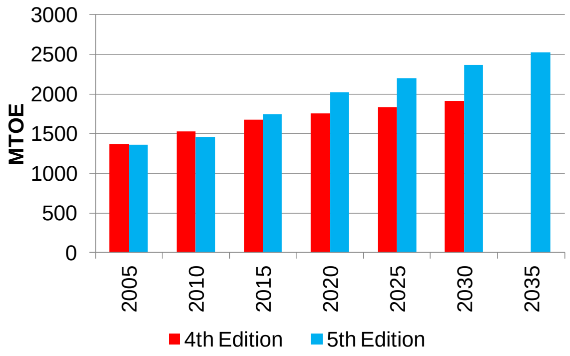
KEY TREND #5

Gas production growth speeds up, and could challenge coal

As discussed in Chapter 12, the growing production of unconventional gas, especially in the US and Canada, has far exceeded expectations of only a few years ago. This is primarily the result of new technology for producing shale gas, including horizontal drilling and hydraulic fracturing. Although this development was anticipated and discussed in the 2009 *APEC Demand and Supply Outlook – 4th Edition*, the technology has continued to prove itself in the real world over the interim.

Figure 1.8 shows the projected APEC gas production in our previous *APEC Energy Demand and Supply Outlook – 4th Edition* and this *Outlook – 5th Edition*. It can be seen that our projected gas production is now significantly higher after 2015.

Figure 1.8: APEC Projected Gas Production



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

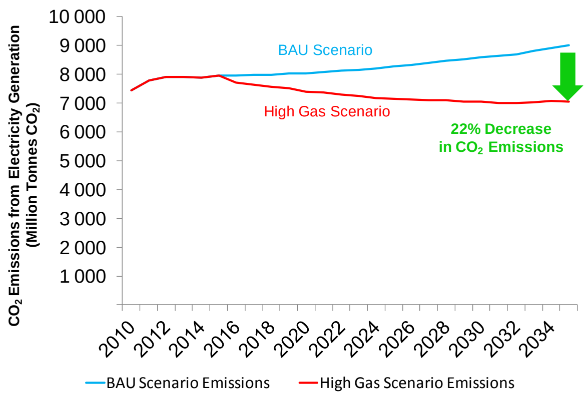
The business-as-usual scenario shown in Figure 1.8 does not include significant shale gas development outside North America and includes fairly conservative estimates of production from both conventional and non-shale-gas unconventional resources outside of North America. However, as discussed in Chapter 12, the conventional and unconventional gas resources of the Asia–Pacific region are immense. And with LNG prices in Asia several times as high as those in North America the economics of gas development outside of North America, as well as further gas development in North America for export, should be compelling.

With appropriate policies and regional cooperation, the APEC economies could use their gas resources to move toward a cleaner energy system, while promoting energy security and mutual prosperity. To illustrate some of the benefits that might accrue from removing the barriers to gas production and trade, APERC developed an alternative 'High Gas Scenario'. In the High Gas Scenario, APERC estimated the gas production that might be available without raising prices if existing constraints on gas production and trade were reduced. In this still-conservative scenario, gas production on an APEC-wide basis was about 30% higher compared to business-as-usual by 2035.

There are many ways the additional gas could be used in the APEC region, almost all of them positive in terms of economics, energy security, and/or the environment. Using gas to replace coal in electricity generation is an especially good option from a CO_2 emissions perspective, since gas-fired generation typically has less than half the CO_2 emissions of coal-fired generation per unit of electricity produced.

APERC therefore assumed the additional gas in the High Gas Scenario would be used to replace coal in electricity generation. As shown in Figure 1.9, the additional gas in the High Gas Scenario could reduce CO_2 emissions from electricity generation in 2035 by about 22% compared to business-as-usual. This implies an overall reduction in energy CO_2 emissions of about 8% compared to business-as-usual.

Figure 1.9: High Gas Scenario – Reduction in CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

It is important to recognize that, in some APEC economies, there is growing public concern over the environmental risks of unconventional gas development. These concerns will need to be addressed through better regulation if gas development is to win the public confidence it will need to deliver benefits like those illustrated in this scenario.

KEY TREND #6

New renewable energy (NRE) goes mainstream

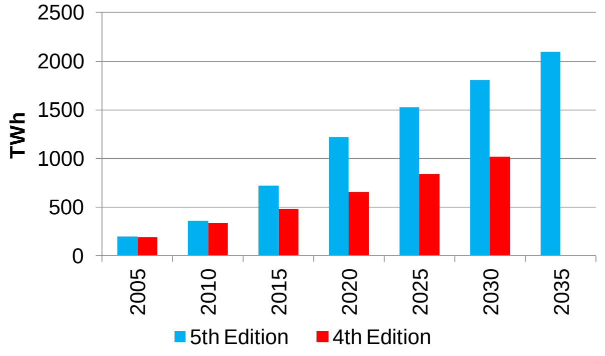
Two forces are driving new renewable energy (NRE) into the mainstream, especially in electricity production. The first is that many APEC economies are responding to the climate change challenges with policies to promote NRE development. These may include:

- feed-in tariffs under which electric utilities are required to buy electricity generated from renewables at a guaranteed price
- renewable portfolio standards, which require electric utilities to obtain a minimum fraction of their electricity from renewable sources
- carbon pricing, such as a tax on CO_2 emissions, which discourages the use of fossil fuels
- regulations limiting greenhouse gas emissions.

Some APEC economies are also promoting the use of biofuels in transportation through requirements that gasoline and diesel fuels have a minimum biofuel content.

The second force driving NRE into the mainstream is technological improvement that continues to reduce the cost and improve the performance of renewable energy. A number of APEC economies have been making substantial investments in research and development to improve renewable energy technology. Businesses and entrepreneurs also perceive a growing market for this technology and are responding with investments of their own. Reductions in the cost of solar photovoltaics (PV) have been especially impressive, with the cost of solar PV electricity now approaching the retail price of electricity in some cities.

Figure 1.10: APEC Projected Electricity Production from New Renewable Energy (NRE)



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

Figure 1.10 compares projected electricity production from new renewable energy (NRE) sources in this *Outlook – 5th Edition* with that of the previous *Outlook – 4th Edition*. Reflecting the two forces discussed above, the figure shows a significant upward revision to projected APEC NRE supplies.

The growth in NRE projected in this *Outlook – 5th Edition* is impressive in percentage terms. This is especially true in electricity generation where NRE output will grow at an average of 7.4% per year over the outlook period, which is the fastest growth of any form of electricity generation. However, the overall role of NRE in energy supply remains modest under business-as-usual assumptions, even in 2035. Further expansion of renewable energy will be needed to meet the challenge of climate change.

An earlier APERC study (APERC, 2010, p. 82) concluded that the APEC region should have a non-fossil primary energy share of about 30% by 2030 if the APEC region is to contribute to stabilizing concentrations of greenhouse gases in the atmosphere at 450 ppm of CO_2-equivalent. This compares to a share of 18% by 2030 in our business-as-usual scenario. The same study also concluded that to meet this goal, APEC's low-carbon electricity generation share (which could include both nuclear and carbon capture and storage) should reach 60% by 2030. This compares to a share of 36% by 2030 in our business-as-usual scenario.

KEY TREND #7

Big opportunities to improve efficiency, especially in transportation

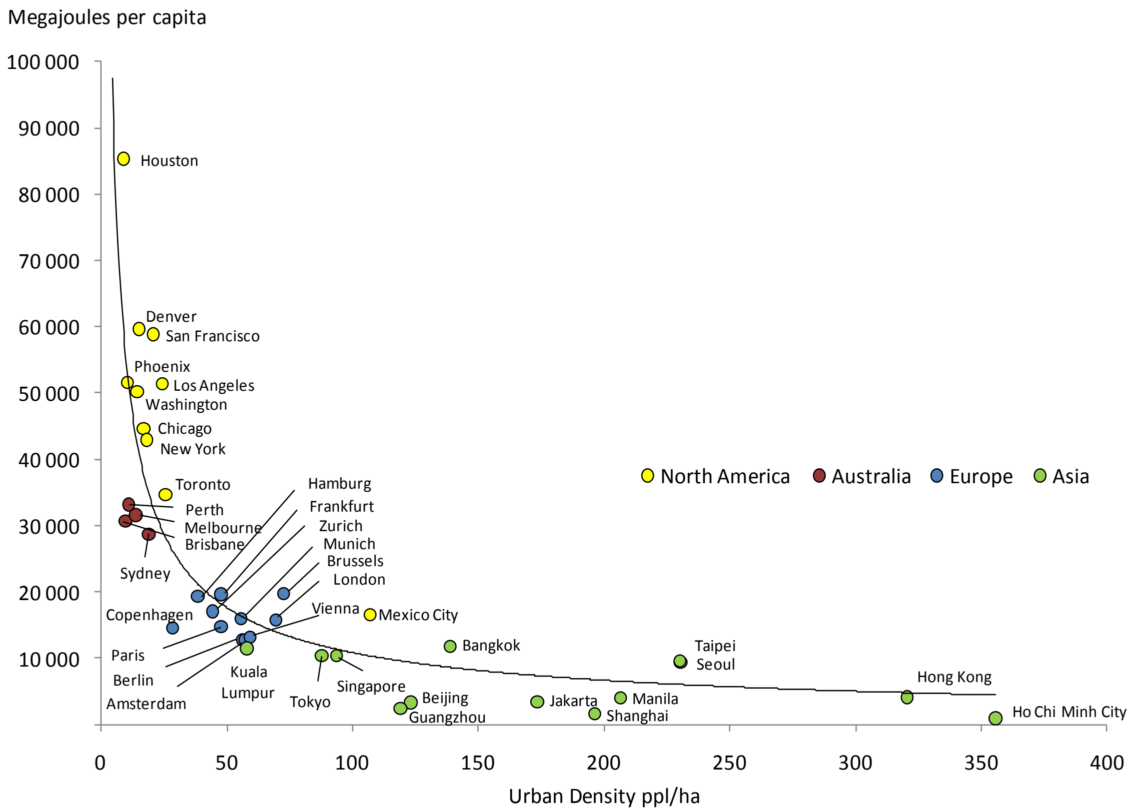
Improving energy efficiency remains the largest and cheapest opportunity to help create a more sustainable energy future. Although there are a set of market failures (discussed in Chapter 4) that tend to inhibit energy efficiency improvements, addressing these market failures offers a unique opportunity to protect the environment, help the economy, and save money for energy users all at the same time. This *Outlook – 5th Edition* closely examines two alternative approaches for improving energy efficiency in the transport sector: alternative urban development and alternative vehicle designs.

Alternative Urban Development Scenarios

The 'Alternative Urban Development' scenarios start from the observation that cities vary dramatically in their per capita energy consumption. It can be seen in Figure 1.11, for example, that per capita transport energy demand in Tokyo or Singapore is about one-seventh what it is in Houston. What if we could design future cities to be more like Tokyo or Singapore and less like Houston?

Of course, redesigning cities is a long-term undertaking. However, the APEC region will be doing a huge amount of city building over the next few decades. The United Nations (2009) estimates that the urban population of the APEC region will grow by 576 million people, or 38%, by 2035 compared to 2010. By 2050, the growth will be 782 million or 51%. And, of course, much of the existing building stock will also be replaced over this time. Clearly, the rapid growth of APEC's cities presents a unique opportunity to build them in an energy-efficient manner.

Figure 1.11: Per Capita Transport Energy Demand vs. Urban Density



Source: Adapted from IUPT/ISTP (1995)

Our model of the energy-saving potential for alternative urban development builds on the observed correlation between per capita urban transport energy use and urban population density that is clear from Figure 1.11. This is, however, a correlation, not necessarily causation. Urban planning can introduce transport-energy-saving design characteristics in a number of ways, including:

- diversity (better mix of land uses, improved jobs–housing balance)
- design (more street connectedness, greater pedestrian/bicycle friendliness)
- transport infrastructure (increased focus on transit over road and parking investments).

More compact cities (those with a higher population density) tend to have lower energy use than less dense 'sprawling' cities for at least three reasons:

1. *Direct effect.* Compact cities have shorter travel distances.
2. *Indirect effect.* Compact cities *tend* to have more of the energy-saving design characteristics discussed above.
3. *Reverse effect.* Cities with the energy-saving design characteristics discussed above *tend* to develop in a more compact way.

In short, building energy-efficient cities will require a full range of better planning decisions, not just higher population densities.

In our modelling, however, we take population density as an indicator of a city's energy efficiency. We ask, what if APEC cities could grow to be like today's higher density cities rather than like today's sprawling cities—like them in all ways, not just population density.

Specifically, we looked at four possible alternative futures:

1. *Business-As-Usual (BAU).* In this scenario urban population density declines at a rate of 1.8% per year, consistent with current worldwide trends.

2. *High Sprawl.* In this scenario urban population density declines at 3.6% per year, or twice the current worldwide trend, consistent with the observed rate in some APEC cities.

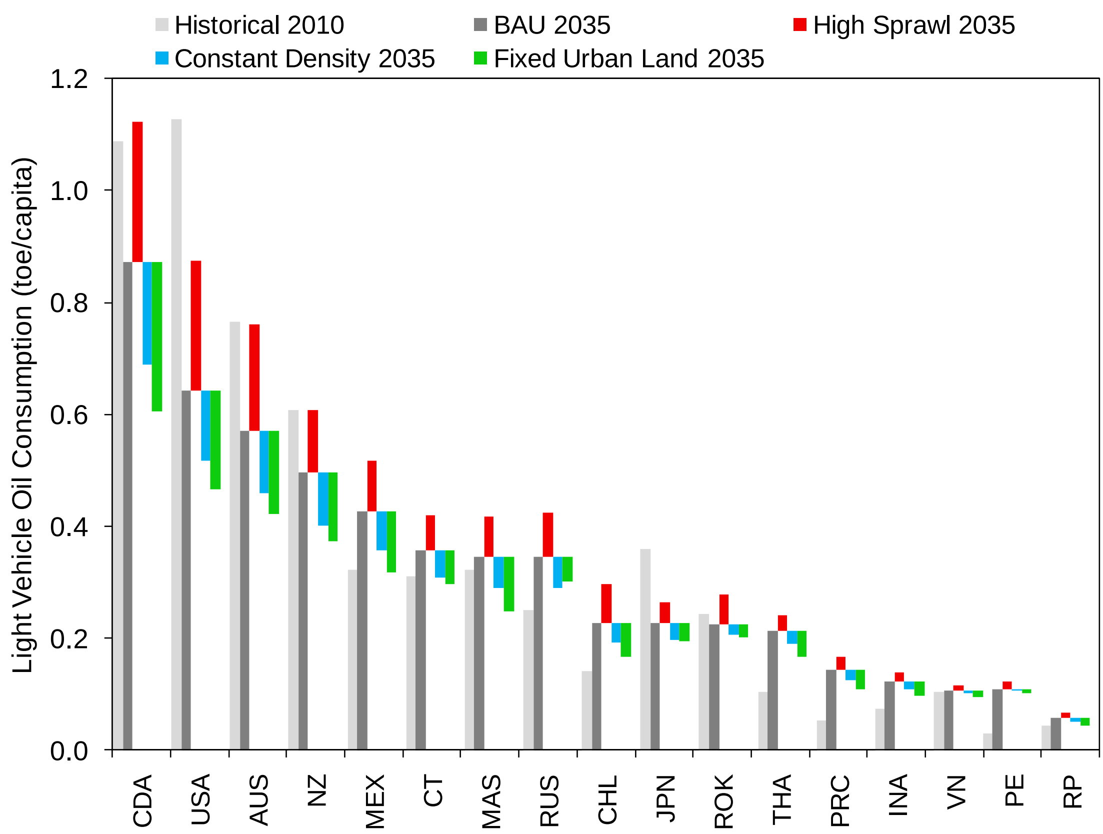
3. *Constant Density.* In this scenario the urban population density remains constant, so cities expand in land area in proportion to their population growth.

4. *Fixed Urban Land.* In this scenario the land area of the city remains constant, with population expansion accommodated through growing 'up' rather than 'out'.

The impacts of these scenarios on urban transport energy use by 2035 could be quite dramatic, as shown in Figure 1.12. Note that the alternative urban development scenarios were not run for Brunei and Papua New Guinea due to lack of data, and were not run for Singapore or Hong Kong, China due to their natural geographical limitations.

Overall, the Constant Density scenario would reduce APEC urban transport oil product demand by about 16% by 2035 compared to business-as-usual; the Fixed Urban Land scenario would reduce it by 24%. On the other hand, the High Sprawl scenario would increase oil product demand by about 25% compared to business-as-usual.

Figure 1.12: APEC Light Vehicle Oil Demand Per Capita under Alternative Urban Development Scenarios



Source: APERC Analysis (2012)

Virtual Clean Car Race

Another way to improve transportation energy efficiency is by introducing alternative vehicle designs. The 'Virtual Clean Car Race' alternative scenarios looked at the impacts of introducing four alternatives to conventional internal combustion light vehicles:

1. *Hyper Cars*. These are conventionally powered vehicles with light carbon-fibre bodies and other energy-efficient features.
2. *Electric Vehicles*. These are 100% electric-battery-powered vehicles of otherwise conventional design.
3. *Natural Gas Vehicles*. These are compressed natural gas internal combustion vehicles of otherwise conventional design.
4. *Hydrogen Vehicles*. These are powered by fuel cells running on hydrogen; they are of otherwise conventional design.

We made the assumption in each of four sub-scenarios that each vehicle was introduced uniformly in each economy starting in 2013, with a new vehicle market share rising to 50% by 2020. While not intended to be realistic, these assumptions allow a straightforward comparison of the energy-saving potential of each vehicle type.

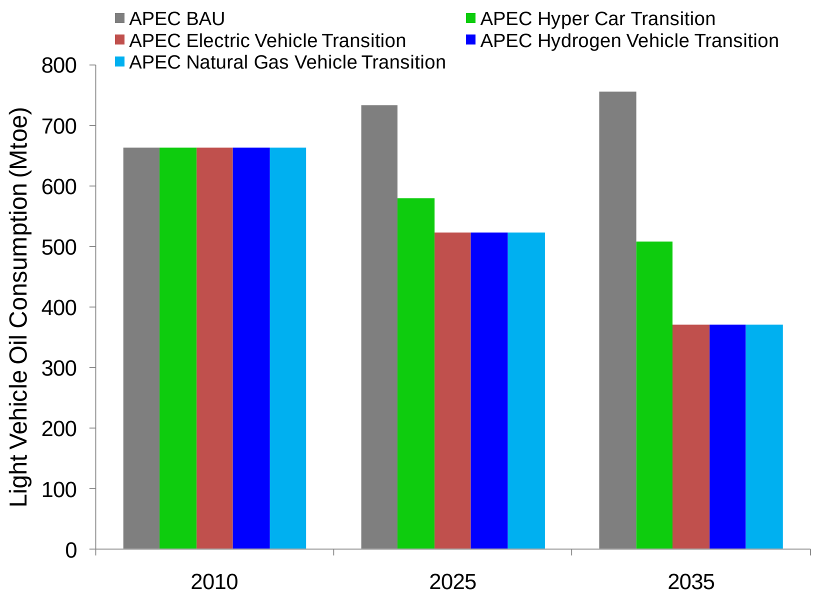
For the Electric Vehicle Transition scenario, we assumed the electricity came from the grid, with additional electricity produced from fossil fuels, either coal or gas, as projected by our electricity supply model. Hydrogen for the hydrogen vehicles was always assumed to be produced by reforming natural gas. We chose not to assume renewable sources were used to produce the additional electricity and hydrogen, since this would be counting the benefits of additional renewable energy supply as a benefit of electric or hydrogen vehicles, which it is not. There is considerable room in every APEC economy to add renewable energy supply without using hydrogen or electric vehicles at all.

The alternative vehicles could potentially provide two types of benefits:

- lower oil demand, thereby increasing energy security
- lower greenhouse gas emissions.

Figure 1.13 shows the impact of the alternative vehicles on oil products demand. It can be seen that by 2035, oil demand when using electric, natural gas, or hydrogen vehicles is about half what it would be compared to using conventional vehicles. This is not surprising, since these vehicles use no oil product for fuel and, by assumption, will constitute about half the vehicle fleet by 2035. Hyper cars also use significantly less oil product than conventional vehicles, reflecting their high fuel efficiency—more than twice that of a conventional vehicle.

Figure 1.13: Impact of Alternative Vehicles on APEC Light Vehicle Oil Product Consumption



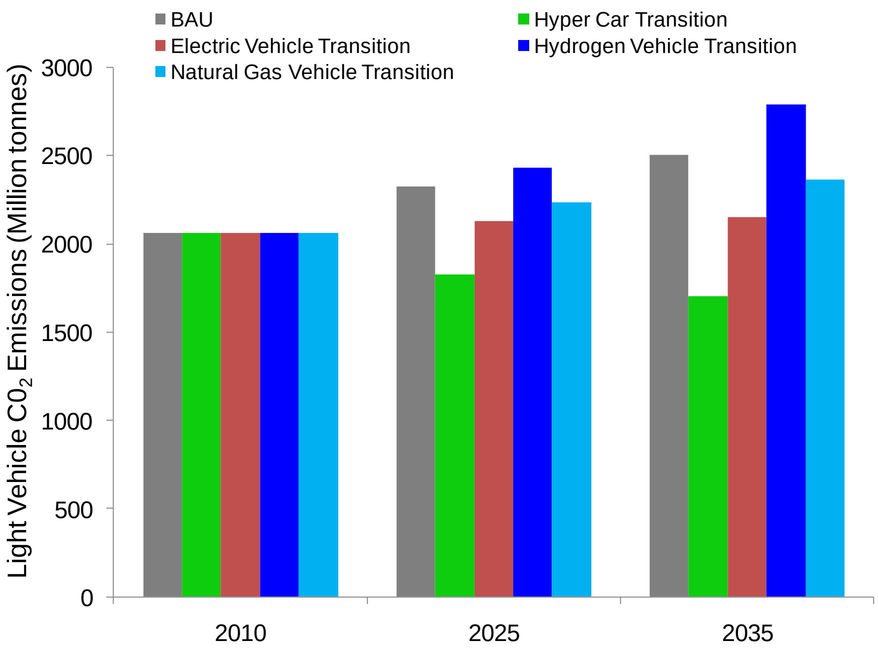
Source: APERC Analysis (2012)

Figure 1.14 shows the impact of the alternative vehicles on CO_2 emissions from fuel combustion. The figures shown include the additional emissions required to produce electricity for the electric vehicles and hydrogen for the hydrogen vehicles.

Here, the hyper cars are the clear winner, reflecting their efficiency, which is more than double that of a conventional vehicle. Since they make up about half the fleet in 2035, CO_2 emissions are about 32% lower than in the business-as-usual scenario. Natural gas vehicles offer a modest reduction in CO_2, reflecting the lower emission factor of natural gas compared to oil products. Electric vehicles also offer only a modest reduction in CO_2 emissions, reflecting our assumption that the electricity is produced from fossil fuels. The impacts of electric vehicles on CO_2 varied considerably between economies, with electric vehicles offering a larger reduction in emissions for those economies where natural gas, rather than coal, was the marginal source of electricity. Hydrogen vehicles turned out to be worse than conventional vehicles from a CO_2 emissions perspective, reflecting the inefficiencies of producing hydrogen from natural gas and then converting the hydrogen to electricity in the vehicle fuel cell.

Of course, the ideal vehicle would have the light weight and high efficiency of the hyper cars, combined with the reduced dependence on oil of any of the other three alternative vehicle types. Both technology paths should be pursued.

Figure 1.14: Impact of Alternative Vehicles on APEC Light Vehicle CO_2 Emissions from Fuel Combustion



Source: APERC Analysis (2012)

HAVE WE DEALT WITH A CHALLENGE LIKE CLIMATE CHANGE BEFORE?

The challenges posed by climate change can sometimes seem overwhelming to those of us who are attempting to do something about them. Avoiding a tragic outcome will require major, and potentially expensive, changes in government policies and technology in a number of sectors. The broad public will need education, both because public support will be required to make these changes happen politically, and because individual behaviour will need to change, too. And all of this needs to happen on a worldwide scale. Has anything like this been done before? The answer is a qualified 'yes'. There are many similarities between the challenges posed by climate change and the challenges posed by infectious diseases in the late nineteenth century.

It is easy to forget the threats that infectious diseases once posed, since no one today, at least in the developed economies, can remember the time when infectious diseases like tuberculosis, pneumonia, typhoid, cholera, scarlet fever, whooping cough, and diphtheria were both common and deadly. But in the United States, for example, in the 1870s and 1880s, one-fifth of all infants died in their first year of life, and even those who survived until adulthood faced a one-in-four chance of dying between the ages of 20 and 30 (Tomes, 1998, p. 25). Moreover, the disease rates were rising alarmingly in fast-growing cities.

Fortunately, at just this time, a new wave of scientific discovery was suggesting that a variety of micro-organisms, colloquially referred to as 'germs', were capable of causing diseases. Today, the germ theory of disease is one of the most widely known and widely accepted findings of science, but in the late nineteenth century, this was not yet the case. Indeed, to many at the time, it seemed rather radical to suggest that diseases were being caused by living organisms. As of 1880, the majority of the medical community found this whole concept hard to accept (Tomes, 1998, p. 27). From 1865 to 1895, Western medicine underwent a virtual civil war over the germ theory of disease. In Europe and the United States, the profession divided into hostile camps that debated in medical journals and textbooks. But by the 1890s, it had become scientific orthodoxy (Tomes, 1998, p. 28).

Inspired by the known value of smallpox vaccinations, many early converts to the germ theory of disease dreamed of developing vaccines or 'internal antiseptics' that could prevent or cure diseases. But, aside from a few exceptions like the rabies vaccine and the diphtheria antitoxin, such hopes for a silver bullet were repeatedly dashed (Tomes, 1998, p. 45). It was not until the 1930s and 1940s that sulfa compounds, penicillin, and other antimicrobial drugs were discovered. As with climate change today, the focus had to be on prevention.

And, as with climate change, prevention was a daunting and expensive task. It required a radical expansion of collective public health practices, including municipal sewerage systems, water purification, garbage collection, building codes, and food inspection. Indeed, our modern conceptions of government responsibility for public health date from the period from 1890 to 1930 (Tomes, 1998, p. 6).

Prevention also required private responses. Entrepreneurs, for one, saw opportunities in the germ theory of disease to promote modern plumbing, soaps, disinfectants, sanitary packaging, water filters, and so forth. Their advertisements, while sometimes exaggerated or inaccurate, still served an important educational role (Tomes, 1998, Chapter 3).

But this era also saw huge educational campaigns to change individual behaviour. In the United States, for example, this role was assumed by a wide variety of organizations, including municipal and state health departments, life insurance companies, women's clubs, settlement houses (organizations that provided charitable services to the poor), Boy Scouts and Girl Scouts, youth service organizations like YMCAs and YWCAs, and labour unions. The era happened to coincide with expanded educational opportunities for women, especially in social work, home economics, and nursing. Many women of this pioneer generation dedicated themselves to bringing the insights of "household bacteriology" to every homemaker (Tomes, 1998, pp. 9–10).

Today, we take all these changes for granted. As Tomes (1998, p. 2) puts it "The rituals of germ avoidance are so many and so axiomatic that we scarcely can remember when or where we first learned them". Yet for the people of the late nineteenth century, these must have seemed like huge and wrenching changes with high costs and uncertain benefits. But still they made it happen, and it can happen again.

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2 APEC ENERGY DEMAND AND SUPPLY OVERVIEW

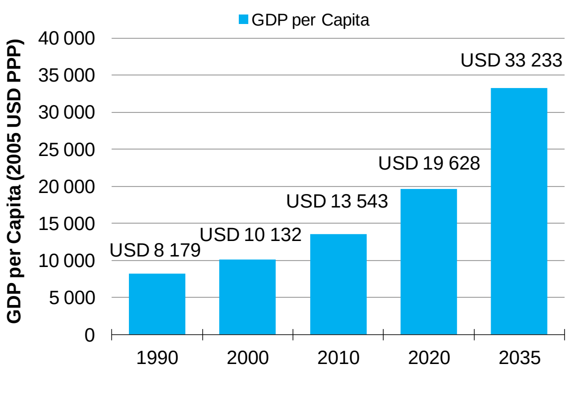
This chapter presents an overview of the business-as-usual (BAU) energy demand and supply results for the APEC region as a whole. We also discuss a key driver behind these results—GDP per capita—and, where appropriate, some policy implications.

GDP PER CAPITA

Chapter 1 discussed our assumptions about APEC-wide economic growth and population growth. Before examining our BAU demand and supply projections, it is worth examining the implications of economic growth and population growth for average GDP per capita in the APEC region and in the individual APEC economies. This is what will shape the kind of energy services consumers are able to afford.

Figure 2.1 shows that average GDP per capita in the APEC region will rise from USD 13 543 (2005 USD PPP) in 2010 to USD 33 233 by 2035. To put these figures in perspective, the average APEC GDP per capita in 2010 is comparable to the 2010 GDP per capita of Chile (USD 13 644), Malaysia (USD 13 244), Mexico (USD 12 427), or Russia (USD 14 348). By 2035, APEC GDP per capita will be comparable to the 2010 GDP per capita of Australia (USD 35 460), Canada (USD 35 383) or Chinese Taipei (USD 32 249).

Figure 2.1: APEC Average GDP per Capita



Source: APERC Analysis (2012)

As a result of the projected large increases in GDP per capita in the APEC region, by 2035 we can expect to see energy used throughout the APEC region in ways typical of the wealthier APEC economies today. This will include a much wider use of energy in motor vehicles, in intercity travel, in more spacious and more climate-controlled housing, in more home appliances, in commercial services (such as restaurants, hotels, healthcare facilities, retail stores, entertainment and recreational facilities, and educational institutions), as well as in industry. Hundreds of millions more people in the APEC region will be rising out of poverty. This is a good economic future if it can be achieved.

FINAL ENERGY

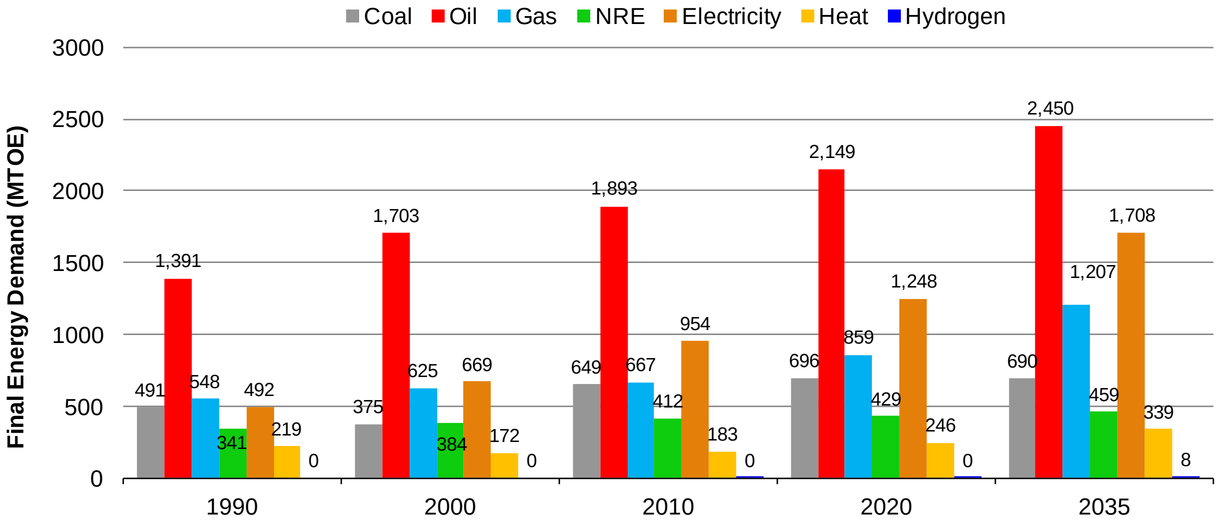
The consequence of this increase in wealth, at least under our BAU assumptions, will be a corresponding increase in the final demand for energy. Final energy is energy in the form it is finally consumed; this means final energy statistics count electricity consumption rather than the primary energy used to make the electricity.

As shown in Figure 2.2, demand for every form of final energy will rise. The largest absolute increase between 2010 and 2035 will be in the demand for electricity (up 754 million tonnes of oil equivalent (Mtoe)), reflecting the growth in demand in the residential and commercial ('other') sectors and in industry.

However, growth in electricity demand will be followed closely by the growth in demand for oil products (up 557 Mtoe), reflecting the increase in motor vehicle use. This will be offset somewhat by increasing vehicle fuel efficiency. Natural gas demand will also rise significantly (up 540 Mtoe).

In percentage terms, the final demand for purchased heat (mainly from district heating systems) will grow the fastest in the 2010–2035 period (up 85%), followed closely by natural gas (up 81%) and electricity (up 79%). Final demand for other fuels will grow more slowly. New renewable energy (NRE) final demand will grow by only about 11% because the demand for this fuel in 2010 was dominated by traditional residential biomass. Residential biomass demand is not expected to grow significantly, since consumers will be increasingly able to afford commercial fuels.

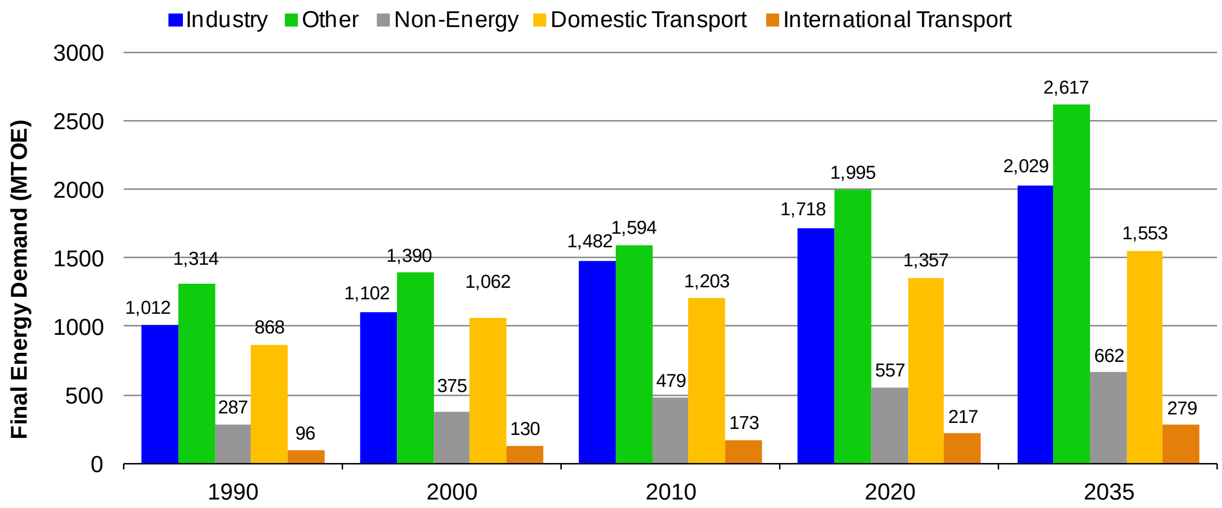
Figure 2.2: APEC Final Energy Demand by Energy Type



Source: APERC Analysis (2012)

Figure 2.3 shows that, between 2010 and 2035, final demand will grow in all the five sectors we model. The 'other' sector (residential and commercial) will grow the fastest in both absolute (up 1023 Mtoe) and percentage (up 64%) terms. However, international transport will grow almost as quickly (up 61%), reflecting an increasingly globalized economy. Domestic transport demand, on the other hand, will be the slowest growing sector, with energy demand growing by 'only' 29%. In this sector, increasing auto ownership will be offset somewhat by increasingly efficient vehicles.

Figure 2.3: APEC Final Energy Demand by Sector



Source: APERC Analysis (2012)

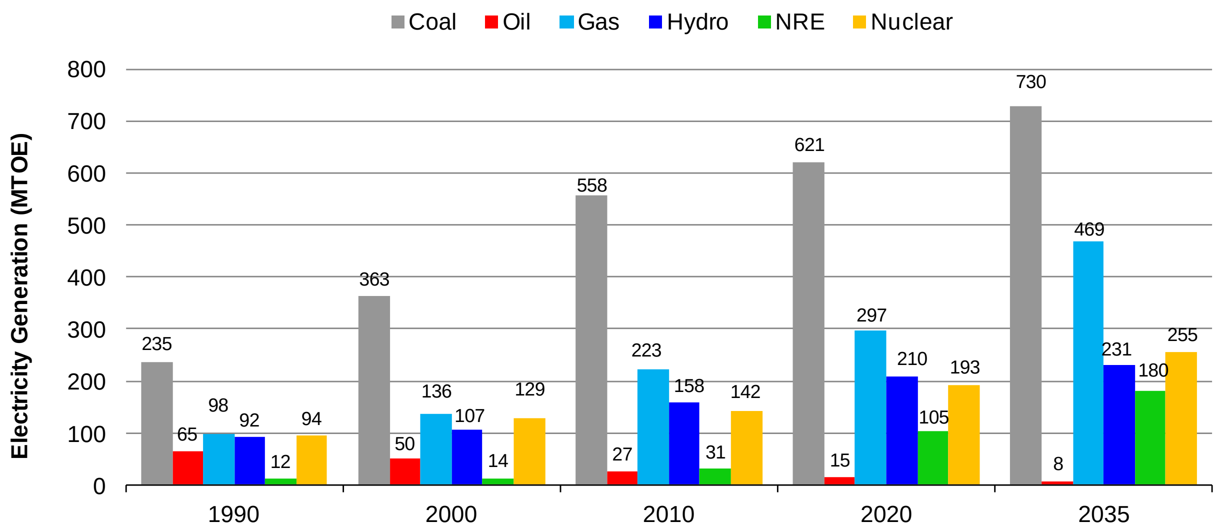
ELECTRICITY SUPPLY

As shown in Figure 2.4, coal was by far the dominant source of primary energy for electricity generation in the APEC region in 2010. Under our BAU assumptions, it will continue to be so in 2035. Coal has the advantages of being widely available and relatively inexpensive in many APEC economies. Therefore, it will experience significant growth: 172 Mtoe or 2002 terawatt-hours (TWh). Growth in China's output of electricity from coal accounts for most of this growth (161 Mtoe or 1872 TWh), while coal generation in the United States is projected to decline by 37 Mtoe or 426 TWh.

The absolute demand for natural gas generation will grow much more rapidly than coal (246 Mtoe or 2867 TWh). Gas has the advantages of also being widely available in many APEC economies and environmentally preferable to coal, since its greenhouse gas emissions are generally lower. New renewable energy (NRE) (which does not include hydro) will show the third-largest absolute growth of 150 Mtoe or 1740 TWh, spurred by declining costs and supportive government policies in many economies. Despite the re-examination of policies on nuclear energy in many APEC economies, nuclear generation is also projected to show a significant growth of 113 Mtoe or 1315 TWh. About two-thirds of this growth will be in China.

In percentage terms, the picture is different. NRE will have by far the largest percentage growth of 490%, followed by gas (111%), and nuclear (89%). As discussed in Chapter 15 (see Figure 15.5), the growth of NRE in electricity generation is dominated by wind energy. Coal generation will grow by about 31%.

Figure 2.4: APEC Electricity Generation by Primary Energy Source



Source: APERC Analysis (2012)

PRIMARY ENERGY SUPPLY

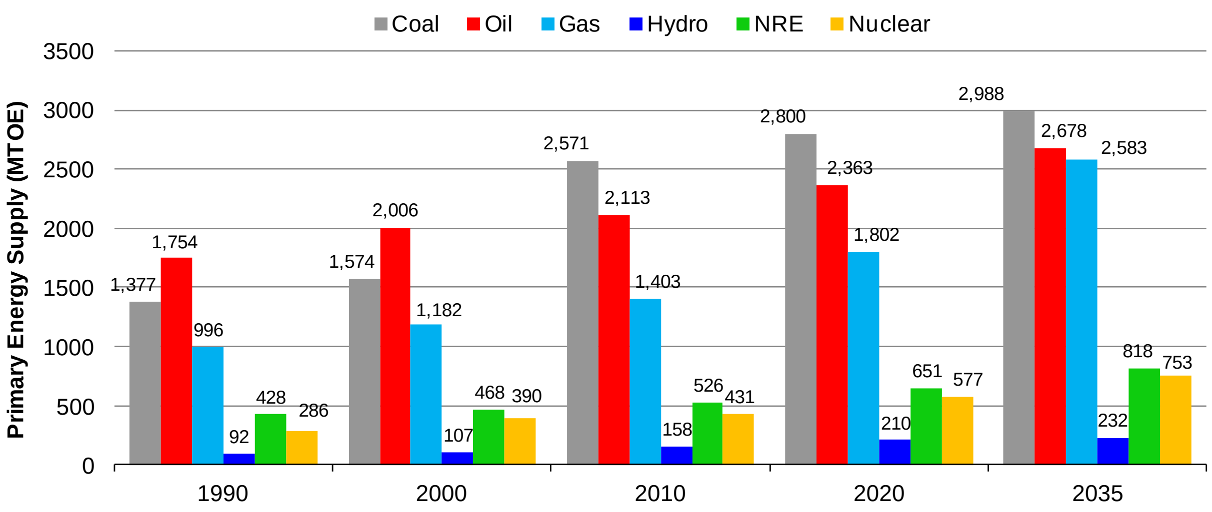
As shown in Figure 2.5, under BAU assumptions coal, oil and natural gas run a close competition to be APEC's leading primary energy source by 2035, with coal still having a slight lead in 2035.

In absolute terms, gas will have the fastest growth in demand between 2010 and 2035 (up 11879 Mtoe). As discussed in Chapter 12, gas supply is benefiting from new technology that allows the economic development of unconventional gas resources. However, our BAU projection may be conservative in that it does not assume large-scale development of shale gas outside of North America. The demand for oil will also grow significantly in absolute terms—565 Mtoe.

Gas also has the largest growth in percentage terms—up 84%. Perhaps surprisingly, nuclear energy is projected to show the second fastest growth in percentage terms, about 75%. As noted above, about two-thirds of this growth will be in China.

NRE will take third place with 55% growth. As discussed above, the use of NRE will grow quickly in electricity generation (up 490%). It will also grow quickly in the domestic transport sector in the form of biofuels (about 130%). In both sectors, this growth will be spurred by favourable existing government policies toward NRE in many APEC economies, as well as technological improvements. However, the use of NRE in the residential and commercial ('other') sector, which accounted for about 60% of the NRE demand in 2010, is not expected to show significant growth. As explained above, many residential and commercial consumers in developing economies are expected to switch their cooking and heating from traditional biomass to commercial fuels as they become able to afford it

Figure 2.5: APEC Primary Energy Supply by Energy Source

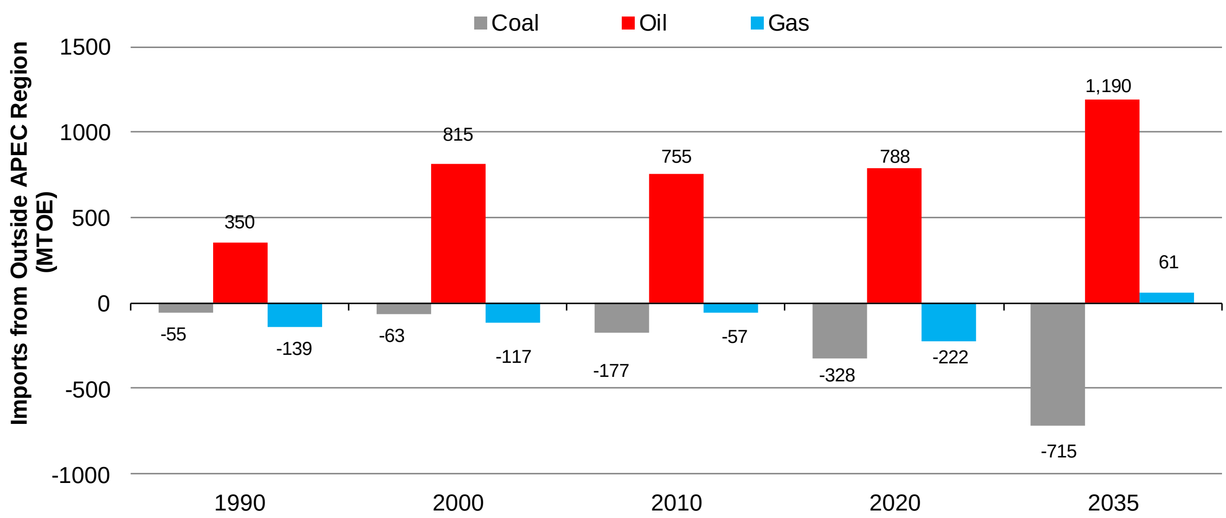


Source: APERC Analysis (2012)

ENERGY IMPORTS FROM OUTSIDE THE APEC REGION

As shown in Figure 2.6, under BAU assumptions, over the 2010–2035 period the APEC region will be a growing exporter of coal to the rest of the world, roughly self-sufficient in gas, and a large and growing importer of oil. In 2010, the APEC region imported about 36% of its primary supply of oil. By 2035, this will rise to about 44% of a significantly larger primary supply of oil. As discussed in Chapter 1, this rising dependence on imported oil poses a serious threat to the economic stability and energy security of the APEC region.

Figure 2.6: APEC Net Imports from Outside the APEC Region



Source: APERC Analysis (2012)

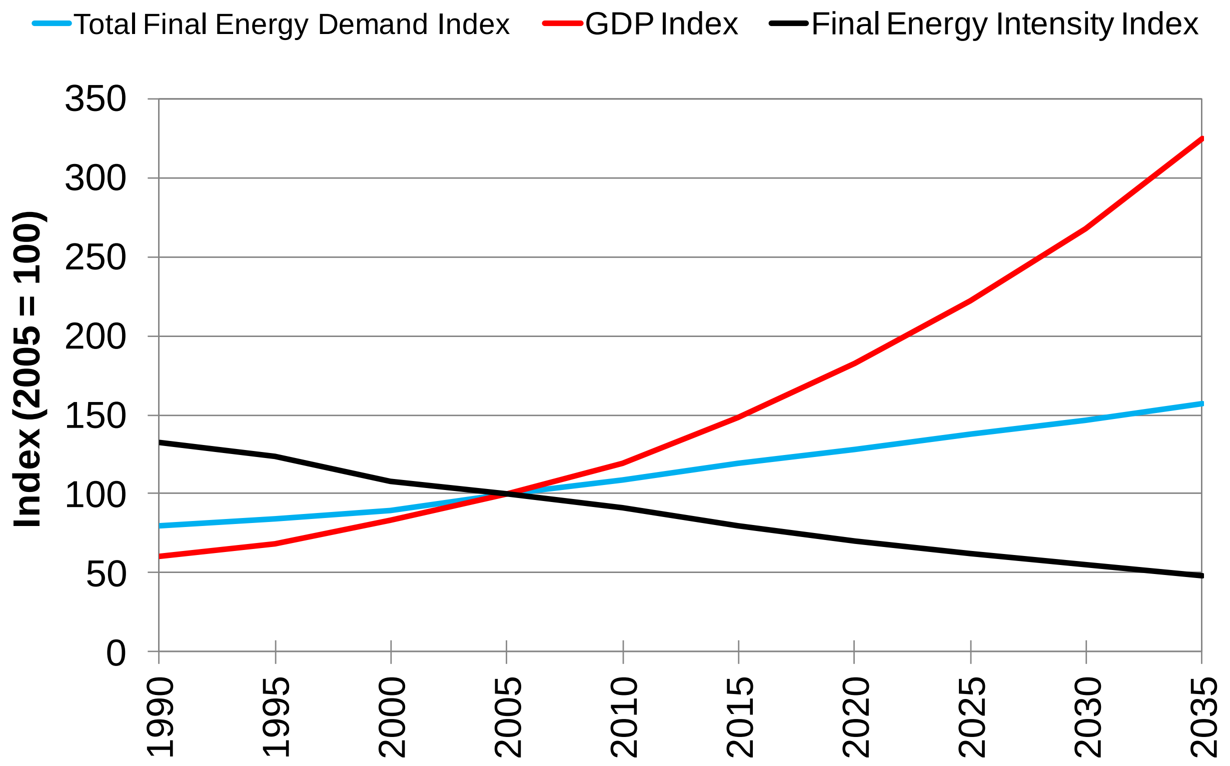
ENERGY INTENSITY

The APEC leaders have agreed to "aspire to reduce APEC's aggregate energy intensity by 45% by 2035" (APEC, 2011), using 2005 as the base year. Energy intensity is defined as energy use divided by gross domestic product (GDP). The APEC energy intensity goal is intended to encourage the APEC economies to work together to improve their energy efficiency to gain economic benefits (cost savings, less exposure to energy price increases), improved energy security, and improved environmental sustainability.

The model results presented here suggest the APEC region will meet the APEC leaders' energy intensity goal under BAU. The APEC leaders did not specify whether energy intensity is to be calculated based on final energy demand or primary energy supply. Figure 2.7 shows the intensity results based on final energy demand, while Figure 2.8 shows the intensity projection based on primary energy supply.

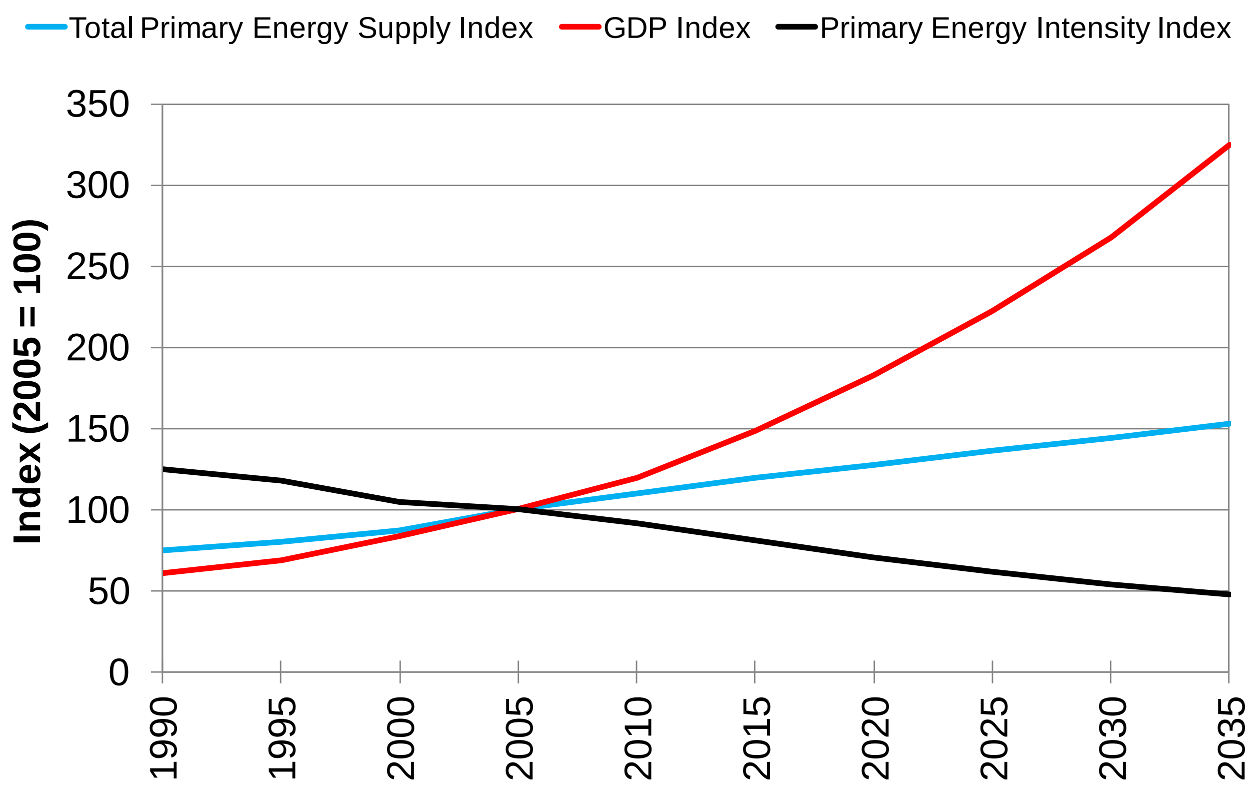
The results in the two cases are virtually identical. Final energy demand increases by about 57% while primary energy supply increases by about 53%. GDP increases by about 225%. The net result in is a decline in final energy intensity of about 48% and a decline in primary energy intensity of about 47%, both exceeding the 45% goal.

Figure 2.7: APEC Final Energy Intensity Improvement



Source: APERC Analysis (2012)

Figure 2.8: APEC Primary Energy Intensity Improvement



Source: APERC Analysis (2012)

Changes in energy intensity can result from changes in energy efficiency as well as from changes in economic structure (where economic sectors with different energy intensities grow or contract at different rates). Changes in economic structure, such as a transition from manufacturing to service industries, can significantly change the energy intensity of an economy.

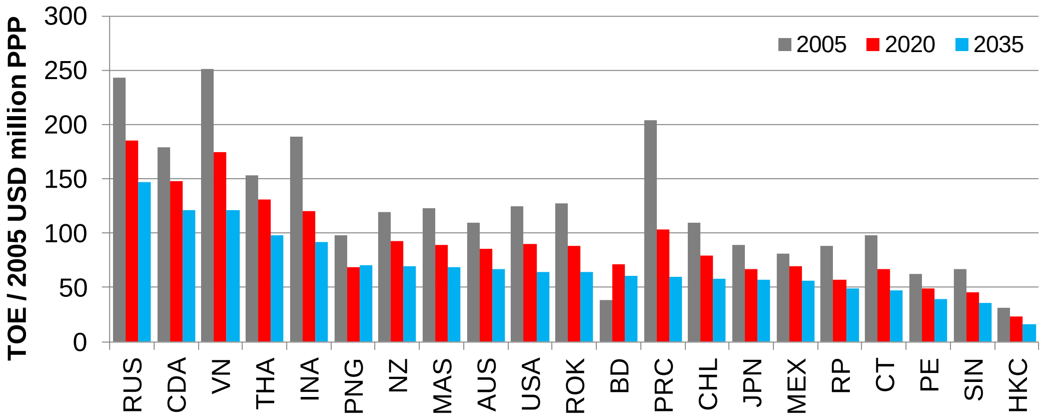
Figure 2.9 shows the expected changes in final energy intensity by economy, while Figure 2.10 shows the expected changes in primary energy intensity by economy.

Every APEC economy, with the exception of Brunei Darussalam for final energy intensity only, is expected to show a significant improvement in energy intensity between 2005 and 2035. (Brunei Darussalam is an outlier only because in 2010 they opened a large export-oriented methanol plant, which significantly increased their industrial energy demand.) There will be a tendency for the economies with the highest energy intensity to show the highest levels of intensity improvement. This will happen as global competitive pressures, government policies, and international cooperation lead all APEC economies to move toward international best practice.

The fact it is likely APEC will meet the APEC leaders' goal for energy intensity improvement under BAU should not be a cause for complacency. As noted in the previous section, despite the improvement in energy intensity, oil imports into the APEC region will grow significantly, posing serious economic and energy security risks. Greenhouse gas emissions from fuel combustion will also rise significantly, the opposite of what the best science says is needed to deal with the challenges of climate change.

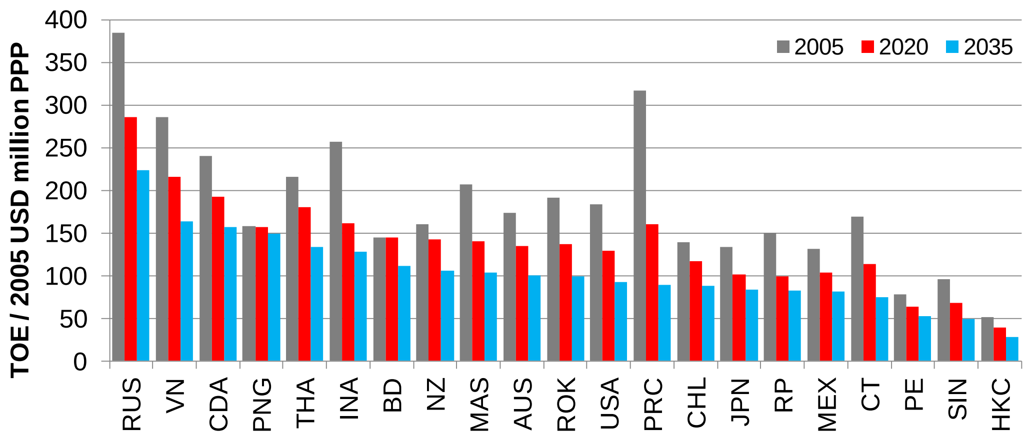
There are a number of factors that can explain the variations in energy intensity among APEC economies. The ratio can be affected by many non-energy-related factors such as climate, geography, travel distances, home sizes and industrial structures (IEA, 2008). As such, it would be misleading to judge an economy's energy-efficiency performance based on its energy intensity alone.

Figure 2.9: APEC Final Energy Intensity by Economy



Source: APERC Analysis (2012)

Figure 2.10: APEC Primary Energy Intensity by Economy



Source: APERC Analysis (2012)

APEC'S ENERGY INTENSITY GOAL: THE LESSONS LEARNED

When the APEC leaders first agreed on an energy intensity improvement goal in 2007, the goal was an improvement of at least 25% by 2030 with 2005 as the base year (APEC, 2007). The goal was revised upward in 2011 to an improvement of 45% by 2035 with 2005 as the base year (APEC, 2011) since it was becoming apparent that APEC economies would easily surpass the original goal. APERC's research work to support the APEC Energy Working Group (EWG) in establishing a revised goal suggests three key lessons that any organization wishing to set an energy intensity improvement goal may wish to keep in mind:

1) *Energy intensity improvement is happening surprisingly quickly, but not quickly enough to meet the world's energy challenges.* Large reductions in energy intensity, in the order of 35–40%, can be expected between 2005 and 2035. However, because of expected rapid economic growth, especially in developing economies, these improvements in energy intensity will not stop the growth of energy demand, with its associated threats to the environment and the stability of the world economy.

2) *It is difficult to find a definition of energy intensity that can make it suitable for use as an indicator of regional energy efficiency.* There are at least three alternative approaches to measuring energy demand, the numerator in the calculation of energy intensity (energy demand/GDP). First, energy intensity can be calculated based on the 'physical energy content' method used by the International Energy Agency (IEA), the OECD, and Eurostat (IEA et al., 2004). However, under this approach, energy intensity will increase (get worse) if an economy uses more nuclear or geothermal electricity generation. The reason is that, under this approach, both nuclear and geothermal have large 'losses' between their primary energy input (nuclear-produced steam and geothermal steam, respectively) and their final energy output (electricity), and are thus counted as inefficient forms of generation. This anomalous outcome runs counter to a presumed objective of the energy intensity improvement goal, which is to encourage low-carbon energy sources, including nuclear and geothermal.

   A second alternative is to calculate energy intensity based on final energy demand (energy after conversion to electricity) rather than primary energy supply. This approach would give a clearer measure of end-user energy efficiency improvement, which is the focus of energy efficiency improvement efforts in many economies. However, it would not reflect the improvements an economy makes in the efficiency of its electricity generation, which in many economies represents a major opportunity to improve energy efficiency.

   A third alternative is to use primary energy calculated using the 'direct equivalent method', as used in the United Nations Statistics Division and various IPCC (Intergovernmental Panel on Climate Change) reports (Moomaw et al., 2011, Appendix II.4). This approach simply counts one unit of electricity generated from nuclear or renewables other than biomass as one unit of primary energy, effectively assuming generation from these low-carbon sources to be 100% efficient. This method would avoid the anomalous outcome of the 'physical energy content method', while still reflecting improvements in fossil fuel generating efficiency. However, it is less well-known among policy-makers and therefore potentially confusing to them.

   The EWG took no position as to whether primary energy or final energy should be used to calculate energy intensity, but it did reject the direct equivalent method for the calculation of primary energy (APEC EWG, 2011). Therefore, primary energy in this publication is calculated using the 'physical energy content' method.

3) *Whether the GDPs of individual economies are converted to a common currency using market exchange rates or purchasing power parity (PPP) can dramatically change the energy intensity improvement calculations.* To calculate energy intensity for a group of economies, one must first calculate their aggregate GDP, the denominator in the calculation of energy intensity (energy demand/GDP). The literature suggests that PPP is the more correct aggregation approach because it is the actual purchasing power of each economy that will drive its energy use (Samuelson, 2012). Energy intensity improvement will typically be downward biased if aggregate GDP is calculated using market exchange rates rather than purchasing power parities. The reason is the economies with the highest market exchange rates relative to purchasing power tend to be the developed economies, which also tend to have lower growth rates than developing economies. Hence, aggregate GDP growth will be slower if calculated using market exchange rates than it would be using PPP, causing energy intensity to decline more slowly. In this publication, all GDP values are consistently expressed in terms of 2005 PPPs.

This sidebar is a summary of Samuelson (2012), a draft paper intended for future publication in a professional journal.

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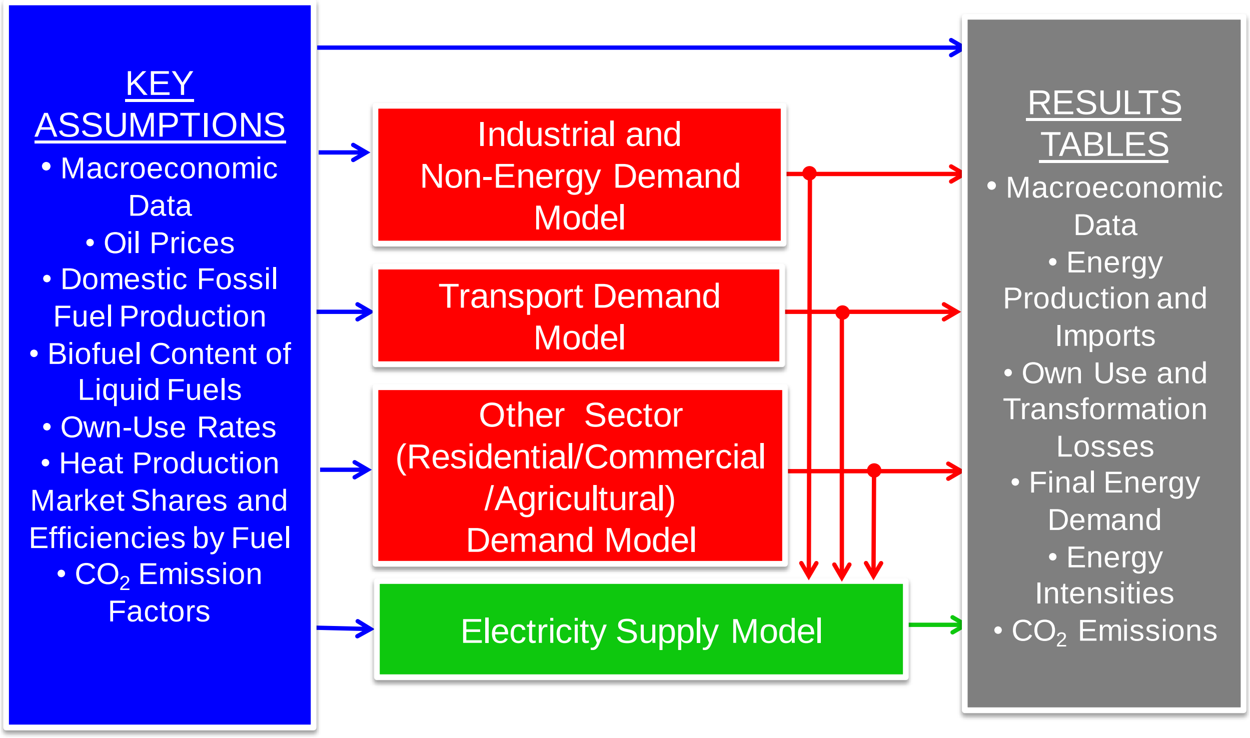
3 OVERVIEW OF APERC'S ENERGY DEMAND AND SUPPLY MODEL

Figure 3.1: Structure of APERC's Model



This chapter presents an overview of the model APERC has used to project energy demand and supply by economy and for APEC as a whole. It also discusses the key assumptions that were made in developing these projections.

MODEL OVERVIEW

Figure 3.1 shows the overall structure of the model for each economy; the model is always the same for each of the 21 APEC economies. APERC's regional and APEC-wide results are simply sums of results for the relevant economies.

The modelling process begins by assembling a database of key assumptions for each economy. These key assumptions are either required by more than one of the sub-models or are used in the summary sheets to estimate results not modelled in one of the sub-models. These key assumptions include:

- historical and projected macroeconomic data (including population, GDP, employment, and agricultural value-added projections)
- historical and projected crude oil prices
- historical and projected domestic fossil fuel production (including coal, oil, and gas)
- historical and projected percentage content of biofuel in road gasoline, road diesel, and rail diesel
- historical and projected average energy sector own-use rates (for coal, oil, and gas)
- historical and projected fuel shares and efficiency rates for heat production (coal, oil, gas, new renewable energy (NRE), and nuclear)
- CO_2 emissions factors for coal, oil, and gas.

The development of these key assumptions estimates is discussed in subsequent sections of this chapter.

There are three sub-models that estimate energy demand in key sectors. These are:

- *The Transport Demand Model.* This sub-model projects demand in the transport sector, for both domestic and international transport. It is discussed in more detail in Chapter 5 on Transport Sector Energy Demand.
- *The Industrial Demand Model.* This sub-model projects demand in the industrial sector, for both energy consumed in industry and 'non-energy'. Non-energy refers to coal, oil, and gas used as feedstocks in the production of petrochemicals and other non-fuel products. This sub-model is discussed in more detail in Chapter 6 on Industrial Sector Energy Demand.
- *The Other Sector Demand Model.* This sub-model projects demand in the residential, commercial, and agricultural sectors. It is discussed in more detail in Chapter 8 on Residential, Commercial, and Agricultural Sector Energy Demand.

These three sub-models also require a number of additional assumptions. These are examined in the chapters that discuss each sub-model.

The fourth sub-model is:

- *The Electricity Supply Model.* This takes as inputs the demand for electricity projected by the three sub-models (above) and simulates the production of this electricity from primary fuels. It also simulates the capacity expansion for each type of electricity generating capacity.

Finally, the Results Tables pull together the results of all four sub-models and present them in an organized fashion. They include a complete energy supply and demand balance sheet for each economy, known as the Summary Table.

The Results Tables are, however, not just passive reports; they contain 'models' for some outputs not modelled in the four sub-models, although the models are fairly simple. These outputs include:

- *Energy sector own-use.* This is the energy consumed in the energy sector itself, including in energy production and in refineries. These projections are based on the loss rates in the Key Assumptions database (see above). However, energy losses in the production, transmission, and distribution of electricity are modelled in the Electricity Supply Model. The demand for fuel used to operate gas and oil pipelines is modelled in the Transport Demand Model.
- *CO_2 emissions from energy combustion.* These are modelled by multiplying the assumed emissions factors for each fuel by the quantities of each fuel demanded. This modelling is discussed in more detail in Chapter 16 on Carbon Dioxide Emissions.
- *Liquid biofuel demand.* The Transport Demand Model estimates the final demand for gasoline and diesel fuel in the road sector and diesel fuel in the rail sector. The Results Tables break each of these demands into the demand for oil product and the demand for biofuel, based on the percentage content of biofuel shown in the Key Assumptions database (see above).
- *Heat production.* The Other Sector Demand Model and the Industrial Demand Model estimate the demand for heat (usually in the form of steam) in these sectors. The Results Tables use the fuel shares and efficiency rates shown in the Key Assumptions database (see above) to estimate the demand for the primary fuels needed to produce heat. Note, 'heat production' refers only to heat produced for sale; it does not include self-produced heat.

The Results Tables also calculate projected energy intensities for each economy (see Chapter 2) and produce a set of graphs for each economy, some of which are reproduced in Volume 2.

Because of their size, the Results Tables for each economy are not reproduced in this report. Rather, they are available on-line on the APERC website http://aperc.ieej.or.jp. There is an on-line document that explains how to read the Results Tables and defines the terms used.

The APERC website includes business-as-usual (BAU) Results Tables for each APEC economy, along with a Results Table for the APEC region as a whole. It also includes a similar set of Results Tables for the High Gas Scenario discussed in Chapter 12 on Natural Gas Supply.

HISTORICAL DATA SOURCES AND KEY ASSUMPTIONS

This section discusses the historical data sources and key assumption projections for key assumptions other than macroeconomic data, oil prices, and domestic fossil fuel production. Macroeconomic data and oil prices are discussed in later sections of this chapter. Domestic fossil fuel production is discussed in Chapter 10 on Primary Energy Demand and Supply.

Historical Data on Energy Demand and Supply

Many of the graphs and tables in this outlook report, as well as the Results Tables, show historical data for 2009 and prior years for comparison with APERC's future outlook. For all economies except Papua New Guinea, this data is from International Energy Agency (IEA) statistics (IEA, 2011c). It is reproduced here with the kind permission of the IEA and is ©2011 IEA/OECD. For Papua New Guinea, the historical data is from the APEC Energy Database (APEC, 2011).

Biofuel Content of Gasoline and Diesel

Historical data on the percentage content of biofuel in road gasoline, road diesel, and rail diesel was obtained from the IEA (IEA, 2011c). Future projections for the BAU scenario were estimated by APERC researchers based on the requirements of the existing laws and regulations in each economy. For economies with no legal biofuel requirements, researchers estimated the amount of biofuel that might be economic in a competitive market, which was generally a very small or zero amount.

Energy Sector Own-Use Rates

Historical data on the percentage energy sector own-use of each fuel was obtained from the International Energy Agency (IEA, 2011c). In most cases, the 2009 percentage rates were assumed to continue into the future. However, in some cases APERC researchers made adjustments based on projected changes to the economy's energy infrastructure or production methods.

Fuel Shares and Efficiency Rates for Heat Production

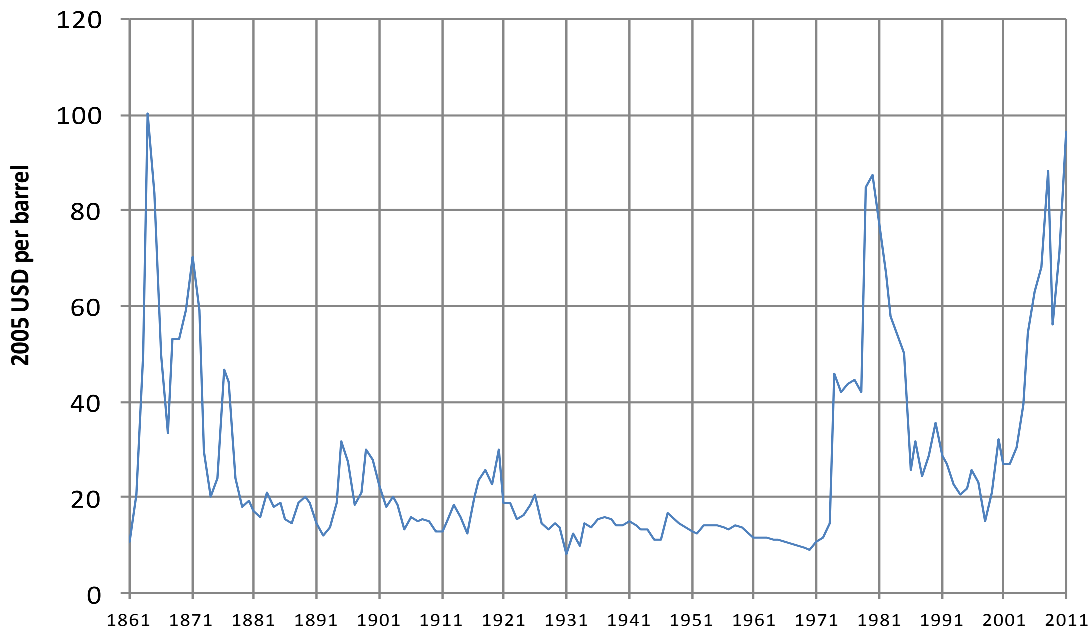
Historical data on fuel shares and efficiency rates for heat production for each fuel was obtained from the IEA (IEA, 2011c). In most cases, the 2009 fuel shares and efficiency rates were assumed to continue into the future. However, in some cases APERC researchers made adjustments based on projected changes to the economy's energy infrastructure or primary energy production. Note, only a few APEC economies have significant commercial heat production.

OIL PRICE AND AVAILABILITY ASSUMPTIONS

Crude Oil Prices and Resources Availability

As depicted in Figure 3.2, crude oil prices have been historically volatile. Particularly since the 1970s, oil prices have been susceptible to geopolitical events that have affected global supply. The major price upswings were caused by the Arab Oil Embargo and the Iranian Revolution in the 1970s, and more recently by the Iraq War and the social movements known as the 'Arab Spring' in North Africa and the Middle East. This volatility has made crude oil prices rather complex to analyse and project.

Figure 3.2: International Crude Oil Prices, 1861–2011



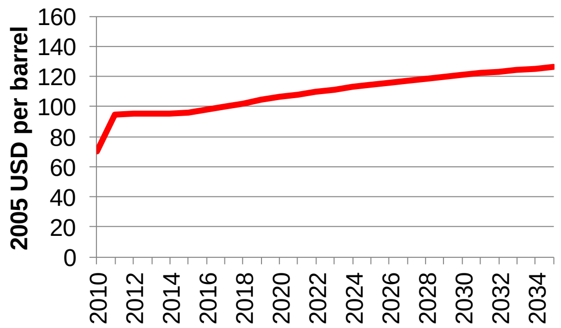
Source: BP (2012)

APERC bases its crude oil price assumptions on the modelling work of the IEA for their *World Energy Outlook 2011* (IEA, 2011b). In particular, APERC follows the crude oil price assumptions of the IEA's Current Policies scenario which, like APERC's BAU scenario, assumes the continuance of existing policies. The IEA bases its crude oil price projections on a sophisticated field-by-field model of the worldwide crude oil supply (IEA, 2011a).

There are many different crude oil prices in the world. The crude oil price projected by IEA is an average price for crude oil imports into IEA member economies. However, over the long term, this price tends to closely mirror the price of key marker crudes, such as Brent and West Texas Intermediate (WTI).

Figure 3.3 shows APERC's assumed crude oil prices for this edition of the *APEC Energy Demand and Supply Outlook*. The oil price assumed by 2035 amounts to USD 126 per barrel, and represents a 79.2% jump from the IEA's 2010 average crude oil import price. Despite the smooth trend suggested by the projection, unpredictable events are nearly certain to cause prices to continue to fluctuate dramatically, as they have in the past.

Figure 3.3: APERC's Crude Oil Price Assumptions, 2010–2035



Note: Actual data from 2010 and 2011
Source: IEA (2011b)

Aside from the uncertainties due to unpredictable short-term events, there are also uncertainties about the long-term evolution of oil supply. In particular, the perspectives of analysts differ on the long-term sufficiency of oil resources. However, there appears to be a reasonable alignment between the views of the Organization of the Petroleum Exporting Countries (OPEC), which represents the major oil exporting economies, and those of the IEA, which represents the major oil importing economies.

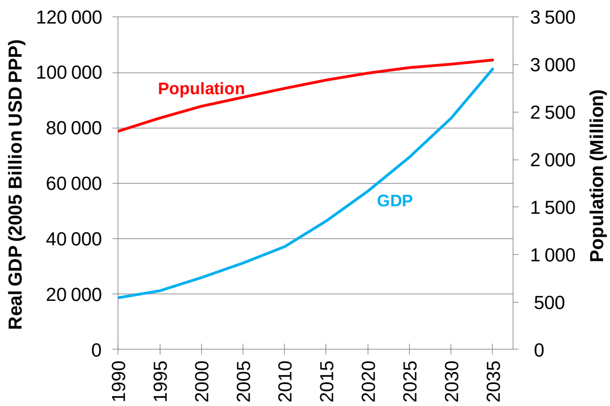
OPEC's opinion is "the world has enough oil resources to meet demand and satisfy consumer needs for decades to come" (OPEC, 2011, p. 2). The IEA's position accepts the "end of cheap oil" and stresses the risks of underinvestment by Middle Eastern and African oil producing countries, but does not appear to question the basic adequacy of oil resources for the foreseeable future (IEA, 2011b, p. 41).

There is a general consensus that unconventional resources will be increasingly important to the world's oil supply, and that these resources will be difficult and costly to develop. Consequently, it is likely higher prices will prevail in the years to come.

MACROECONOMIC DATA ASSUMPTIONS

Figure 3.4 shows the assumed APEC-wide GDP and population up to 2035; Table 3.1 shows the assumed APEC-wide growth rates for GDP and population for the same period. Reflecting the growing GDP share of fast-growing developing economies and the recent demographic trends, the GDP growth rate over the 25-year outlook period is assumed to be slightly higher than that of the previous 20 years, while the population growth rate is a bit lower.

Figure 3.4: Assumed APEC GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Table 3.1: Assumed APEC GDP and Population Growth Rates

Growth	GDP (%)	Population (%)
1990—2005	3.4	1.0
2005—2010	3.6	0.7
2005—2030	4.0	0.5
2005—2035	4.0	0.5
2010—2035	4.1	0.4

Sources: Global Insight (2012) and APERC Analysis (2012)

GDP, Employment, and Agricultural Value-Added

Historical figures and future projections of GDP, employment, and agricultural value-added for all economies except Brunei Darussalam and Papua New Guinea were obtained from IHS Global Insight (Global Insight, 2012), a well-known macroeconomic forecasting service, as of May 2012. In a few cases, the data was modified by APERC researchers based on data from the United States Department of Agriculture (USDA, 2011) as of December 2011, or from other sources. Projections for 2032–2035 are trend extrapolations by APERC.

For Brunei Darussalam and Papua New Guinea (economies not covered by IHS Global Insight), historical and projected GDP data was obtained from the United States Department of Agriculture (USDA, 2011) as of December 2011. Employment in these economies was assumed to grow in proportion to the population, while agricultural value-added was assumed to grow in proportion to GDP. Projections for 2031–2035 are trend extrapolations by APERC.

For all economies, the original source data on real GDP in local currency was converted to 2005 purchasing power parity (PPP) values using conversion rates from the World Bank (The World Bank, 2008, Summary Table).

Table 3.2 shows the assumed projections of total GDP and GDP per capita, by economy. The economies that have the lowest income per capita in 2010 will tend to have the largest percentage increases in GDP. There will thus be a tendency in the APEC region toward less income disparity between economies by 2035.

Population Assumptions

Historical and projected population figures for each economy are based on data and projections by Global Insight (2012). They are generally based on United Nations projections (United Nations, 2011).

Table 3.2: Assumed Projections of Total GDP and GDP per Capita by Economy

Economy	Total GDP (Billion USD PPP)			GDP Growth Rate (%)	GDP per Capita (USD PPP)		
	2010	2020	2035	2010–2035	2010	2020	2035
Australia	790	1 038	1 533	2.7%	35 460	41 103	52 755
Brunei Darussalam	18	22	28	1.7%	45 763	46 731	50 564
Canada	1 206	1 539	2 170	2.4%	35 383	40 543	49 320
Chile	233	375	724	4.6%	13 644	20 299	36 259
China	9 120	19 564	45 117	6.6%	6 802	14 099	32 415
Hong Kong, China	295	447	729	3.7%	41 818	59 667	86 727
Indonesia	931	1 603	3 341	5.2%	3 880	6 106	11 605
Japan	3 946	4 430	4 672	0.7%	30 807	35 539	40 044
Korea	1 321	1 885	2 727	2.9%	27 415	37 845	54 025
Malaysia	376	576	1 000	4.0%	13 244	17 450	25 325
Mexico	1 410	2 056	3 433	3.6%	12 427	16 326	24 515
New Zealand	110	142	203	2.5%	25 258	29 500	37 570
Papua New Guinea	15	27	45	4.4%	2 217	3 311	4 044
Peru	248	407	788	4.7%	8 417	11 945	20 956
Philippines	332	526	1 006	4.5%	3 561	4 792	7 443
Russian Federation	2 014	2 868	4 505	3.3%	14 348	20 336	33 617
Singapore	264	398	632	3.6%	51 801	71 057	102 588
Chinese Taipei	743	1 078	1 687	3.3%	32 249	47 598	70 611
Thailand	530	783	1 505	4.3%	7 674	10 864	20 392
United States	13 088	16 843	24 362	2.5%	42 157	49 305	62 389
Viet Nam	250	462	1 148	6.3%	2 845	4 803	11 055

Source: APERC Analysis (2012), based on data from Global Insight (2012) and USDA (2012)

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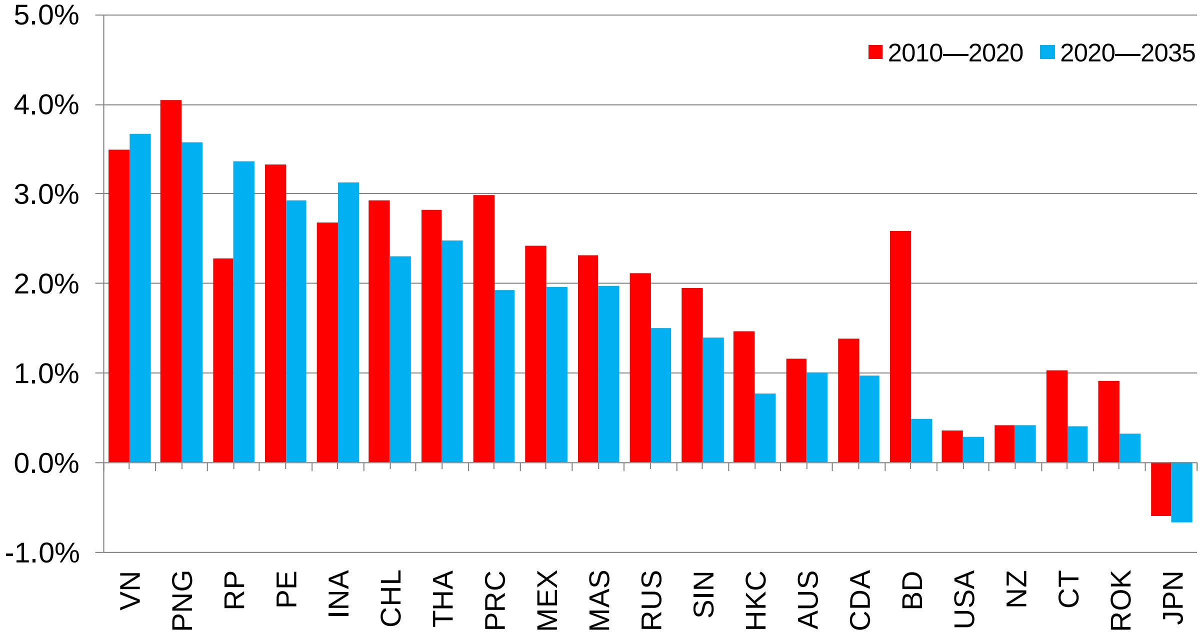
4 FINAL ENERGY DEMAND

TOTAL FINAL ENERGY DEMAND

The projected APEC final energy demand will increase over the outlook period from 4758 Mtoe in 2010 to 6861 Mtoe in 2035. This represents an increase of 44%, and an average annual growth rate of 1.5% between 2010 and 2035.

Figure 4.1 shows the growth rates by economy for the periods 2010–2020 and 2020–2035. As one would expect, the developing economies tend to have the faster growth rates, while final energy demand in the developed economies grows more slowly or, in the case of Japan, actually declines.

Figure 4.1: Annual Percentage Growth Rates in Final Energy Demand by Economy



Source: APERC Analysis (2012)

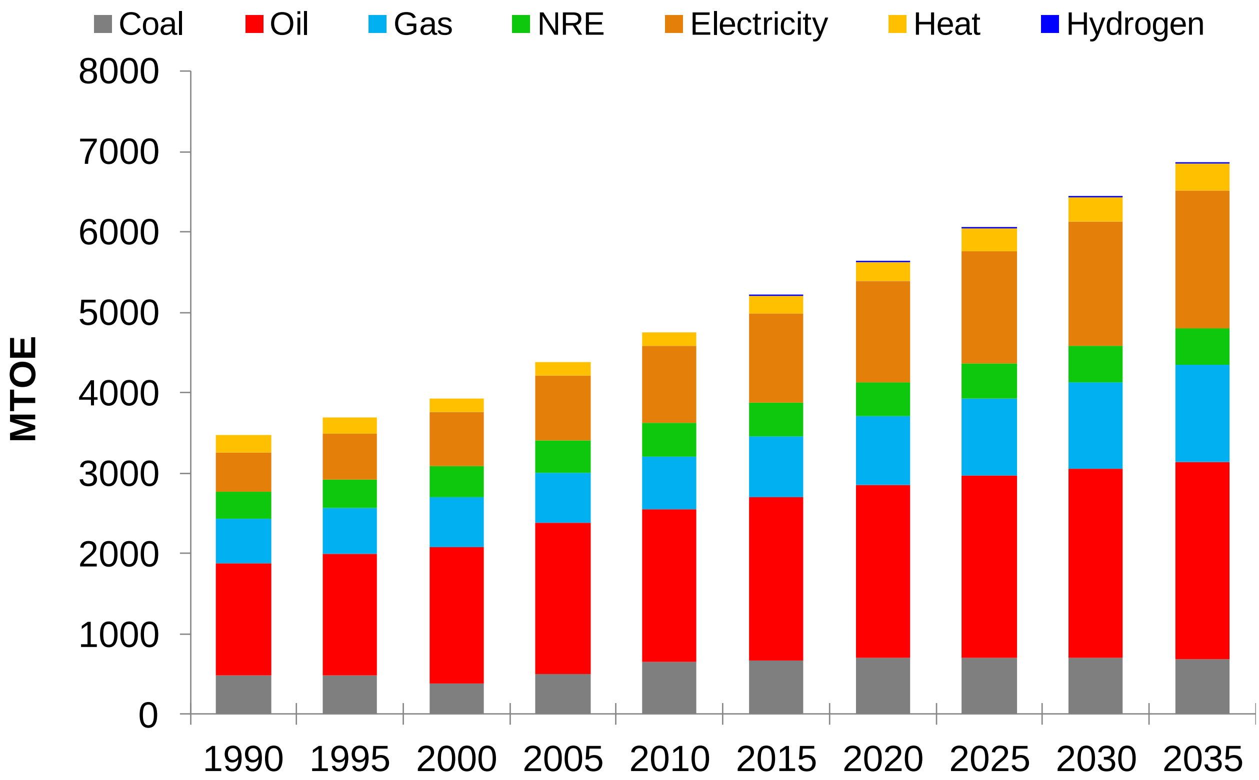
Final Energy Demand by Energy Source

Figure 4.2 shows the total APEC final energy demand by energy source. Figures 4.3 and 4.4 show these results broken out by economy. Note the difference in the vertical axis scales for the latter two figures.

Figures 4.3 and 4.4 show that China and the US will dominate the final energy demand in the APEC region: together they will account for more than 60% of the APEC final energy demand in 2035. China's final energy demand had already overtaken that of the US in 2010, and it is projected to grow at a rate of 2.3% over the 2010–2035 period, compared to 0.3% for the US.

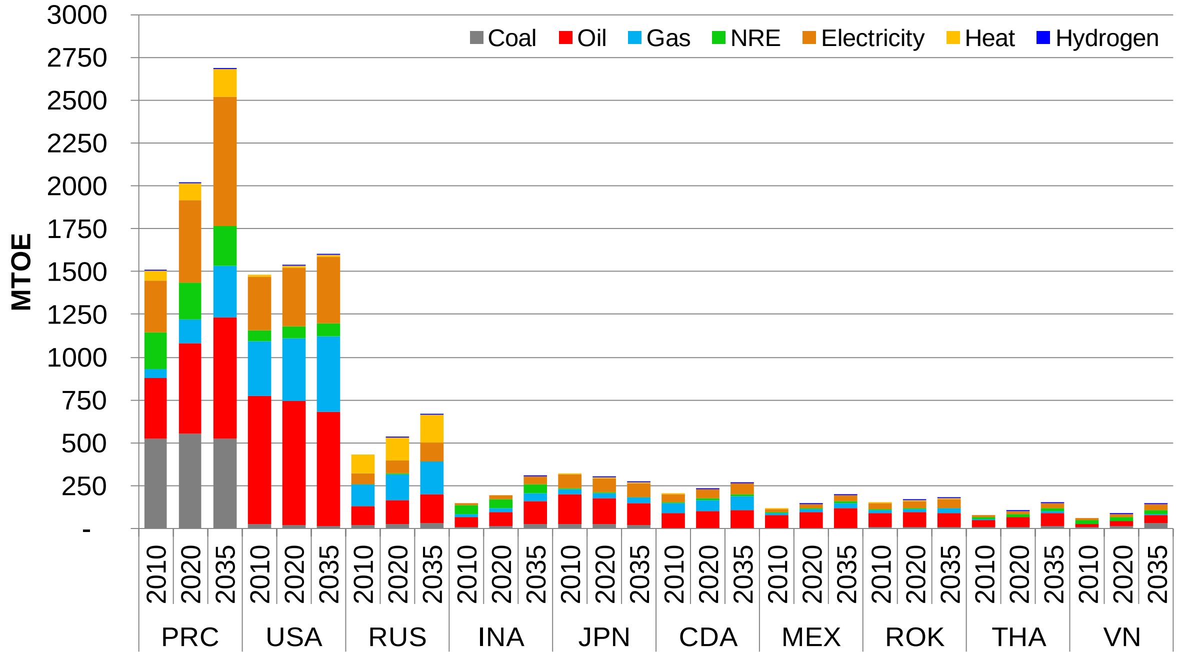
China will also clearly dominate the final demand for coal in the APEC region, accounting for about 76% of the APEC region's final coal demand in 2035. (Note that final demand for coal excludes the demand for coal in power plants, which will be much more widely distributed across the APEC economies.) The US has historically dominated demand for oil in the APEC region, accounting for about 40% of the region's final oil demand in 2010, but by 2035, China's demand for oil will slightly exceed that of the US; at that time, China's share of APEC oil demand will be 28% while the US share will be 27%.

Figure 4.2: APEC Final Energy Demand by Energy Source



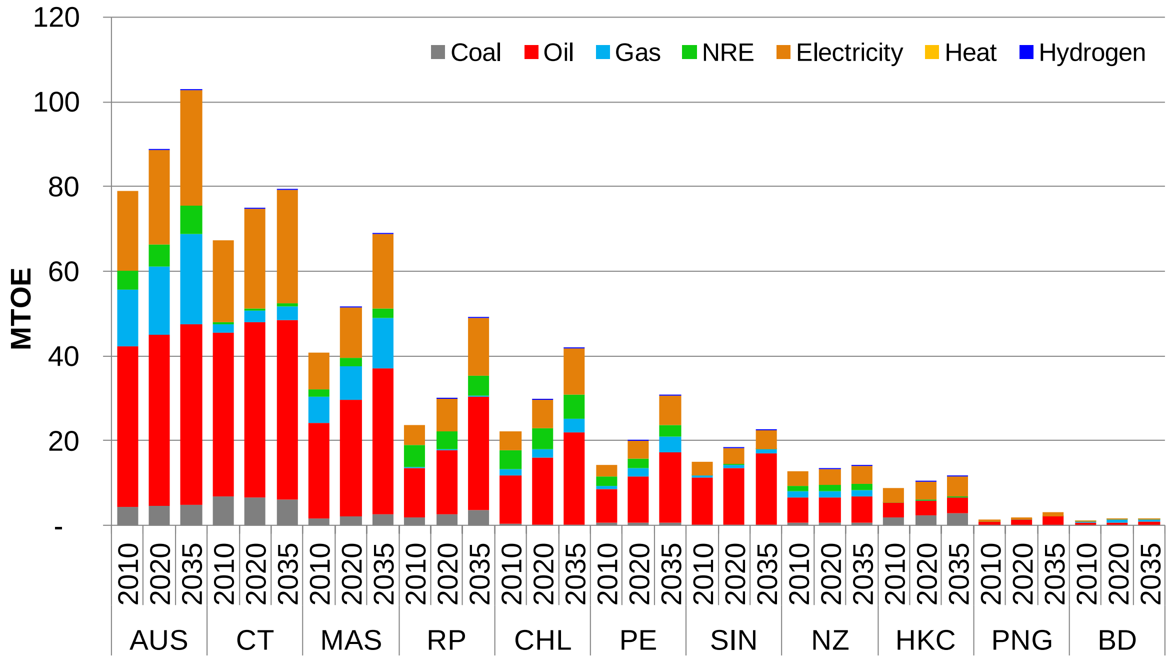
Source: APERC Analysis (2012)

Figure 4.3: Final Energy Demand by Energy Source, Higher Final Demand Economies



Source: APERC Analysis (2012)

Figure 4.4: Final Energy Demand by Energy Source, Lower Final Demand Economies

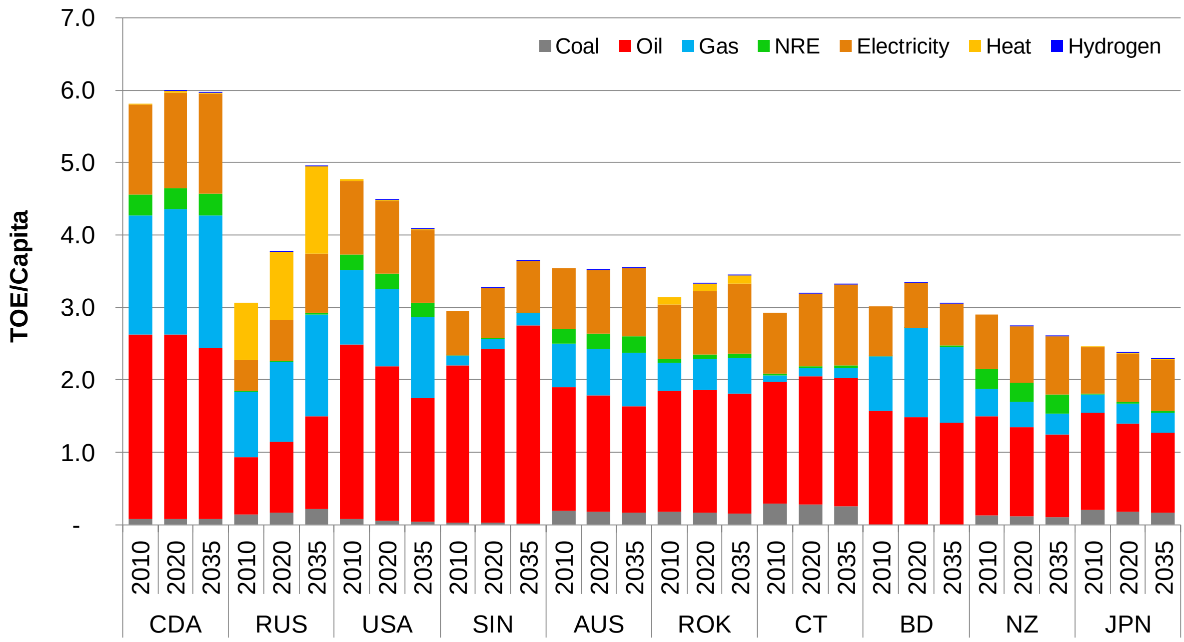


Source: APERC Analysis (2012)

Figures 4.5 and 4.6 show the final energy demands by energy source on a per capita basis. Again, note the differences in the vertical axis scale between the two figures. There are stark differences in final energy demand per capita between the economies with the highest per capita demand and the economies with the lowest per capita demand. Naturally, per capita consumption tends to be highest in the developed economies and lowest in the developing economies. Some developing economies are projected to show large increases in per capita final energy demand.

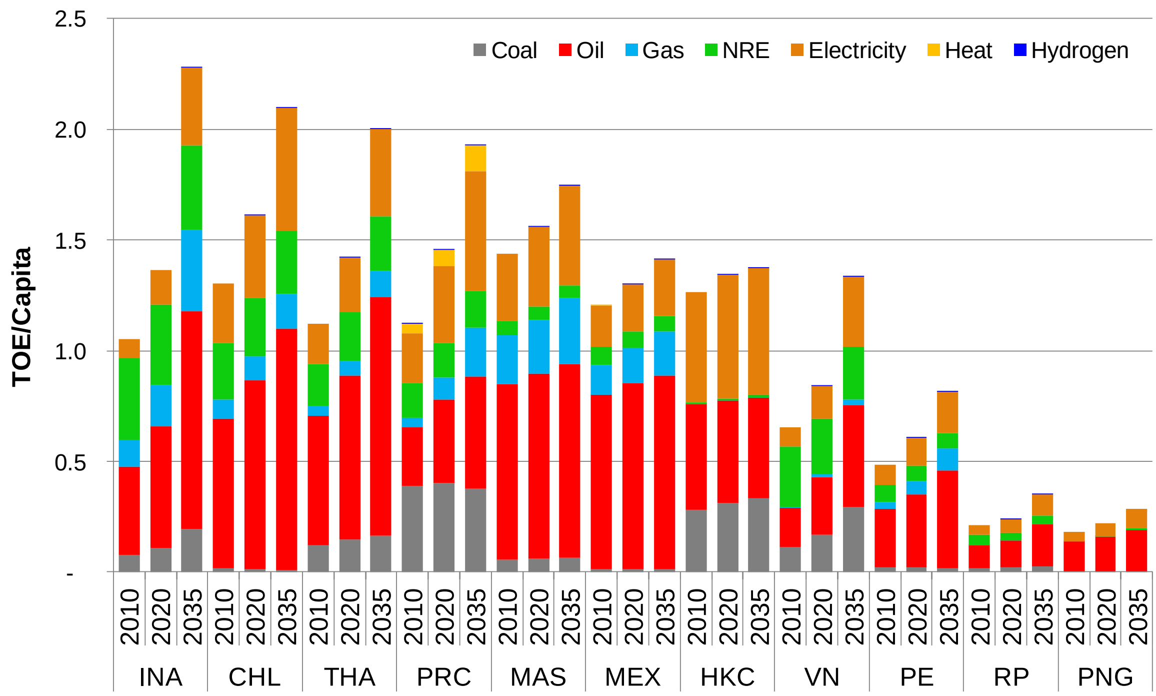
There is little that can be said in general regarding the differences in per capita use of various energy sources between economies, except that the developed economies tend to use more of just about every energy source. The notable exception is new renewable energy (NRE), which tends to be more heavily used in developing economies, in the form of biomass used in the residential sector.

Figure 4.5: Final Energy Demand by Energy Source Per Capita, Higher Final Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 4.6: Final Energy Demand by Energy Source Per Capita, Lower Final Demand per Capita Economies



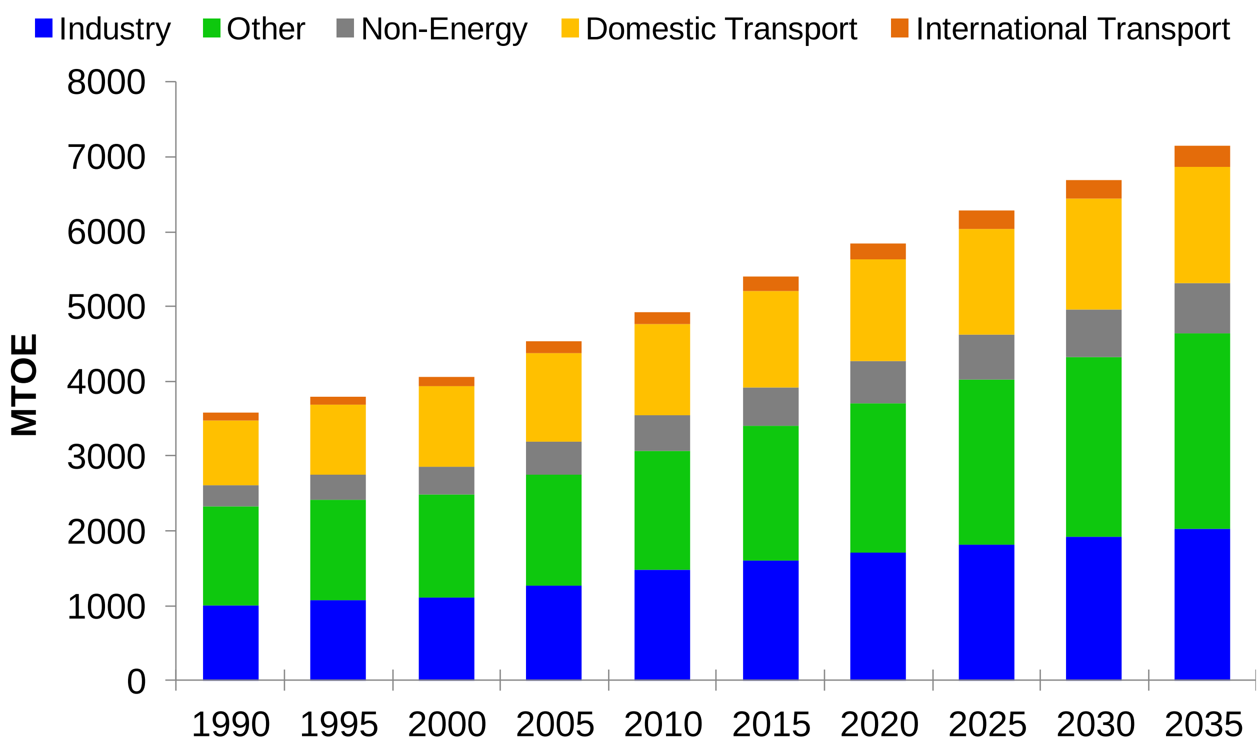
Source: APERC Analysis (2012)

Final Energy Demand by Sector

Figure 4.7 shows the total APEC final energy demand by sector. Figures 4.8 and 4.9 show these results broken out by economy. Figures 4.10 and 4.11 show the same results on a per capita basis. These sector figures include the international transport sector, which was not included in the final energy demand by energy source figures above. Under International Energy Agency (IEA) statistical conventions, international transport is not considered part of an economy's final demand, presumably because it is not necessarily consumed within the economy's borders. Singapore and Hong Kong, China have disproportionately large demands for international transport energy, due to their roles as major international shipping and air transport hubs. Without this international transport demand, they would otherwise rank in the mid range of the APEC economies in per capita energy demand.

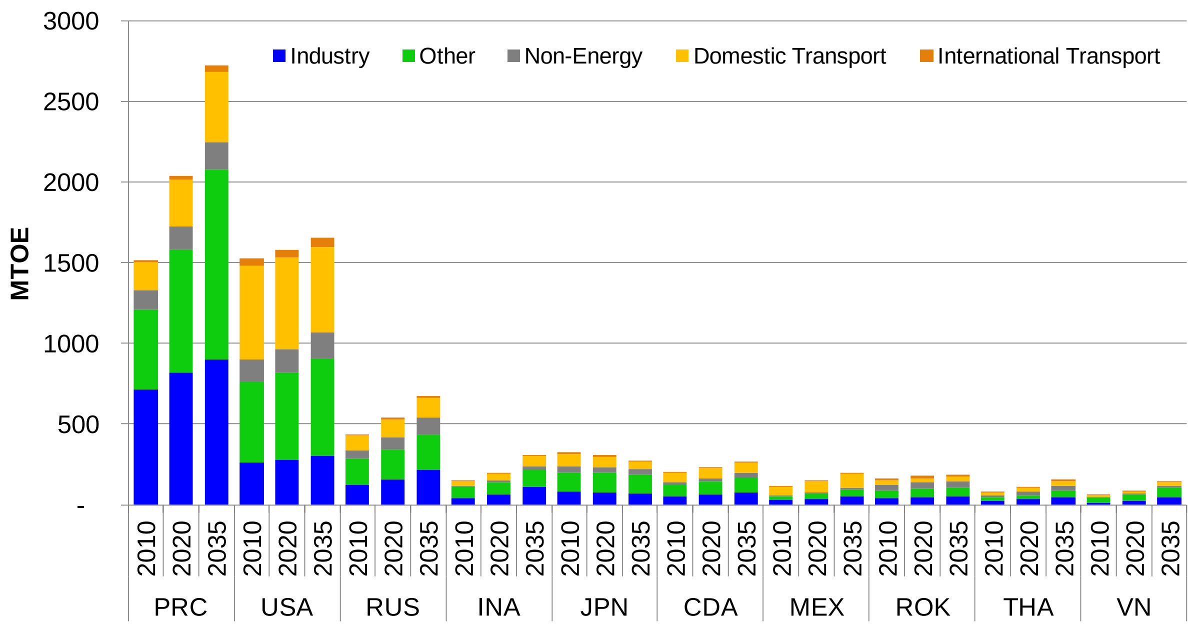
In general, developed economies tend to use more energy in every sector. Transport demand tends to be especially large in the developed economies and, not surprisingly, non-energy use tends to be largest in economies that have large refinery industries.

Figure 4.7: APEC Final Energy Demand by Sector



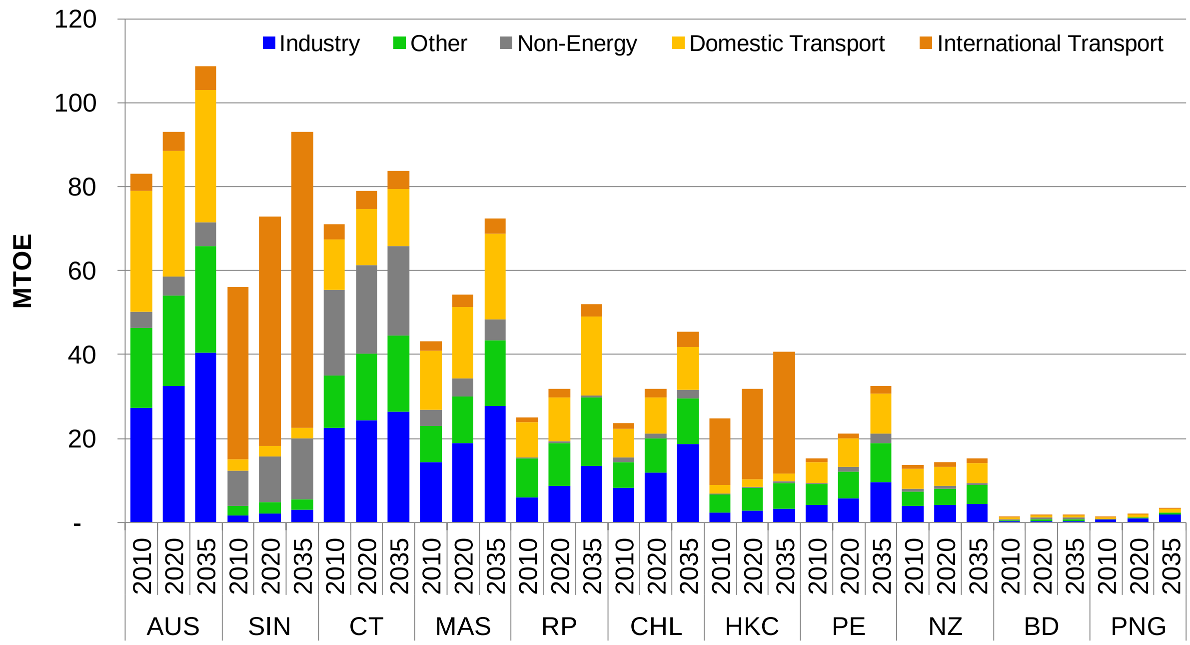
Source: APERC Analysis (2012)

Figure 4.8: Final Energy Demand by Sector, Higher Final Demand Economies



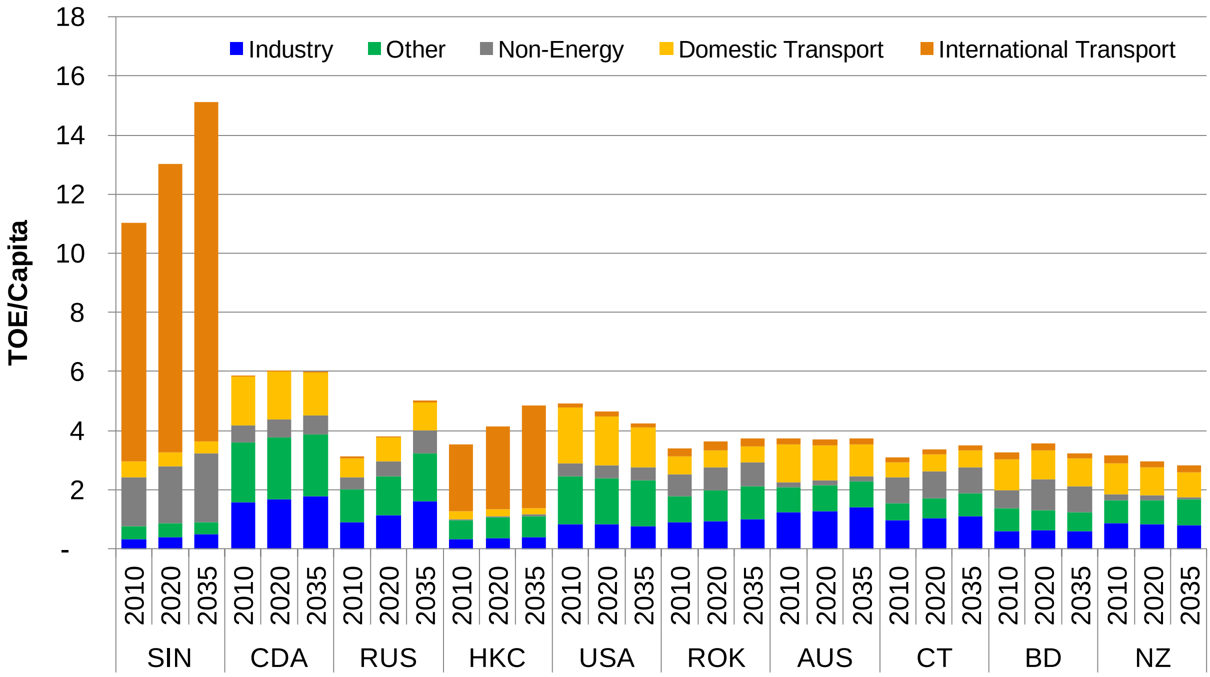
Source: APERC Analysis (2012)

Figure 4.9: Final Energy Demand by Sector, Lower Final Demand Economies



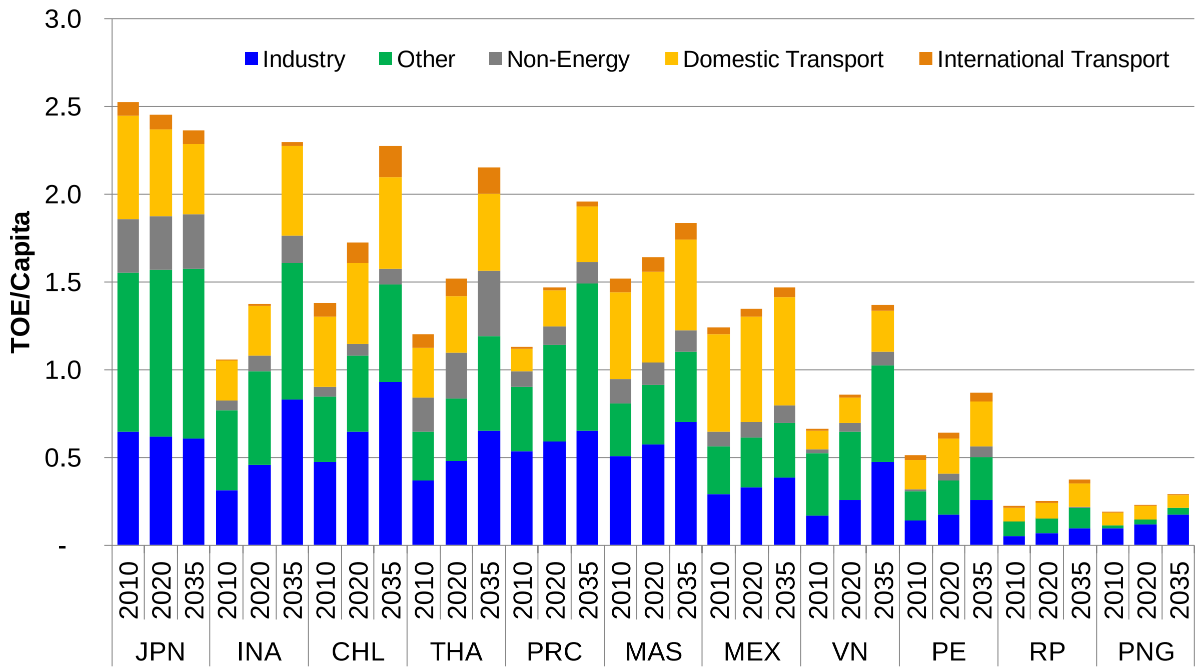
Source: APERC Analysis (2012)

Figure 4.10: Final Energy Demand by Sector Per Capita, Higher Final Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 4.11: Final Energy Demand by Sector Per Capita, Lower Final Demand per Capita Economies



Source: APERC Analysis (2012)

MARKET FAILURES AND ENERGY EFFICIENCY

Chapters 5–8 discuss the energy challenges and opportunities in specific energy-using sectors. Before examining specific sectors, however, it is appropriate to examine the challenges and opportunities presented by energy demand in general. The key message of the remainder of this chapter, is that there are many opportunities to improve the efficiency with which energy is used. These opportunities should be viewed as equal in significance to measures on the supply side for achieving a more sustainable energy future.

At first glance, saying that there are many opportunities to improve energy efficiency does not sound like a particularly useful insight. After all, by 'working smarter' (such as better planning, better engineering, or improved technology) the efficiency of virtually every economic activity could be, and probably will be, improved. But the key point of this section is that the opportunities to improve energy efficiency are particularly large and often obvious because *energy demand is different* from other economic activities.

In the case of energy demand, there are strong economic barriers that tend to deter people from 'working smarter'. The result is that there are many actions that energy users could take to improve energy efficiency that do not get taken, even though they would be economic from the perspective of society as whole. These actions do not get taken because they are not economic, or perhaps not even possible, from the perspective of the energy user. Before we can improve energy efficiency, we need to address the *market failures* that cause the behaviour of energy users and the interests of society as a whole to diverge.

The Market Failures

There are at least four kinds of market failures that lead to energy inefficiency.

1. *Lack of information*. Energy users generally want to compare the energy efficiency of the options they face, but may be unable to do so due to lack of information. This may occur in several ways:

   Lack of data. Energy users shopping for a place to live, a vehicle or an appliance, may want to compare the energy efficiency of the various alternatives, but are unable to do so due to a lack of reliable data.

   Lack of skills. Most consumers are not engineers, and may find the calculations involved in comparing options with different upfront and ongoing costs to be difficult or beyond their capabilities. Even large organizations may not have engineers with knowledge of the latest technologies for improving energy efficiency.

   Lack of time. Even those energy users who have the skills to compare alternatives may not have the time to actually perform the analysis.

2. *Split incentives*. The lack of information described above can frequently be compounded by the fact that the person who makes a decision that affects energy use is not the person who pays the resulting energy costs. Consequently, the decision that gets made is not the correct one from the perspective of society. Some examples:

   Landlord/tenants. The landlord generally pays the cost of energy-efficiency improvements in apartments and offices. The tenant, however, typically pays the energy bills, and thus receives the benefits of these investments.

   Building developers/buyers. The developer pays the cost of features to enhance energy efficiency in buildings, but the ultimate buyer receives the benefits.

   Internal organization. In many governments and companies, the administrative unit that manages the capital budget is not the administrative unit that manages the operating budget. Each may seek to minimize their own costs without regard to the impact on the overall organization.

   Free energy. In some situations, customers are not expected to pay separately for the energy they use. Hotel guests, for example, have no incentive to limit their use of air conditioners, heaters, hot water, and lights.

3. *Underpricing of energy*. In most parts of the world, energy is underpriced relative to its real costs to society. Consequently, energy users have less incentive to improve the efficiency of their activities than would be socially optimal. Some examples:

   Externalities. In most economies, the energy price typically includes the costs of producing the energy, but not the costs of its adverse impacts on the environment, including greenhouse gas emissions and local pollution.

   Subsidies. In some economies, energy is explicitly subsidized, so its price does not even cover the full costs of production.

4. *Financing constraints.* Energy users may wish to make an investment that would improve their energy efficiency, but lack the capital or the access to financing that is required. This is a particular problem not only for low-income consumers, but also in the public and non-profit sectors (such as schools, hospitals, and municipal governments), where capital budgets are often tightly constrained.

The Policy Remedies

Improving energy efficiency is generally a very attractive approach, both politically and economically, for creating a more sustainable energy future. Because of the market failures outlined above, energy efficiency improvements offer a unique opportunity to protect the environment, help the economy, and save money for energy users all at the same time.

The policy prescriptions for improving energy efficiency generally, will directly address the market failures outlined above.

1. *Provide better information.* This may take the form of requiring labels or ratings on appliances, vehicles, and residential/commercial buildings. Ideally, the labels or ratings should be easily understood by people with limited technical training and/or limited time (APERC, 2010 and APERC, 2011). Websites can also be useful in promoting public education and making information available on energy-saving products and technologies.

2. *Set minimum energy efficiency standards for appliances, vehicles, buildings, and commercial/industrial equipment.* As long as the standards are set at a level that energy users would choose for themselves if they had the option to choose, then both energy users and society will be better off. These standards should include active devices to help energy users monitor and reduce waste, such as devices to shut off the heat and air conditioning in unoccupied hotel rooms. See the further discussion of energy efficiency standards and labeling, as well as building energy efficiency codes and labeling, in Chapter 8.

3. *Raise the price of energy to reflect its full costs to society.* This should include putting a price on carbon in some fashion (such as a carbon tax or emissions trading) as well as additional charges to cover the costs of local pollution and other environmental damage, related to energy production and use. In those economies that subsidize energy, the subsidies should be rationalized and phased out as quickly as possible, while protecting those energy consumers who are truly in need (see the sidebar in Chapter 10 'APEC's Goal to Rationalize and Phase Out Fossil Fuel Subsidies').

4. *Ensure that financing is available for cost-justified energy efficiency investments.* These investments will provide benefits that exceed their costs. Therefore, given proper legal and regulatory frameworks, there should be little risk to the lender and little cost to the taxpayer.

5. *Promote energy service companies.* Energy service companies (ESCOs) can provide a total solution for large energy users wishing to improve their energy efficiency. Such a company has engineers trained to identify opportunities for energy saving and to propose appropriate energy-saving investments. Once appropriate investments are identified, the ESCO can provide the necessary financing, manage the implementation, and provide subsequent maintenance. The ESCO can often do all this in return for a share of the energy cost savings to the customer, so the customer is guaranteed to profit from the arrangement.

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5 TRANSPORT SECTOR ENERGY DEMAND

The continued dependence on oil-derived fuels for transport poses two major concerns for all APEC economies, especially the oil importing economies. First, there is the oil security concerns discussed in Chapter 11. These oil security concerns mean continued oil price volatility will be a near certainty, and there will be significant risks of supply disruptions. Second, oil is a fossil fuel and its use in the transport sector is a major source of greenhouse gas emissions in all APEC economies. For these reasons, there is a strong need to reduce dependence on oil in the transport sector.

Motorization correlates closely with economic growth. However the relationship between the two varies greatly depending on the circumstances. For developing economies, growing income is usually accompanied by rapid growth in vehicle ownership per capita. As economies become wealthier, the growth in vehicle ownership slows down. Eventually economies approach vehicle saturation, or a maximum vehicle ownership level per capita. At this point, growth in per capita vehicle ownership slows to almost zero. However, the level of vehicle ownership per capita at which saturation is reached is strongly tied to the way cities are planned. This suggests better urban planning is a key policy for reducing oil dependence in transport.

More broadly, transport energy demand is a combination of three variables. These variables are: the demand for mobility, the transport mode used for mobility and the energy efficiency of the mode. Policies for reducing energy use in transport correspond to these variables: 'Avoid' (the demand for mobility), 'Shift' (to alternative modes) and 'Improve' (energy efficiency). Better urban planning is the main tool to accomplish 'Avoid' and 'Shift'. On the other hand, better vehicle design is the main tool to accomplish 'Improve'.

All three variables also respond to the price of energy. In the transport sector, this primarily means the price of oil. In recent years oil prices have increased rapidly. Under business-as-usual (BAU), real oil prices are assumed to remain high by historical standards, and to rise to above USD 120 per barrel by 2035. This is a key reason why the growth in oil demand in APEC economies is expected to be moderate over the outlook period.

This chapter first examines the BAU model results for the APEC region. It then discusses two sets of alternative scenarios exploring options for better urban planning and better vehicle design.

BUSINESS-AS-USUAL TRANSPORT DEMAND RESULTS

Energy Demand

Figures 5.1 and 5.2 show the projected domestic transport energy demand by economy and by fuel under a business-as-usual (BAU) scenario. Note the differences between the scales of the vertical axes in the two figures. Over the outlook period domestic transport energy demand in the APEC region is projected to increase from 1203 million tonnes of oil equivalent (Mtoe) in 2010 to 1555 Mtoe in 2035, or a compound annual growth rate of 1.1%. The OECD APEC member economies, which tend to be economically more mature, are projected to show a net decline in domestic transport energy demand from 790 Mtoe in 2010 to 720 Mtoe in 2035 (-0.4% compound annual growth rate). In contrast, non-OECD APEC economies, which tend to be developing economies, show an increase from 415 Mtoe to 880 Mtoe (a 3.2% compound annual growth rate) over the same period.

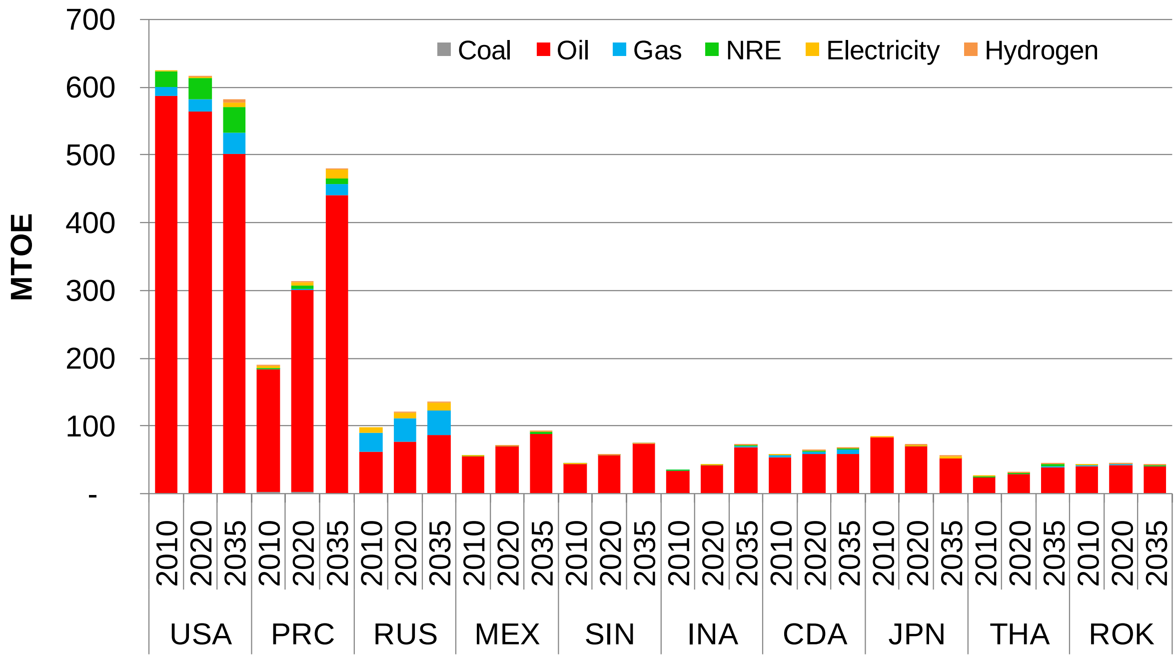
Oil remains the primary fuel used in the transport sector, supplying 87% of domestic transport demand in 2035, a small reduction from 92% in 2010. Growth in alternative fuels is supported by the growing use of biofuels, natural gas and electricity.

The United States (US) and Japan are two notable exceptions to the trend of increasing energy demand in the domestic transport sector. In the economies of the US and Japan, transport energy demand is projected to decline 8% and 38% respectively between 2010 and 2035. The US transport energy demand is projected to decline due to more stringent Corporate Average Fuel Economy (CAFE) energy efficiency standards for vehicles, combined with an already nearly saturated vehicle ownership and a greater use of alternative vehicles. These factors will outweigh the growth in the vehicle fleet due to population growth. Japan's transport energy demand decline is more pronounced, with the compounded effect of a declining population leading to a shrinking vehicle fleet in combination with the aforementioned factors (see the United States and Japan economy reviews detailed in Volume 2).

Perhaps the most notable transport energy demand development in the APEC region is the transport energy demand growth in China. By 2035, transport energy demand in this huge economy is expected to be about 2.5 times that of 2010. This growth in transport energy demand will be driven by two key factors. Firstly, economic growth will continue rapidly with real per capita income expected to rise to a purchasing power parity (PPP) equivalent of about USD 32 400 in 2035 (a level that will put China among the wealthy economies, as detailed further in Table 3.2 of Chapter 3). The high economic growth will result in the rapid growth in per capita vehicle ownership, which will be particularly apparent during the 2010 to 2020 period. By 2035, vehicle ownership is projected to reach 343 vehicles per 1000 people, up from 58 per 1000 people in 2010 (as detailed ahead in Table 5.1). Secondly, the urban population will continue to increase rapidly, not only in China but across all APEC economies.

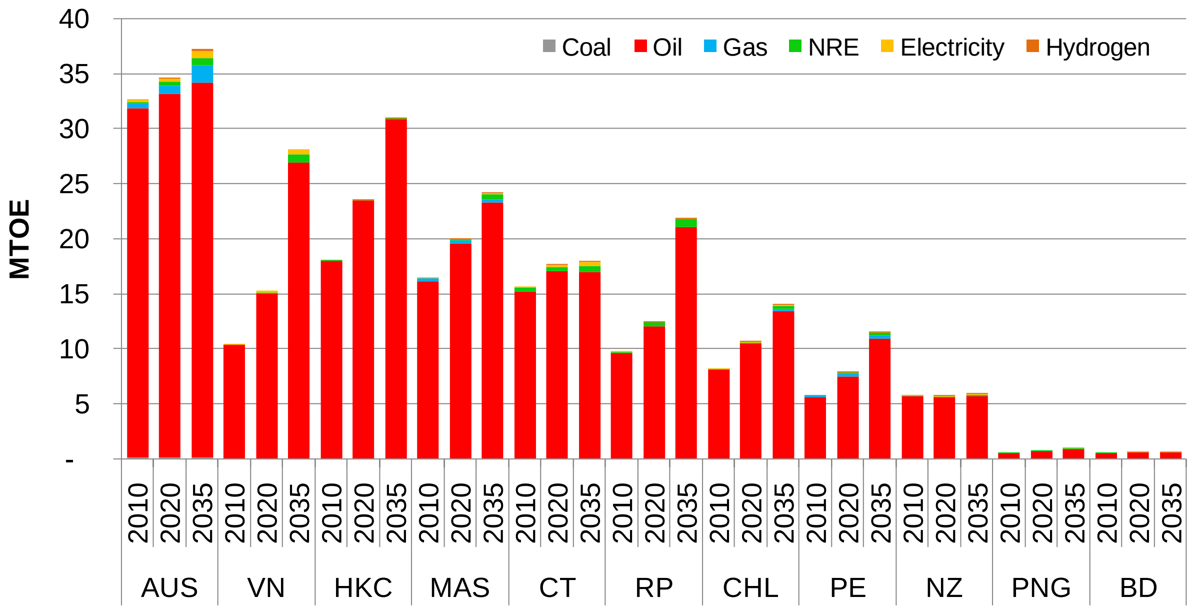
The corresponding growth rates in transport energy demand between 2010–2020 and 2020–2035 are shown in Figure 5.3. China's growth in transport energy demand is especially rapid in the current decade with an annual growth rate between 2010 and 2020 of 5.1%. This growth rate will ease between 2020 and 2035 to 2.9%, due to the increasing adoption of alternative vehicles, the slower growth in vehicle ownership and the continued improvement in the fuel efficiency of conventional vehicles. Growth in transport energy demand is also rapid in other developing APEC member economies. Economies with annual transport energy demand growth rates exceeding 3% in the period 2020–2035 include Viet Nam, the Philippines and Indonesia.

Figure 5.1: Transport Sector Energy Demand by Energy Source, Larger Economies



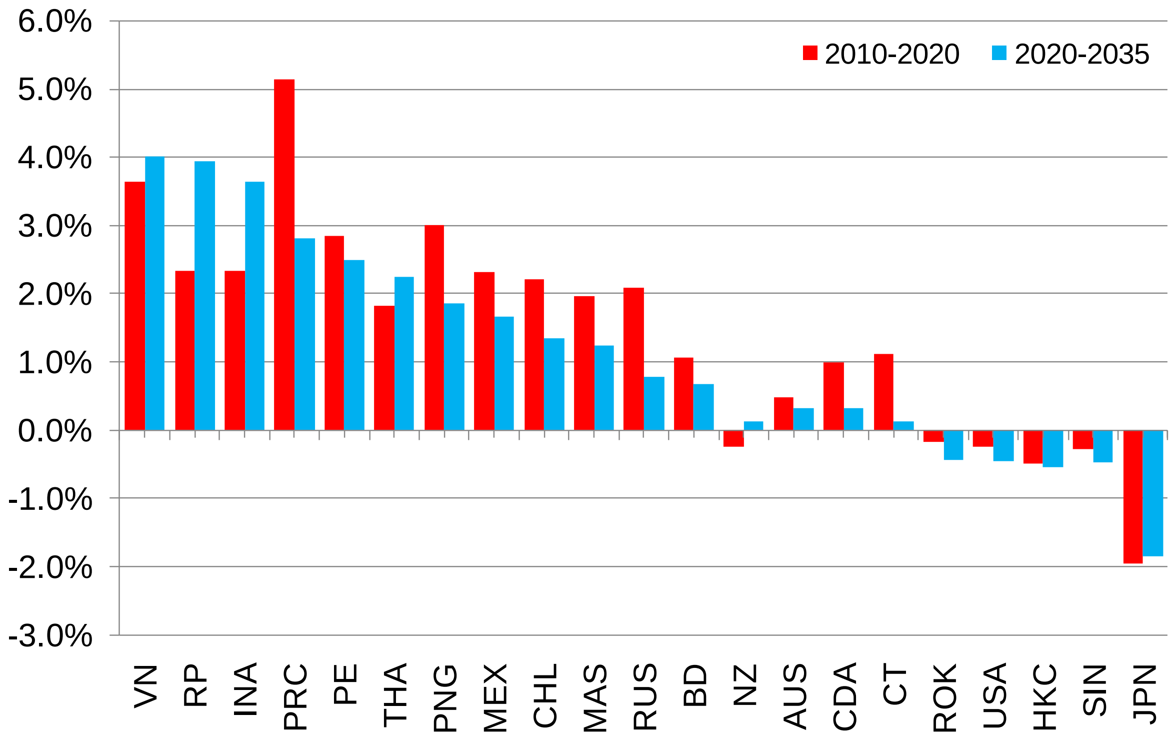
Source: APERC Analysis (2012)

Figure 5.2: Transport Sector Energy Demand by Energy Source, Smaller Economies



Source: APERC Analysis (2012)

Figure 5.3: Transport Final Energy Demand Average Growth Rate



Source: APERC Analysis (2012)

Vehicle Ownership

Table 5.1 shows the change in vehicle ownership across the APEC economies. As a whole, per capita vehicle ownership (in vehicles per 1000 people) in the APEC region is projected to grow at an average annual growth rate of 2.8% over the outlook period.

Future Vehicle Technology Mix

Figure 5.4 shows the change in vehicle technology within the light vehicle fleet in the APEC member economies in 2010, 2020 and 2035. The vehicles types assessed are defined as follows:

- Conventional (Gasoline or Diesel Fueled) Vehicles
- Natural Gas Vehicles
- Hydrogen Fuel Cell Vehicles
- Hybrid Electric Vehicles (Gasoline or Diesel Fueled)
- Plug-in Hybrid Vehicles
- LPG (Liquefied Petroleum Gas) Vehicles
- Battery Electric Vehicles.

Biofuels are not considered here. The reason is that biofuels are usually mixed with oil products and used in vehicles that differ only slightly, if at all, from conventional vehicles. Therefore, APERC models biofuels as a change in liquid fuel supply, rather than as a change in vehicle technology. Refer to the Biofuels discussion in Chapter 15 on Renewable Energy Supply.

APERC models the share of new vehicle sales for each of the vehicle types each year by simulating consumer choices. The consumer choice model takes into account differences in initial purchase price, fuel cost, driving range and refuelling availability. Overall, the adoption of alternative vehicles in APEC economies over the outlook period is modest in the BAU case.

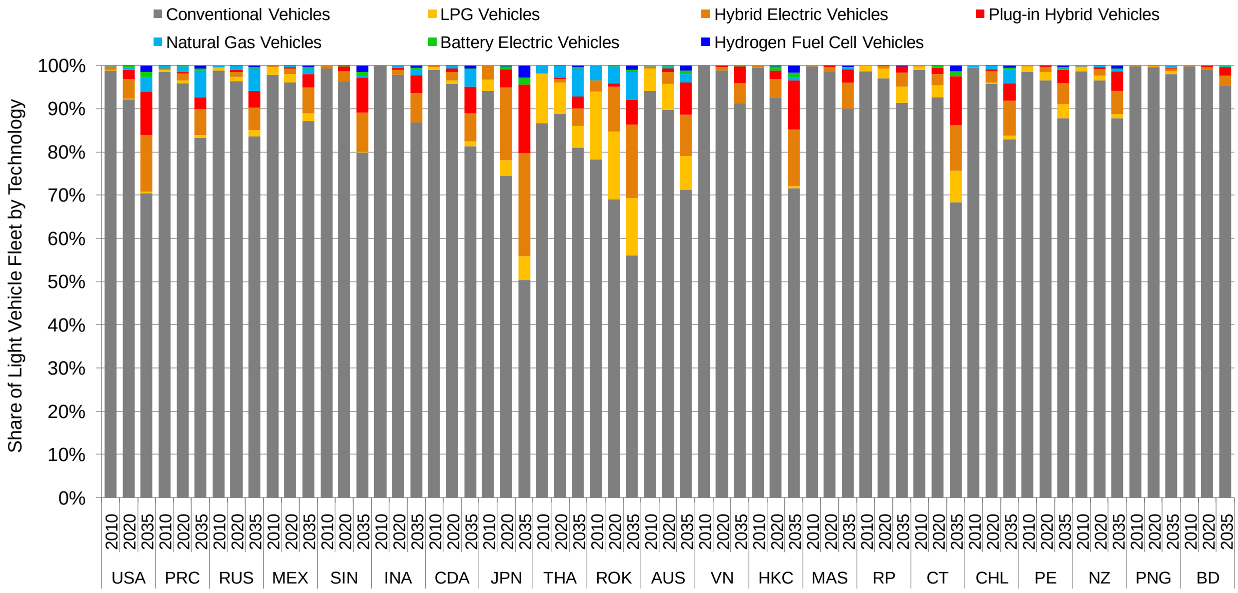
However, the developed APEC economies are world leaders in both the technological development and adoption of alternative vehicles. Several economies including the US, Japan and China currently have temporary rebate subsidies to encourage the adoption of alternative vehicles. Although these subsidies are not assumed to remain in place over the long term, in Japan the share of alternative vehicles in the light vehicle fleet, even excluding LPG and hybrid vehicles, reaches 20% by 2035.

Table 5.1: Vehicles per 1000 Population in APEC Economies: History and Projection including Compound Annual Growth Rates (2000–2035)

Vehicle Ownership (per 1000ppl)	2000	2005	2010	2015	2020	2025	2030	2035	2010-2020	2020-2035
Australia	627	662	691	705	725	746	769	792	0.5%	0.6%
Brunei Darussalam	408	452	544	603	640	662	676	684	1.6%	0.5%
Canada	543	570	591	621	645	663	677	689	0.9%	0.4%
Chile	132	150	178	212	260	311	359	399	3.8%	2.9%
China	13	24	58	114	167	223	280	343	11.1%	4.9%
Hong Kong, China	81	70	74	76	78	79	79	79	0.5%	0.2%
Indonesia	25	42	77	85	109	148	205	272	3.4%	6.3%
Japan	574	594	581	580	581	583	585	587	0.0%	0.1%
Korea	260	324	357	375	389	398	405	410	0.9%	0.3%
Malaysia	225	292	358	420	475	520	556	582	2.9%	1.4%
Mexico	186	204	265	295	337	383	427	466	2.4%	2.2%
New Zealand	649	725	711	700	700	707	715	725	-0.2%	0.2%
Papua New Guinea			10	13	17	22	26	31	5.7%	4.0%
Peru	45	50	62	92	131	180	234	291	7.7%	5.4%
The Philippines	32	34	32	32	36	44	58	75	1.1%	5.1%
Russia	174	215	271	322	384	448	506	553	3.6%	2.5%
Singapore	127	144	156	157	157	158	158	158	0.1%	0.0%
Chinese Taipei	251	292	297	336	371	398	419	435	2.2%	1.1%
Thailand	122	146	171	218	286	368	456	535	5.3%	4.3%
United States	755	803	797	799	801	805	808	811	0.1%	0.1%
Viet Nam	7	11	16	24	39	66	114	186	9.1%	11.0%
APEC	164	185	212	248	286	328	373	420	3.1%	2.6%

Source: APERC Analysis (2012)

Figure 5.4: Light Vehicle Fleet Share by Vehicle Technology



Note: There are other feasible, but less widely-studied, alternative vehicle technologies which are not assessed here. These include hydrogen internal combustion vehicles, compressed air vehicles, solar vehicles, ammonia fuelled vehicles, methanol fuelled vehicles, liquid nitrogen fuelled vehicles, and biogas fuelled vehicles.

Source: APERC Analysis (2012)

Potential for Improvements in Conventional Vehicle Technology

Although the adoption of alternative vehicles is modest in the BAU case, conventional vehicles are likely to improve rapidly in energy efficiency in response to high oil prices and existing government regulations. In particular, hybrid vehicle technology will become more widely adopted in conventional vehicles.

However, there remains much additional potential for improvement in the fuel efficiency of conventional vehicles beyond what is assumed in the BAU case. Weight reduction is the largest single component of fuel savings potential. Reducing vehicle weight principally reduces the energy needed for acceleration (Cheah and Heywood, 2011). Emerging lightweight composites, in particular carbon fibre, are becoming increasingly attractive substitutes for traditional steel components in vehicle manufacturing. Composite substitution has the added benefit of secondary weight reductions from the downsizing of various vehicle subsystems including the engine, suspension and braking systems (Cheah and Heywood, 2011). Cheah and Heywood (2011), suggest the greater use of lighter-weight material substitution combined with secondary weight reduction benefits have the potential to reduce the average US new vehicle curb weight by up to 38% or 600 kilograms (kg) by 2030. In addition, it is estimated that for every 100 kg of weight reduction in conventional passenger vehicles, there is a 0.4 litres per 100 km reduction in fuel consumption without changes in the vehicle's performance (Cheah and Heywood, 2011). So far, the integration of composites has been slow due to the vehicle industry's large capital investment in metal fabrication. Could this slow pace be accelerated?

One approach would be to move to a fundamentally different vehicle design. This would be an ultra light-weight vehicle type with a fully carbon composite body, known as the 'hyper car'. To fully capture the weight reduction benefits, the hyper car could employ a hybridized power train as well as low drag and rolling resistance design features. Approximately two-thirds of the fuel efficiency improvement of hyper cars would be attributed to the weight reduction from both composite substitution and component downsizing, with the remaining benefits from power train hybridization and a low drag design. Overall, hyper cars would be approximately 50–60% lighter than the average curb weight of conventional vehicles (Lovins et al., 2005). This is comparable, although slightly more optimistic than the vehicle weight reduction potential stated by Cheah and Heywood (2011).

Ultimately, hyper cars have the potential to reduce fuel consumption per kilometre (km) by 50–66% compared to conventional vehicles sold today (Lovins et al., 2005). Lovins et al. (2005) estimates the fuel efficiency of a hyper car would be around 38 km per litre (90 miles per gallon). Safety should not be a problem since carbon fibre composite components are stronger than traditional steel components.

The additional cost of the hyper car is uncertain since there is, as yet, no large-scale manufacturing. Early estimates range from about USD 5000–7000 in added costs above conventional vehicle costs once mass production is established (Bandivadekar et al., 2008; Cheah and Heywood, 2011; Lovins et al., 2005). This estimate includes the additional costs involved in composite substitution as well as hybrid technology.

The Challenging Economics of Alternative Vehicles

Alternative vehicles can drastically improve energy efficiency and shift reliance away from oil derived fuels. They have the added benefit of reducing local air pollution and some technologies offer near-zero vehicle emissions. So why is their adoption so low under BAU?

While the potential benefits of alternative vehicles are apparent, their upfront capital costs relative to conventional vehicles are higher. Therefore an important obstacle to the adoption of alternative vehicles is consumer acceptance of higher upfront costs in return for later fuel-cost savings.

To illustrate this trade-off, APERC calculated average fuel costs over the life of each vehicle. These fuel costs were calculated as present values—that is, how much the consumer would need to put into an interest-paying bank account on the day the vehicle was purchased to cover the cost of fuel for the vehicle over its entire life. In principle, a rational consumer should not be willing to spend more in extra vehicle purchase costs for an alternative vehicle than the present value of the future savings in fuel costs.

So how much extra should the consumer be willing to spend for an alternative vehicle? Assume the consumer is from the US, and consider first the most extreme case—a hypothetical 'zero energy' vehicle that has no fuel cost at all. Since the average present value of fuel costs for a conventional vehicle in the US is about USD 10 000, assuming a modest 6% interest rate, a typical US consumer should not be willing to pay more than USD 10 000 extra to purchase the 'zero energy' vehicle rather than a conventional vehicle.

The 'zero energy' vehicle is, of course, an ideal case. All real-world vehicles incur some fuel costs, so the consumer should not be willing to spend as much for them as they would be willing to spend for a 'zero energy' vehicle. Figure 5.5 shows the average lifecycle fuel savings for a US consumer for several types of alternative vehicles under three sets of assumptions about energy costs and improvements in conventional vehicle technology. These values will differ in other economies, depending on fuel prices and lifecycle distances driven.

Figure 5.5: Present Value of Lifecycle Fuel Savings relative to US Conventional Vehicle (6% Discount Rate, in USD)

Year	Assumptions	Hybrid Electric	Plug-in Hybrid (16km)	Plug-in Hybrid (48km)	Plug-in Hybrid (96km)	Battery Electric (320 km)	Hyper Car	Zero Energy
Current Technology	Oil $100/bbl Electricity 11c/kWh	$3000	$4400	$5600	$6000	$6900	$6700	$10 300
	*Higher oil prices **favor the economics** of alternative vehicle technologies*							
Current Technology	Oil $126/bbl Electricity 15c/kWh	$4200	$6000	$7600	$8100	$8500	$9000	$14 000
	*Low cost efficiency improvements in conventional vehicles will **limit the economic** potential of alternative vehicles—even with higher oil prices*							
2035 (BAU)	Oil $126/bbl Electricity 15c/kWh	$3700	$4500	$5100	$5400	$5900	$5000	$8600

Assumptions: Vehicle travel is around 15 000 miles (24 100 km) per year per vehicle and vehicle life is 150 000 miles (241 000 km) (RITA|BTS, 2011). Under BAU, the fuel economy of US conventional non-hybrid vehicles improves from around 30 miles per gallon (12.8 km per litre) in 2010 to 45 miles per gallon (19.1 km per litre) in 2035. In all cases a probabilistic trip length distribution is applied to plug-in hybrid electric vehicles in the calculation of the oil and electricity fuel use.

Source: APERC Analysis (2012)

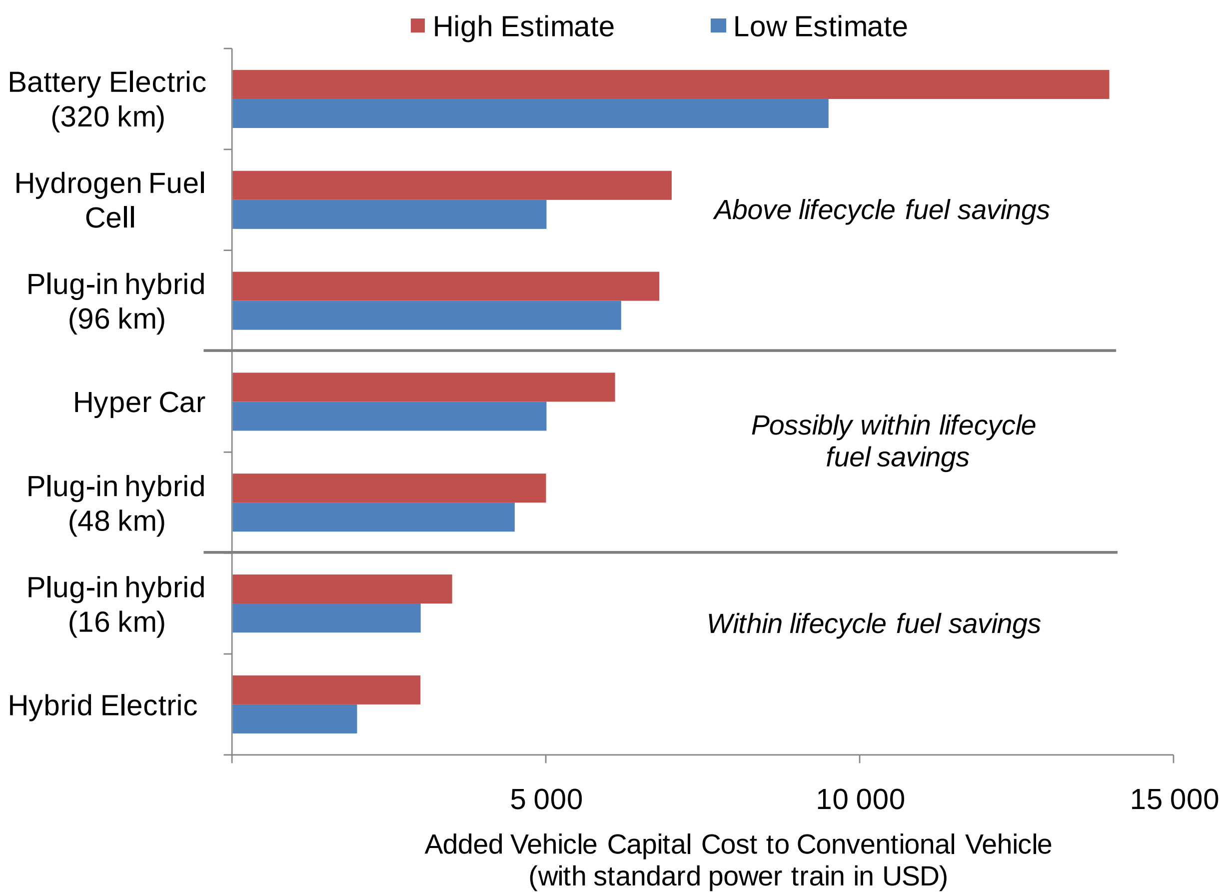
In the top part of Figure 5.5, the present value of lifecycle fuel savings assumes real energy prices over the vehicle's life are constant—at an oil price of USD 100 per barrel and an electricity price of USD 0.11c per kilowatt-hour (kWh). Under this scenario the present value of fuel savings for a Battery Electric Vehicle with a 320 km (200 mile) range is approximately USD 6900. The fuel savings for Plug-in Hybrid Vehicles are variable depending on the electric propulsion range. For a 96 km (60 mile) range Plug-in Hybrid Vehicle, the present value of fuel savings is around USD 6000. As we reduce the electric propulsion range our potential present value of fuel savings decreases accordingly.

In the middle part of Figure 5.5, real oil prices are assumed to increase to USD 126 per barrel in 2035. This aligns with APERC's BAU oil price assumption. Similarly, real electricity prices increase to USD 0.15c per kWh. Under higher energy prices the present value of fuel savings are more substantial, with potential savings reaching USD 8500 for a Battery Electric Vehicle with a 320 km range. For the 'zero energy' vehicle, the present value of lifecycle fuel savings increases to USD 14 000.

In the bottom part of Figure 5.5, the benefit of rising energy costs is counteracted by the potential for low cost energy efficiency improvements in conventional vehicles, as assumed in the BAU case.

The key point here is the extra amount the rational consumer should be willing to pay for an alternative vehicle is not large. For alternative vehicles to penetrate the market, they will have to be priced at levels not a lot higher than a conventional vehicle. Yet, for the most part, this condition was not met under the BAU case. Figure 5.6 shows the expected range of additional capital costs for an alternative vehicle compared to a conventional vehicle in 2035. Only with the 16 km (10 mile) Plug-in Hybrid Vehicle and the Hybrid Electric Vehicle would the additional purchase costs be less than the present value of fuel savings for the average US consumer under BAU.

Figure 5.6: Additional Upfront Cost of Alternative Vehicles above that of Conventional Vehicles by 2035 (Assuming Mass Production)



Sources: APERC Analysis (2012), Kromer and Heywood (2007), Lovins et al. (2005), Cheah and Heywood (2011)

This analysis is probably conservative. Additional barriers for some alternative vehicles include battery degradation (requiring replacement), higher depreciation rates (caused by uncertainty over reliability), the disutility of shorter driving ranges (requiring more frequent refuelling or even limits on the distance the vehicle can be driven in a day), and inadequate refuelling infrastructure. Furthermore, research also shows consumers weigh the upfront vehicle capital cost more heavily than the potential lifecycle fuel savings in their decision-making (Hidrue et al., 2011). This finding implies higher discount rates in relation to consumer choice may be more appropriate, which raises further barriers to the adoption of alternative vehicles. This finding is supported by Train (1986) and other studies that show consumer discount rates for automobile ownership could be as high as 13%.

In short, the economics of alternative vehicles are challenging. The outlook for these vehicles would, of course, be improved by higher energy prices and/or carbon pricing. But, for alternative vehicles to penetrate the market in a big way, an intensive effort will be needed to lower the initial cost of these vehicles to a level competitive with the cost of conventional vehicles.

ALTERNATIVE SCENARIOS

Despite significant improvements in vehicle fuel efficiency, driven in part by high oil prices, the rapid growth of the APEC region's vehicle fleet is expected to continue to push up total oil demand in the transport sector. Under our business-as-usual (BAU) assumptions, we do not project any shift away from conventionally fuelled vehicles during the outlook period, although the penetration of hybrid vehicles, including plug-in hybrids, is expected to rise modestly.

Two alternative scenarios were developed to investigate potential energy-saving opportunities. These scenarios are discussed below.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

Urban areas are major drivers of economic growth. For developing economies the emergence of wealth starts first in major cities, creating inequality in wealth between cities and rural communities. Once economies mature the distribution of wealth is dispersed more equally between urban and rural areas. Urban areas also tend to be the main drivers of motorization in developing economies. However, the way urban areas are planned and managed is a key driver of future demand for vehicle ownership. This section discusses scenarios modelling the impact better urban planning and management could have on light vehicle energy demand, with particular focus on the connection to vehicle saturation.

Better urban planning and management goes by several names. These include 'smart development', 'compact development', and 'transit-oriented development'. Each of them emphasizes the use of public transit, walking and cycling while reducing motor vehicle dependence through infrastructure investment and policies promoting these alternative transport modes. The goal is not only to save energy, but also to promote cities that are healthy, safe, and pleasant places to live.

Smart cities have a lot of transport energy-saving design features and policies. Prominent examples of design features and policies of smart cities include:

- Mixed-use development with reduced distances between housing, jobs, shopping, and community services.
- Inter-connected streets to provide for easier access to destinations.
- Better facilities and environment for walking and bicycling.

- Higher quality transit services and more accessibility of destinations to transit.
- A de-emphasis of urban motorway and parking development, which tend to promote automobile use.
- In some cases, policies or taxes designed to limit vehicle ownership and use such as road and fuel pricing policies.

The Relationship of Population Density to Transport Energy Use

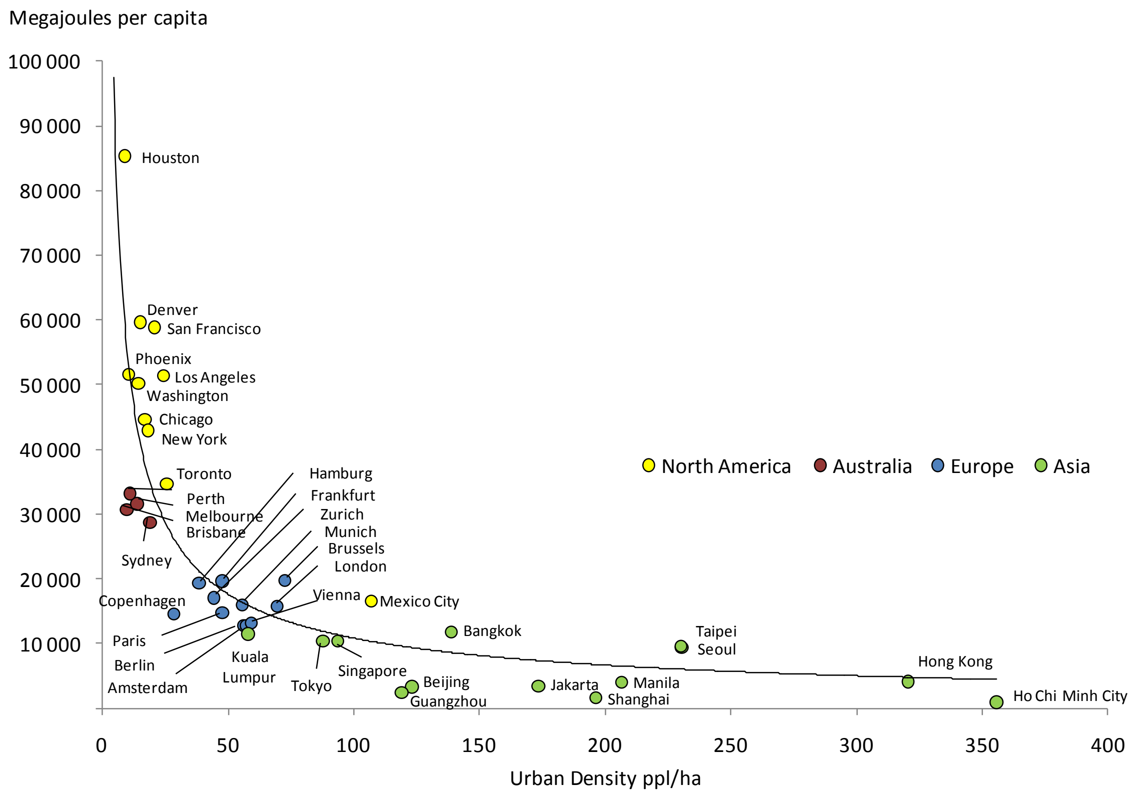
There is strong evidence to suggest cities with a higher population density are cities with a much lower energy use (see Figure 5.7 and Ewing et al., 2008). This is not necessarily a cause and effect relationship, but the two go together for at least three reasons. First, the shorter travel distances in more compact cities contribute directly to lowering transport energy demand. Second, design features and policies that reduce transport energy demand, such as those listed above, tend to have more favourable economics in denser cities, and are therefore more likely to be adopted. And third, the causation can also run the other way: cities that have design features and policies to reduce transport energy demand, such as those listed above, tend to develop in a more dense fashion.

In any case, the correlation between energy use and population density is so strong we can model a city's transport energy use based on its population density. This can be seen in Figure 5.7, which shows the light vehicle energy demand per capita and population densities of various cities.

Note also that the differences in light vehicle energy demand per capita between cities is huge. A comparison of two wealthy cities, Houston and Singapore, is informative. Houston is a sprawling city with a population density of about 15 people per hectare, while Singapore is a more compact city with a population density of about 95 people per hectare. While the income per capita of these two cities is similar, the light vehicle energy use per capita is eight times greater in Houston than it is in Singapore.

What is also apparent from Figure 5.7 is the critical urban density where transport energy demand begins to accelerate rapidly. The critical point is around 50 people per hectare. Urban density above this broad threshold has only a moderate impact on light vehicle energy consumption. However, below this level, light vehicle energy demand rises rapidly.

Figure 5.7: Passenger Vehicle Energy Use per Capita versus the Urban City Density in People per Hectare (Data Year = 1995)



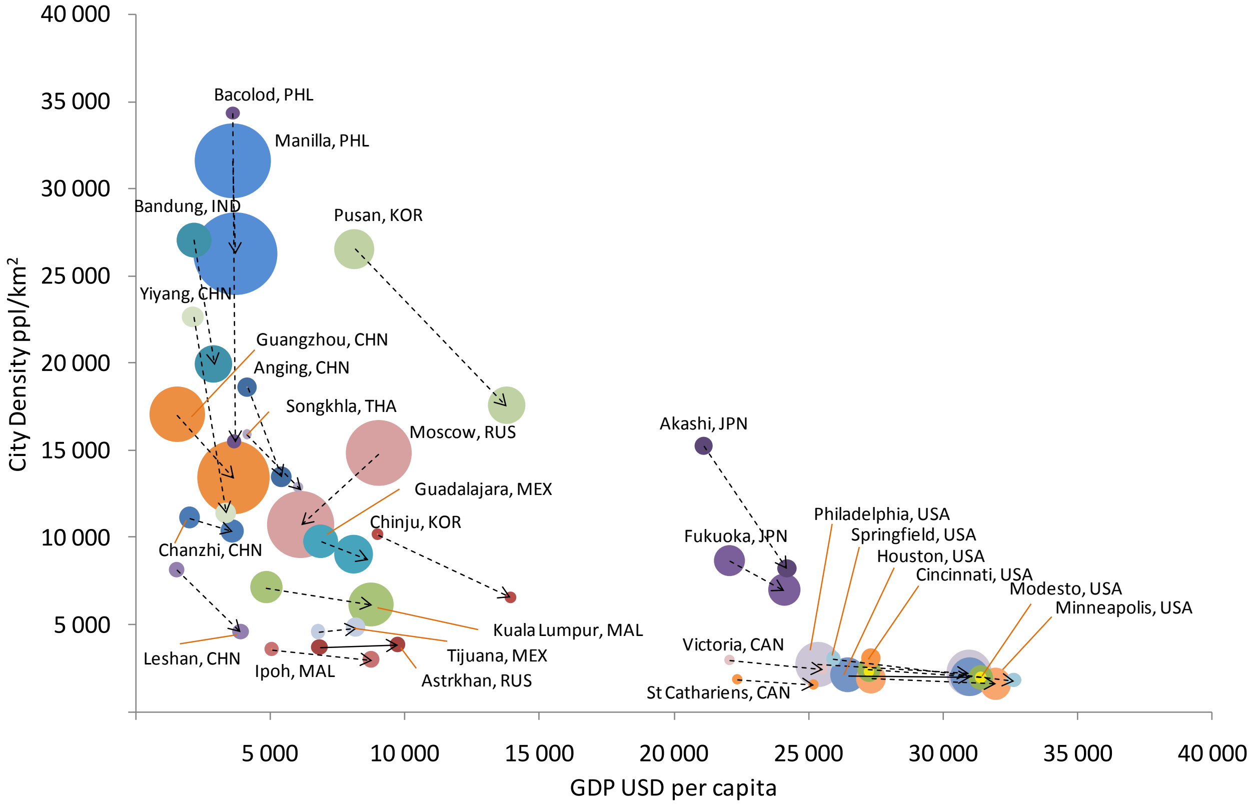
Note: The urban city statistical indicators shown here were collected on a common base year of 1995.

Source: Adapted from UITP/ISTP (1995)

The Declining Trend in Urban Density

Urban density has a long history of decline in both developing and developed cities. A World Bank study in the early 2000s assessed the trend in urban density for over 120 global cities. The study concluded that urban density had declined at an average rate of 1.7% between 1984 and 2002, with the density decline in developing cities up to three times higher than that in developed cities (Angel et al., 2005, p. 205). Figure 5.8 shows the change in urban density relative to the urban population (bubble size) and to the average real gross domestic product (GDP) per capita for the APEC cities assessed. The majority of cities in Figure 5.8 show urban density declining with growing per capita GDP. The decline in urban density is particularly rapid for cities in developing economies, where small changes in per capita GDP result in rapid changes in urban density.

Figure 5.8: Trend in Urban Density for APEC Cities Relative to the Size of Population and Growth in GDP per Capita between 1984 and 2002



Source: Data adapted from Angel et al. (2005)

The Window of Opportunity for Better Urban Planning

As shown in Table 5.2, cities in the APEC region are undergoing rapid urbanization. The United Nations (UN) predicts that by 2050 the urban population in the APEC region will grow by around 700 million people. Approximately 70% of APEC's urban population will be in the non-OECD (developing) APEC economies (UN, 2011).

The developing APEC economies will thus have a one-time opportunity for energy saving urban design which many cities in developed economies have already forfeited. This window of opportunity is closing quickly since once cities mature and infrastructure is built, energy saving urban design becomes increasingly expensive, difficult, and slow to implement.

Table 5.2: Urban Population Growth Projection in the APEC Region among OECD and Non-OECD Economies

(million people)	2010	2035	2050
Total APEC Urban Population	1601	2200	2,327
% Change from 2010		+37%	+45%
Total APEC Non-OECD Urban Population	1037	1518	1606
% Change from 2010		+46%	+55%
Total APEC Non-OCED + Mexico and Chile Urban Population	1140	1653	1749
% Change from 2010		+45%	+53%

Source: Adapted from UN (2011)

Urban Development Scenarios Considered

Given the high correlation between urban population density and energy use, we take population density as an (admittedly imperfect) indicator of better urban planning and management. We ask, what would be the impact on light vehicle energy demand if we could make the cities in the APEC region grow to be more like the denser cities of today's developed economies, rather than the 'sprawling' ones.

Three alternative scenarios are modeled in addition to the BAU case. These scenarios are defined as follows:

- BAU—Urban density continues to decline at the historical world average of 1.7% per year.
- High Sprawl—Urban density declines at 3.4% per year (or twice the historical average), leading to rapid urban land area expansion.
- Constant Density—Urban density is maintained at a constant level (2009) where urban land area expansion is proportional to population growth.
- Fixed Urban Land—Urban land area is fixed and population growth is contained inside existing urban boundaries.

The projected light vehicle energy use is estimated in each scenario by modelling the change in light vehicle ownership as well as the change in unit vehicle travel by each of these vehicles as a function of changes in urban density and income. The urban planning scenarios are conservative in scope as they do not consider the further potential energy savings in the heavy vehicle fleet. The heavy vehicle fleet in some APEC economies accounts for over 50% of road transport energy use.

Vehicle Saturation and Urban Development

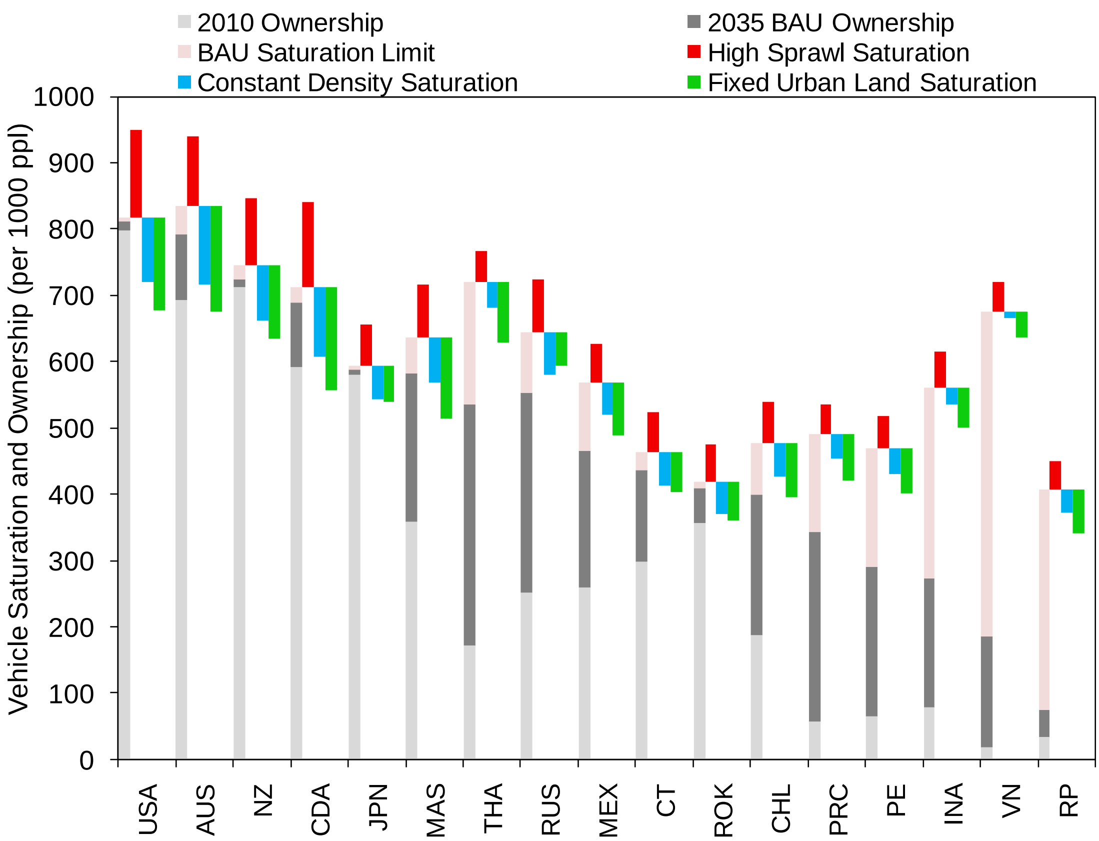
Urban density is highly correlated with the saturation levels of vehicle ownership seen in developed economies. Lower population densities correlate with higher saturation levels of vehicle ownership. In the future, as the developing economies become wealthier, we would expect the vehicle ownership in their urban areas to approach the saturation levels seen today in developed economy urban areas with similar population densities.

There is a similar relationship between urban density and unit vehicle travel that we also model, but it is a bit more complicated. In developing economies, unit vehicle travel is closely related to vehicle ownership. For example, as income grows the number of households shifting from one vehicle to two vehicles increases in response to higher living standards. However, the distance each vehicle now travels is less on a per vehicle basis than in households with a single vehicle.

Urban Development Scenario Results

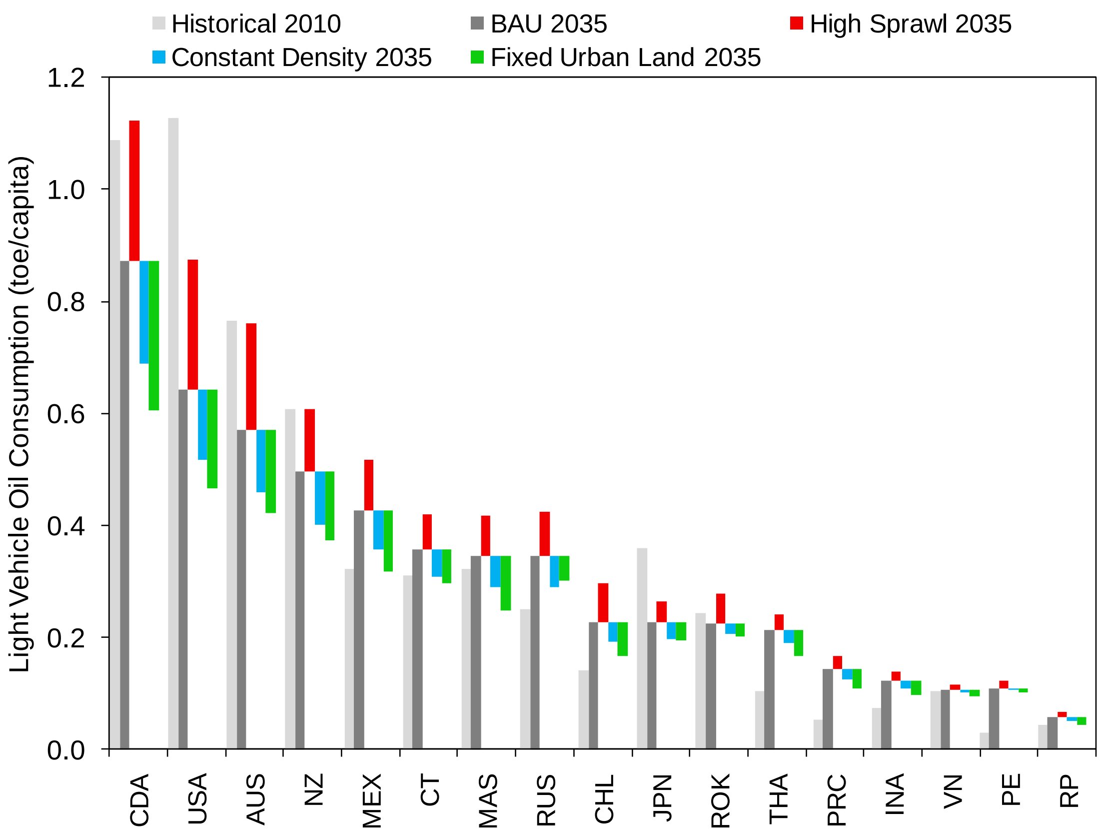
Figure 5.9 shows the change in vehicle saturation under each urban development scenario. Figure 5.10 shows the comparison of per capita oil demand in the light vehicle fleet. The economy rankings are based on the BAU projections for 2035. Singapore and Hong Kong, China are not considered due to their natural land area constraints. Papua New Guinea and Brunei Darussalem are also not considered due to insufficient urban area statistical data.

Figure 5.9: APEC Motor Vehicle Saturation under Urban Planning Alternative Scenarios in 2035



Source: APERC Analysis (2012)

Figure 5.10: APEC Light Vehicle Oil Demand per Capita under Urban Planning Alternative Scenarios

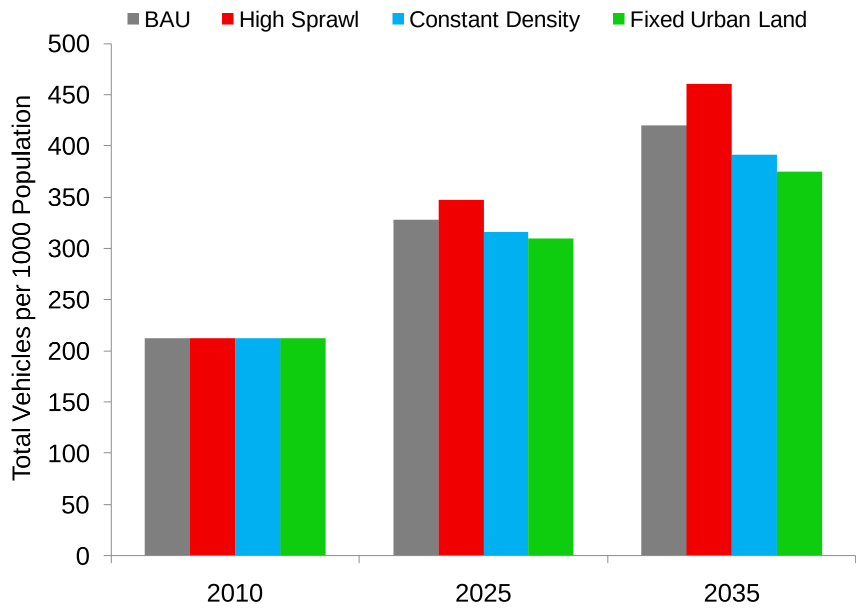


Source: APERC Analysis (2012)

Figures 5.11, 5.12 and 5.13 show the APEC economies' light vehicle ownership per capita, oil consumption and CO_2 emissions for the alternative urban planning scenarios. The APEC region's vehicle ownership per capita accelerates under all alternative urban planning cases. Vehicle growth is driven by rapid economic growth in the developing APEC economies. However, by 2035, the APEC region's vehicle ownership is 10% higher in the High Sprawl scenario compared to BAU.

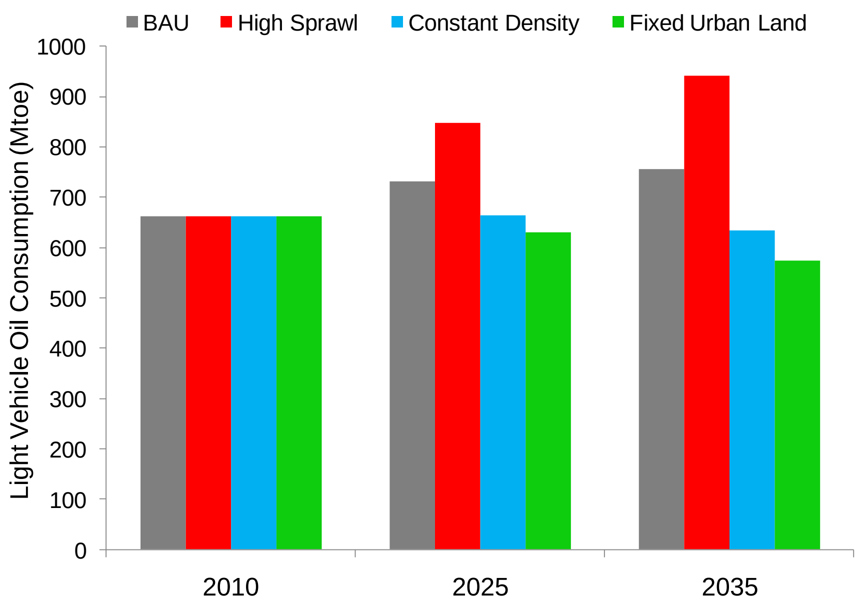
In 2035, the APEC economies' oil use and CO_2 emissions in the light vehicle fleet are 25% higher than BAU under the High Sprawl scenario; but 16% and 24% lower than BAU under the Constant Density and Fixed Urban Land scenarios respectively. Under the Fixed Urban Land scenario, both oil use and CO_2 emissions in the APEC economies' light vehicle fleet decline. The impact on oil use and CO_2 emissions is more pronounced than for vehicle ownership.

Figure 5.11: APEC Vehicle Ownership under the Urban Planning Scenarios



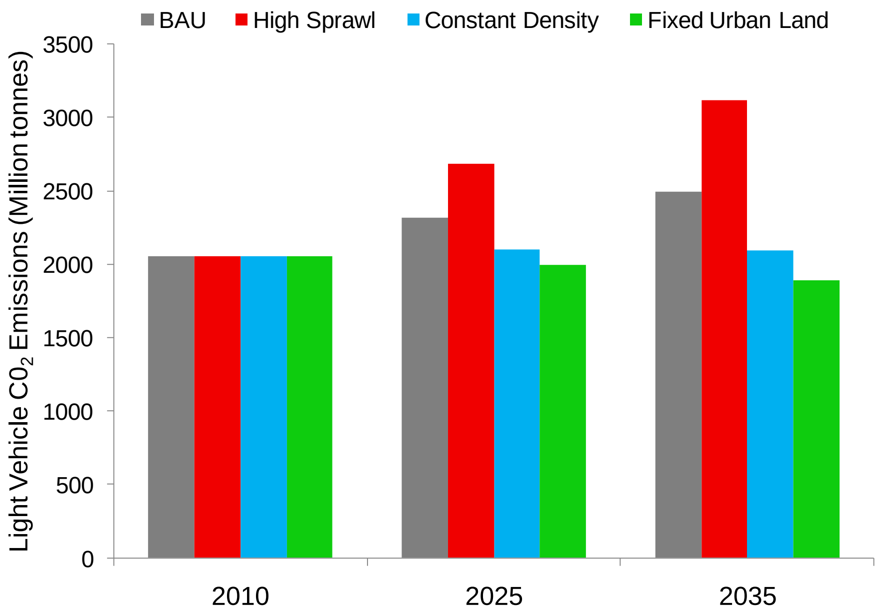
Source: APERC Analysis (2012)

Figure 5.12: Oil Use in the APEC Light Vehicle Fleet under the Urban Planning Scenarios



Source: APERC Analysis (2012)

Figure 5.13: CO_2 Emissions in the APEC Light Vehicle Fleet under the Urban Planning Scenarios



Source: APERC Analysis (2012)

Oil use and CO_2 emissions depend not only on the change in vehicle ownership but also on the change in unit vehicle travel. For compact cities, the unit vehicle travel is lower than for sprawling cities.

Urban Development Scenarios Summary

Urban planning and management has a substantial long-term impact on domestic transport energy use. 'Smart growth' policies could reduce the APEC region's oil use and CO_2 emissions in the light vehicle fleet by 24% compared to BAU by 2035.

There are two additional thoughts regarding these scenarios that should be considered:

- Owing to the anticipated scale of urban growth in developing APEC economies over the next several decades, there is a one-time opportunity to implement energy-saving smart urban design. Once the cities are built, the urban land use patterns and infrastructure become difficult and expensive to alter.
- The oil savings and CO_2 emissions reduction benefits from smart urban design are significant, but these benefits are realized over a long timeframe. The benefits shown in this analysis may be understated due to the limited time horizon of this outlook projection. We would expect the oil savings and emissions reduction benefits of smart urban design to continue to grow in magnitude beyond the end of the outlook period. This is especially true for developing economies, where vehicle saturation may not be reached until well after 2035.

THE VIRTUAL CLEAN CAR RACE SCENARIOS

APEC economies are promoting alternative vehicle technologies and alternative fuels as a means of reducing oil consumption, improving energy efficiency and promoting low-carbon transport (APEC, 2011). The potential for oil savings from the adoption of alternative vehicles is apparent. The impact on CO_2 emissions is less obvious since the emissions from fuel production for specific alternative fuels, such as hydrogen and electricity, must be considered. Therefore, the difference in emissions intensity between vehicle technologies depends on both the efficiency of the vehicle itself (the energy use per km) and the carbon intensity of its fuel (carbon content per energy unit).

Four scenarios are modelled in this analysis to assess the relative merits of four types of alternative vehicles in reducing oil use and CO_2 emissions in each APEC economy. Since these four scenarios simulate a competition between these four vehicle types, we denote these scenarios as the 'Virtual Clean Car Race'.

In each of the four scenarios, we assume sales of new alternative vehicles increase incrementally from BAU, starting in 2013, and rise to a market share 50 percentage points above BAU by 2020 and thereafter. For example, if the market share of natural gas vehicles is 5% of new vehicle sales in 2020 in the BAU scenario, the share of natural gas vehicles would be 55% of new vehicle sales in 2020 in the Natural Gas Vehicle Transition scenario.

The market share of new conventional vehicles in each scenario would be correspondingly reduced. To continue the example, if the market share of conventional vehicles is 90% of new vehicle sales in 2020 in the BAU case, it would be 40% of new vehicle sales in 2020 in the Natural Gas Vehicle Transition scenario. At the same time, the share of alternative vehicles other than natural gas vehicles remains the same in the Natural Gas Vehicle Transition scenario as it was in the BAU scenario. Note that, while the market share of the alternative vehicles in new vehicle sales levels-off at its maximum value by 2020, the actual number of alternative vehicles in the fleet does not level-off until some years later, reflecting the time required for all vehicles in the fleet in 2020 to be replaced.

These assumptions are not intended to be realistic depictions of how alternative vehicle technology might enter the marketplace. Given that it will take many years to implement new vehicle designs and fuelling infrastructures, the assumptions are probably quite unrealistic. However, the assumptions do have two advantages in an exercise designed to compare the merits of the vehicle technologies. First, the number of additional alternative vehicles in each year is always the same in all four cases, allowing an apples-to-apples comparison. Second, the planned transition to at least 50% alternative vehicles in the vehicle fleet can be almost entirely completed by 2035, the final year of this outlook period.

The scenarios to be examined are defined as follows:

- Hyper Car Transition scenario
- Electric Vehicle Transition scenario—this case assumes pure battery electric vehicles
- Hydrogen Vehicle Transition scenario
- Natural Gas Vehicle Transition scenario.

For each of the alternative vehicle types, we have modelled energy consumption and emissions based on published studies. As mentioned earlier, Lovins et al. (2005) report an energy savings potential for the hyper car of between 50–66%. Kromer and Heywood (2007) report that pure electric and hydrogen vehicles have a relative energy use compared to conventional vehicles of about 20% and 30% respectively, that is they consume 80% and 70% less energy. Finally, Semin (2008) reports that natural gas vehicles typically offer energy savings of 10% compared to conventional vehicles.

For the calculation of CO_2 emissions we must also consider the assumptions regarding how the hydrogen and electricity are produced. These are discussed below.

Hydrogen Production Pathways

Hydrogen, like electricity, is an energy carrier not a primary energy source. Therefore hydrogen must be produced from a primary energy resource, either fossil fuel, renewable, or nuclear. There are many possible production paths for hydrogen. Three of these processes are generally regarded as being scalable. These technologies are steam methane reforming or SMR (using natural gas), gasification (using coal or biomass) and electrolysis of water (using electricity).

A major potential advantage of hydrogen (and electric) vehicles is the potential for using a low-carbon primary energy source (renewable, nuclear, or fossil fuel with carbon capture and storage) to produce the hydrogen or electricity. We could have assumed the use of a low-carbon primary energy source for our Hydrogen Vehicle Transition and Electric Vehicle Transition scenarios, in which case these vehicles would have looked very good in terms of CO_2 emissions. However, this assumption would have required us to assume that enough new low-carbon hydrogen or electricity generation capacity is built to meet the energy needs of the hydrogen and electric vehicles. In this case, we would be counting the benefits of this additional low-carbon generation as a benefit of hydrogen or electric vehicles. This did not seem appropriate, especially since you could get the same emission reductions by simply building more low-carbon electricity generation capacity without using any hydrogen or electric vehicles at all.

Therefore, to provide a fair comparison we assumed the use of conventional energy sources in all the Virtual Clean Car Race scenarios. Table 5.3 compares the characteristics of the three processes considered for producing hydrogen. Note that, as shown in the table, coal gasification and SMR require inputs of electricity as well as of fossil fuels.

Table 5.3: Key Indicators for Hydrogen Production Alternatives

Indicator	Coal Gasification	SMR	Electrolysis
Assumed Primary Fuel	Coal	Natural Gas	Electricity from Fossil Fuels
MJ of Energy Input (including Electricity) per Kilogram Hydrogen	231	206	195
Efficiency (MJ Hydrogen per MJ of Energy Input, including Electricity) based on Thermal High Heating Value	61%	69%	72%
Electricity Input (kWh/kg H2)	15.5	11.2	54.2

Note: Electricity as an input is required in both the large scale hydrogen production process of coal gasification and SMR. This is to liquefy the hydrogen gas produced for tanker distribution to forecourt stations. Pipeline distribution of gaseous hydrogen was assumed to be too costly to implement on a wide scale, while distribution using the adsorption properties of a metal hydride is still unproven for large scale distribution applications.

Source: Adapted from Leaver, J et al. (2009)

SMR is the most well established process for hydrogen production. Coal gasification is not as efficient as SMR—but it uses coal, rather than gas, which is cheaper and more readily available domestically in many APEC economies. Although electrolysis appears to be the most efficient of the three production processes in Table 5.3, this does not include the conversion losses involved in making the electricity, which are usually at least 50%. Therefore electrolysis is likely to be the least economic of the three pathways for large-scale hydrogen production (Simbeck and Chang, 2002). For this analysis, we assume all hydrogen production in the APEC region is entirely from large-scale SMR. Its high efficiency and use of gas as a primary fuel should make it the most favorable of the three processes from a greenhouse gas emissions perspective.

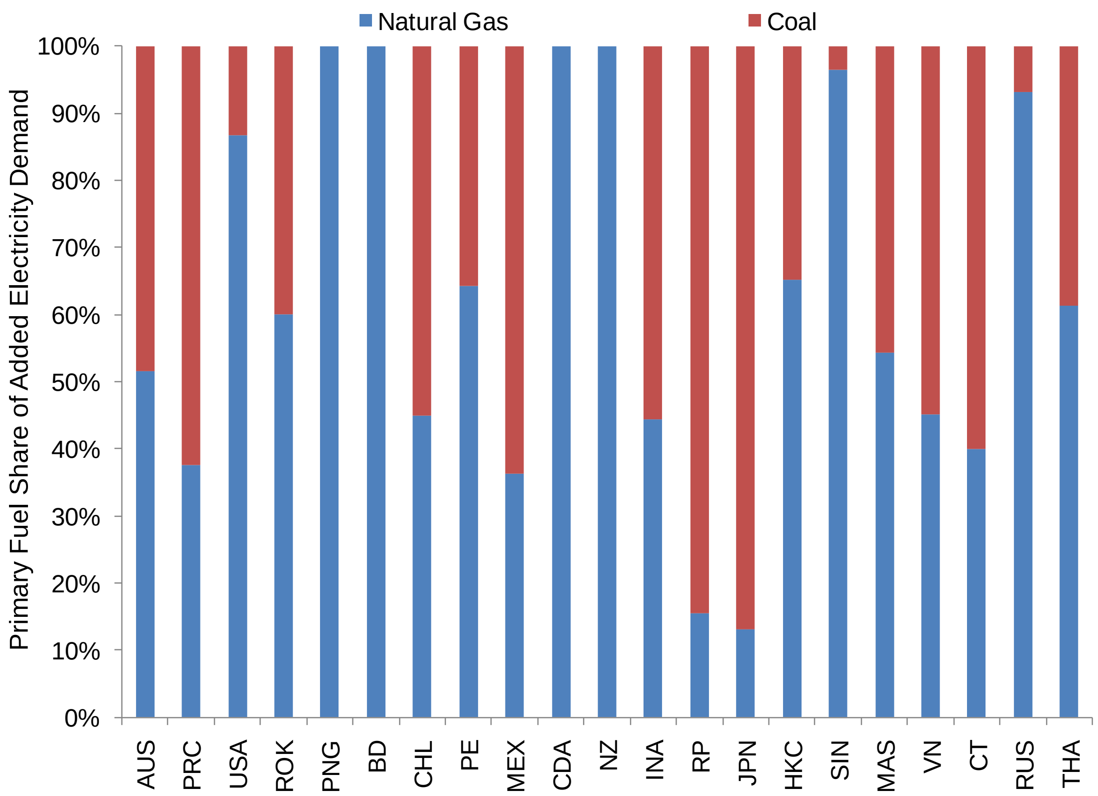
Electricity Production

The additional demand for electricity above BAU in both the Electric Vehicle Transition scenario and the Hydrogen Vehicle Transition scenario is produced from coal or gas. The specific mix of coal or gas used by each economy varies depending on which fuel our electricity supply model (see Chapter 9) determined to be the marginal source of electricity generation in that economy. The ratio of coal to natural gas to meet the additional electricity demand is shown in Figure 5.14.

Virtual Clean Car Race Scenario Results

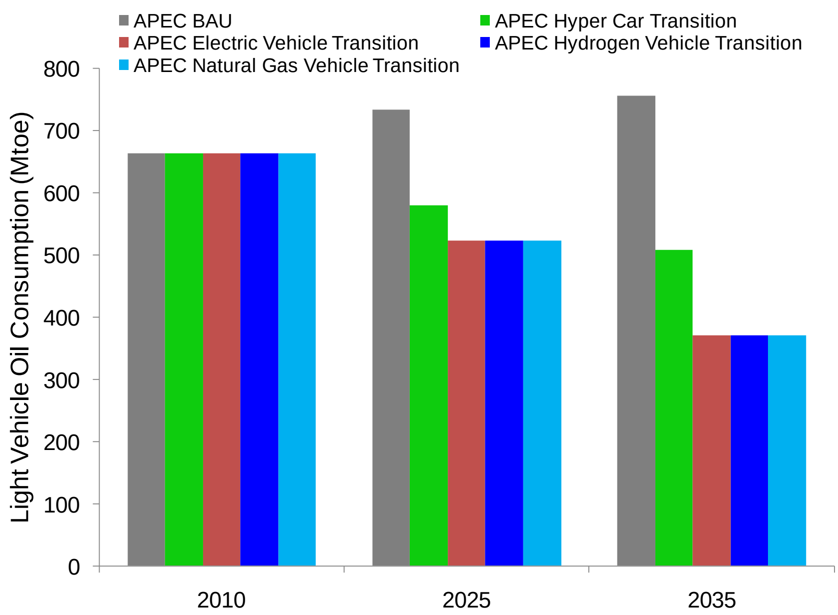
Figure 5.15 shows the APEC region's total light vehicle fleet oil demand in each Virtual Clean Car Race scenario in 2010, 2025 and 2035. In the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios, oil demand has dropped by 51% by 2035 compared to BAU. We would expect the drop to be around 50% as these vehicles constitute about 50% of the vehicle fleet in 2035 in these scenarios and they consume no oil. In the Hyper Car Transition scenario, oil demand has dropped by 32%. We would expect the drop to be around 30% as these vehicles constitute about 50% of the vehicle fleet in 2035 in this scenario, and they are (at this year) roughly 60% more energy efficient than conventional vehicles.

Figure 5.14: Primary Fuel to Meet Added Demand for Electricity in the Electric Vehicle Transition and Hydrogen Vehicle Transition Scenarios



Source: APERC Analysis (2012)

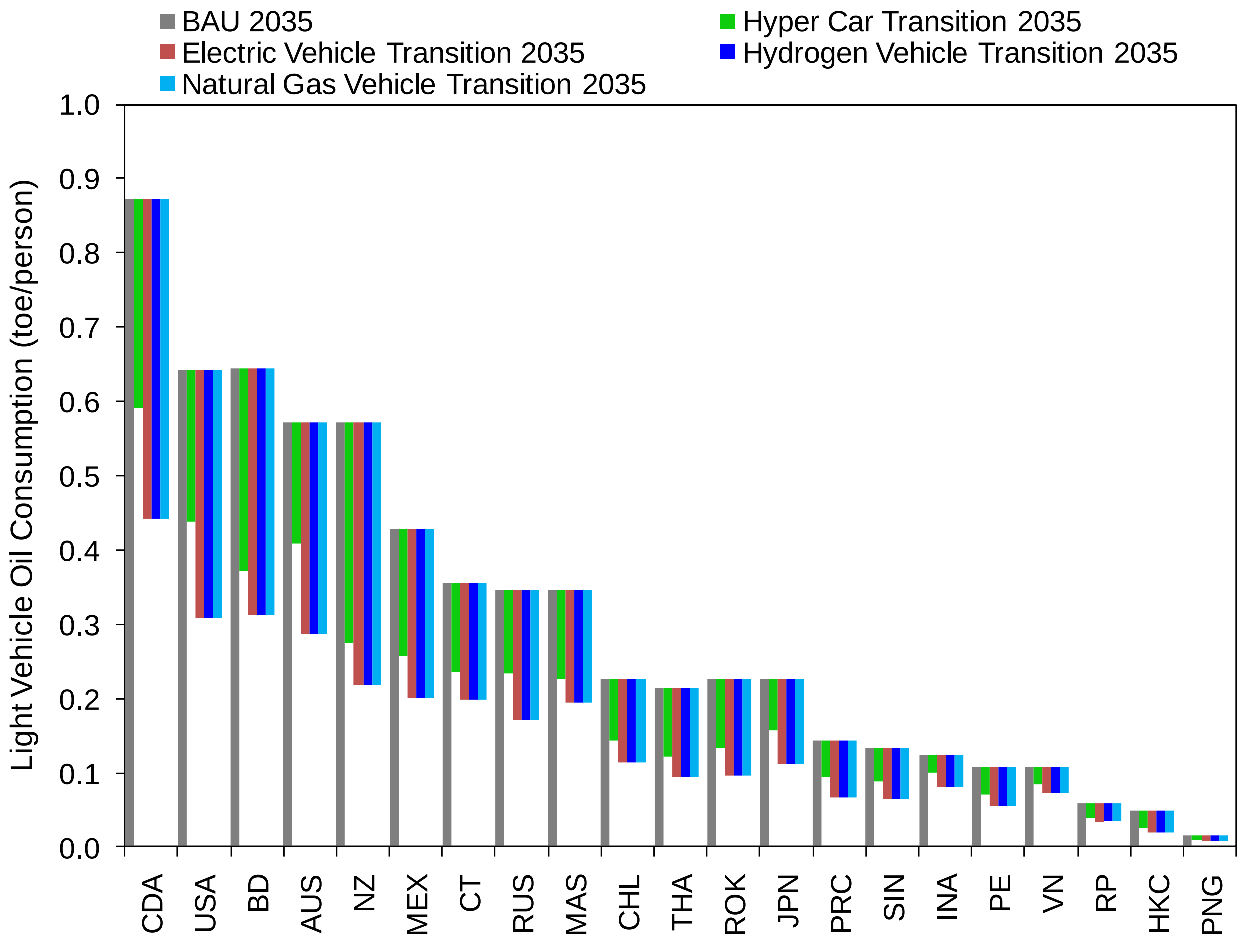
Figure 5.15: APEC Oil Consumption in the Light Vehicle Fleet across the Virtual Clean Car Race Scenarios



Source: APERC Analysis (2012)

Figure 5.16 shows the reduction in oil demand by economy in 2035, compared to BAU. The reduction in oil demand in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios may be a bit less than 50% in those economies with large fleets of motorcycles. Motorcycle oil demand is included in light vehicle energy demand, but the motorcycle fleet was assumed to be unchanged in these scenarios. On the other hand, the reduction may be a bit more than 50% in those economies where alternative vehicles would constitute a significant share of the vehicle fleet in 2035, even under BAU. In this case, the additional 50% of the vehicle fleet that are alternative vehicles can replace more than 50% of the remaining conventional vehicles. The reduction in the Hyper Car Transition scenario similarly varies a bit depending on the size of the motorcycle fleet and the penetration of alternative vehicles in the BAU case.

Figure 5.16: APEC Light Vehicle Oil Consumption per Capita in 2035 for each Virtual Clean Car Race Scenario

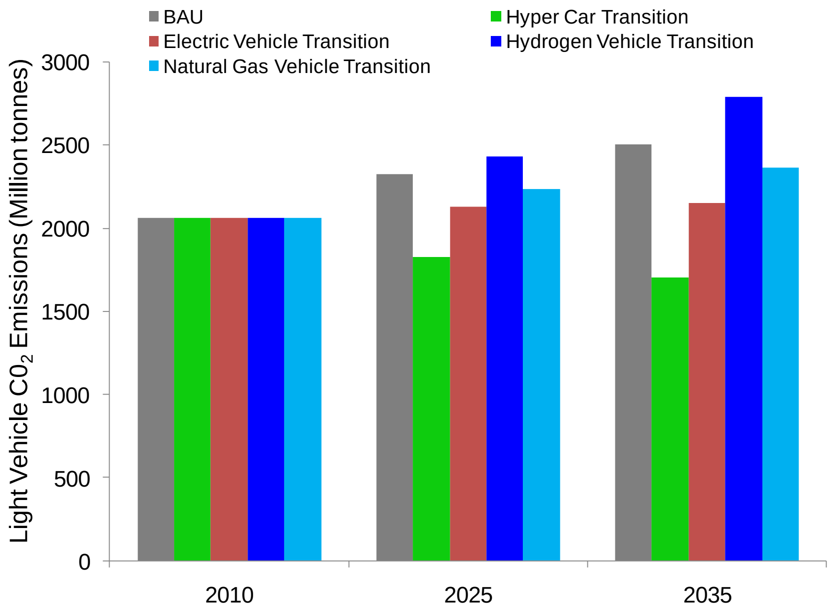


Source: APERC Analysis (2012)

Figure 5.17 shows the APEC region's total light vehicle fleet CO_2 emissions in each Virtual Clean Car Race scenario in 2010, 2025 and 2035. Reflecting its high fuel efficiency, the Hyper Car Transition has the highest potential for CO_2 emissions reductions in APEC economies. The reduction would be about 32% compared to BAU. Again, we would expect the drop to be around 30% as these vehicles are assumed to constitute an additional 50% of the vehicle fleet in 2035 in this scenario, and they are roughly 60% more energy efficient than conventional vehicles.

Emissions reductions for the Electric Vehicle Transition were more modest but still a significant 7%. This more modest reduction reflects the conversion losses in producing electricity from fossil fuels and, in some economies, the use of carbon-intensive coal as a primary energy source. The Natural Gas Vehicle Transition offered a smaller CO_2 reduction of 6%, reflecting the slightly lower carbon intensity of natural gas compared to oil, although efficiency improvement prospects compared to conventional vehicles are lower. The Hydrogen Vehicle Transition actually increased CO_2 emissions, reflecting the losses in the two conversions involved (gas to hydrogen in the hydrogen plant, then hydrogen to electricity in the vehicle).

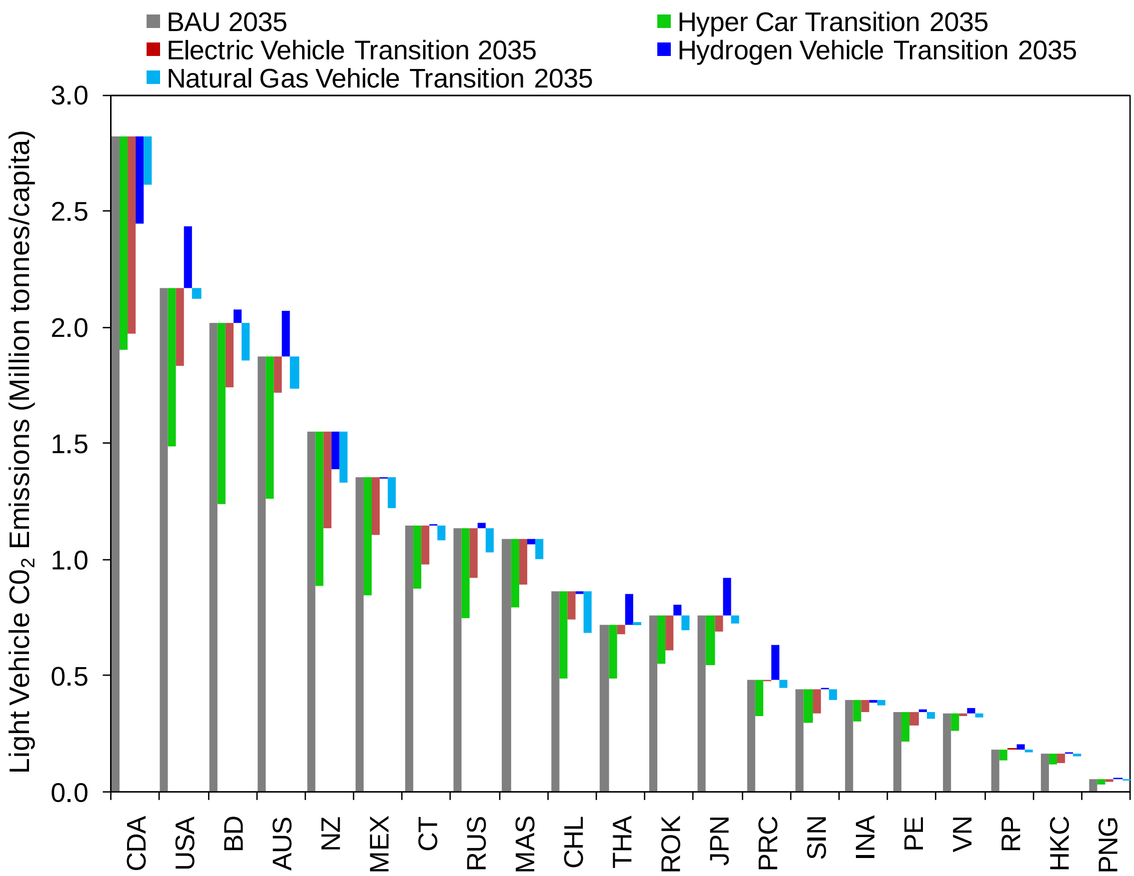
Figure 5.17: APEC CO_2 Emissions in the Light Vehicle Fleet across the Alternative Scenarios



Source: APERC Analysis (2012)

Figure 5.18 shows the CO_2 emissions results by economy. It can be seen that the emissions reductions for the Electric Vehicle Transition scenario vary considerably between economies. This reflects the differences in the gas to coal mix of the marginal generation in each economy, as well as the differences in generation efficiencies. Reductions for the Hyper Car Transition, the Natural Gas Vehicle Transition, and the Hydrogen Vehicle Transition scenarios were more consistent among economies, reflecting the similarities of these technologies across economies.

Figure 5.18: APEC Light Vehicle CO_2 Emissions per Capita in 2035 for the Virtual Clean Car Race Scenarios



Source: APERC Analysis (2012)

Virtual Clean Car Race Scenarios Summary

This analysis shows the way to energy security and low-carbon emissions is not easily achieved through the pursuit of alternative vehicles. All pathways require some compromises between the twin goals of reducing oil dependence and reducing greenhouse gas emissions.

Hydrogen vehicles offer the obvious benefit of energy diversification away from oil. However, the production of hydrogen from gas using SMR would result in a Hydrogen Vehicle Transition scenario that increases the CO_2 emissions in the light vehicle fleet by an average of 15% in the APEC economies. The CO_2 emissions would be significantly higher if coal gasification were used for the production of hydrogen.

Electric vehicles also offer energy diversification away from oil. They are, on average, less carbon intensive than conventional vehicles, but not by a large amount. An Electric Vehicle Transition scenario could reduce the carbon emissions of the light vehicle fleet by an average of 7% in the APEC economies. However, the CO_2 intensity of electric vehicles varies widely by economy and may exceed that of conventional vehicles for economies strongly dependent on coal for electricity generation. Although battery technology is improving, electric vehicles are still at a disadvantage to conventional vehicles, and even hydrogen vehicles, in terms of their driving range, refuelling times, and initial cost (refer to Figure 5.6).

Another alternative to oil-fuelled conventional vehicles is natural gas. Natural gas vehicles traditionally offer greater energy efficiency than conventional vehicles as a result of the high octane content of the fuel enabling more efficient combustion (Semin, 2008). Owing to their higher combustion efficiency, natural gas vehicles offer about a 10% improvement in energy efficiency compared to a conventional gasoline vehicle (Semin, 2008). However, it is expected the energy efficiency of conventional vehicles in the future will match or exceed that of natural gas vehicles with the diffusion of hybrid electric drive, clean diesel, and lighter weight body technologies. Still, we find a Natural Gas Vehicle Transition scenario could offer a small reduction in the APEC region's light vehicle fleet CO_2 emissions of around 6% by 2035.

The best all-around option for reducing both oil dependence and CO_2 emissions would appear to be hyper cars. On an APEC-wide basis, a Hyper Car Transition scenario could reduce light vehicle fleet oil use and corresponding CO_2 emissions by 32% compared to BAU in 2035. A Hyper Car Transition scenario would be relatively easy to achieve compared to the other alternative vehicles. It would require no change in fuelling infrastructure and the vehicles would have a driving range and performance characteristics similar to conventional vehicles.

The results of the Virtual Clean Car Race scenarios indicate that dealing with the twin challenges of energy security and climate change may require looking beyond the options examined here. Three suggestions worth considering are as follows:

1) The hyper car concept could be combined with alternative energy sources. For example, an electric hyper car would use no oil and require considerably less electricity than a conventional electric car. Because of the lower electricity requirements, it would have lower CO_2 emissions than a conventional electric car. Since the electric hyper car would need smaller batteries for any given driving range than a conventional car, it could probably be produced more cheaply.
2) A major potential advantage of electric and hydrogen vehicles is that they could ultimately be powered by primary energy from low-carbon sources. This would allow both a move away from oil and significant reductions in CO_2 emissions. But this conversion should probably be done in the context of a conversion of all electricity generation to low-carbon sources, since it would make no sense for the vehicle fleet to have its own dedicated source of low-carbon electricity while the rest of the economy continued to run on conventionally-generated electricity.
3) Meeting the twin challenges of energy security and climate change in the transport sector is a problem that will require multiple solutions. Vehicle technology changes alone will probably not be sufficient. As discussed at the beginning of this chapter, solutions include 'Avoid', 'Shift', and 'Improve'. The APEC economies would be best served by pursuing all three of these options.

Suggestion #1 implies that electric or hydrogen propulsion, in combination with the hyper car concept, offers a further medium-term opportunity to dramatically reduce oil demand in transportation. Suggestion #2 implies that electric and hydrogen propulsion offers a long-term path to truly low-carbon vehicles. For these reasons, research on electric and hydrogen vehicle technologies continues to merit the support of policymakers.

APERC'S TRANSPORT SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

The transport sector is modelled as five separate sub-sectors in each APEC economy:

1. Road vehicle fleet—further divided into the light and heavy vehicle fleets
2. Aviation—domestic and international
3. Shipping—domestic and international
4. Rail
5. Pipeline.

The road sub-sector has been the major focus of APERC's transport modelling effort, as in most APEC economies it constitutes the largest source of transport energy demand by far.

Energy use in the road sub-sector is modelled as:

Number of Vehicles x Number of Kilometres per Vehicle
x Energy Consumption per Kilometre.

This calculation is performed separately for the light vehicle fleet and the heavy vehicle fleet. Within the light vehicle fleet, it is also performed separately for each of seven vehicle technologies (both conventional and alternative vehicles).

APERC's road vehicle model represents the turnover of the vehicle fleet (purchases and retirements) each year for each vehicle type for each APEC economy. It thus allows the calculation of the number of vehicles of each technology on the road in each economy in each year. The market share for each vehicle technology among newly purchased vehicles each year depends on the merit of that vehicle technology to consumers. Using research detailed in Leaver and Leaver (2011), the calculation of use to the consumer takes into account:

- Upfront capital expenditure
- Annual fuel cost
- Vehicle range limitation
- Refuelling infrastructure availability.

The total number of light vehicles in each economy approaches a saturation level as the GDP per capita rises. But for economies whose GDP per capita is still relatively low, vehicle ownership will be well below the saturation level. APERC's estimate of the saturation level in each economy is a function of the urban population density of major cities (higher population densities imply lower saturation vehicle ownership) as well as the urban population numbers.

Because of the consideration given to urban density in estimating vehicle ownership saturation levels, APERC's estimates of vehicle saturation levels differ from those given in the literature. Table 5.4 shows a comparison of APERC's projected vehicle saturation levels to vehicle saturation levels of available APEC member economies from Dargay et al. (2007).

Table 5.4: Comparison of Long-term BAU Vehicle Saturation Levels of Available APEC Economies

Vehicle Saturation (per 1000ppl)	*APERC 2035*	*Dargay et al*
Australia	825	785
Canada	710	845
Chile	480	810
China	490	807
Indonesia	595	808
Japan	615	732
Korea	440	646
Malaysia	650	827
Mexico	610	840
New Zealand	750	812
Chinese Taipei	485	508
Thailand	770	812
United States	820	852

Sources: APERC Analysis (2012), Dargay et al. (2007)

The number of kilometres travelled per vehicle in each economy is a function of vehicle ownership, energy efficiency, income growth, and oil price. For example, when households shift from one vehicle to two vehicles the distance each vehicle is now driven does not double. Thus in non-OCED economies with strong vehicle ownership growth, unit vehicle travel decreases. In OECD economies with near saturation in vehicle ownership, oil price, income growth and vehicle efficiency have a higher effect on unit vehicle travel. Energy consumption per kilometre depends on the vehicle type and the year of manufacture. Estimates of energy consumption per kilometre by vehicle type, along with projected energy efficiency improvement trends, are drawn from the literature.

The non-road transport sectors employ a much simpler top-down approach, strongly tied to the changes in either GDP or GDP per capita. However, for the aviation and shipping models the demand response is also a function of the oil price. In addition, further consideration is given to possible modal shifts between road, rail, aviation and shipping based on expected infrastructure investment. APERC makes this assessment on a case by case basis for each APEC economy.

This section is a short summary of the APERC transport model. Further details of the mathematical derivation including case studies are given in Leaver, L et al. (2012).

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6 INDUSTRIAL SECTOR ENERGY DEMAND

BUSINESS-AS-USUAL INDUSTRIAL DEMAND

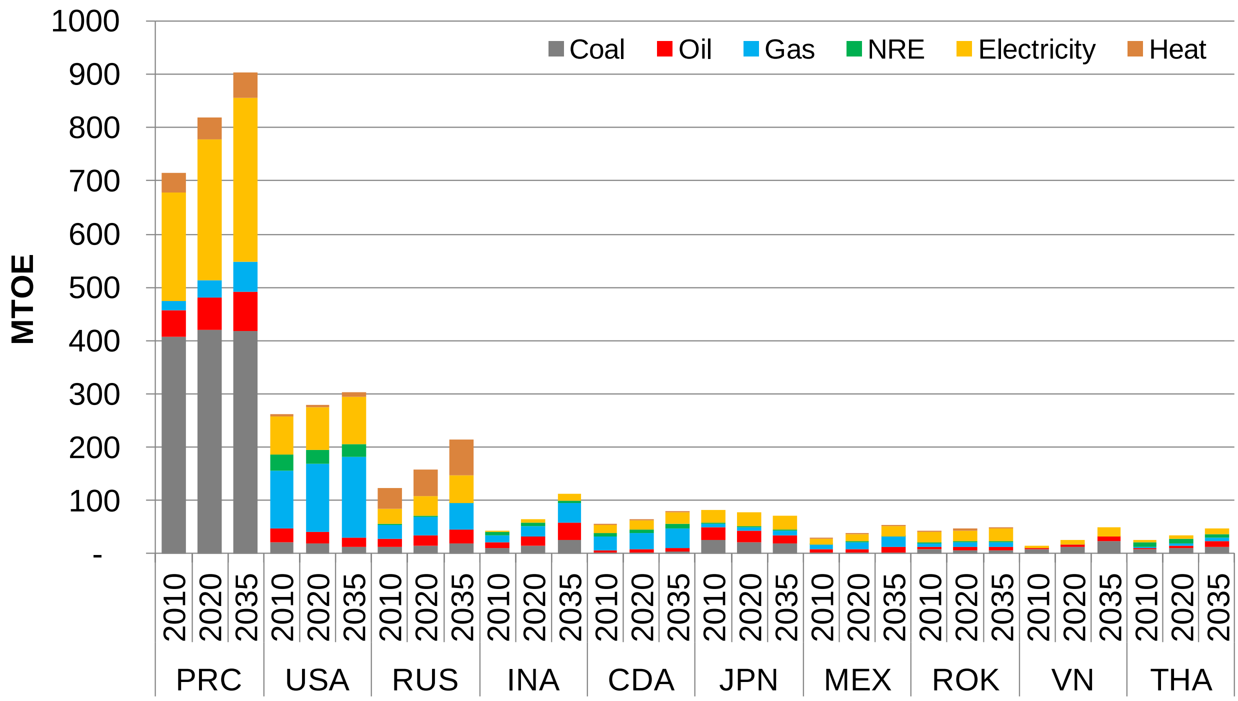
The APEC region's total industrial energy demand in a business-as-usual (BAU) scenario is projected to grow at an annual rate of 1.3% during the outlook period 2010–2035. This is roughly in line with the APEC region's projected total final energy demand annual growth rate of 1.5% over the same period. It translates to an industrial energy demand level of 2 029 million tonnes of oil equivalent (Mtoe) in 2035, up from 1 481.7 Mtoe in 2010.

Industrial Sector Demand by Economy

Figures 6.1 and 6.2 show the projected industrial demand by energy source for each APEC economy during the outlook period 2010–2035. Clearly, the mix of energy sources used varies significantly across the region. The large difference between the vertical axis scales in the two graphs demonstrates the vast difference in energy consumption in the industrial sector between the large and small economies.

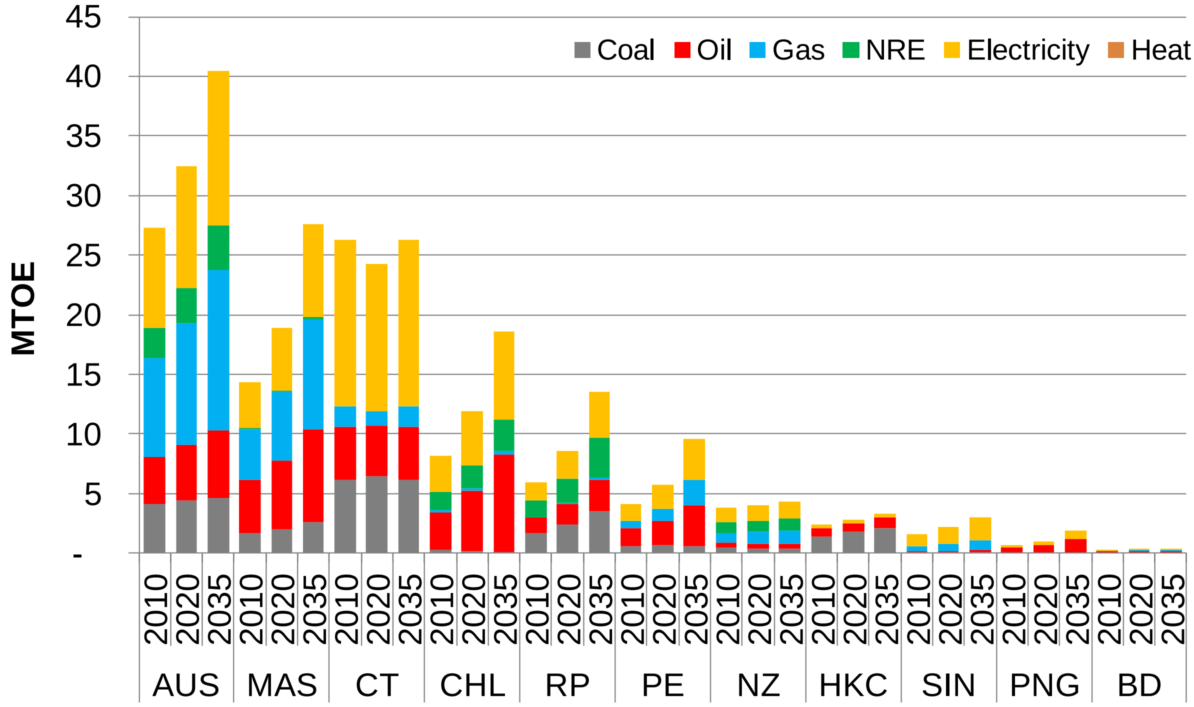
The three economies expected to have the highest industrial energy demand during the outlook period are China, the United States (US) and Russia, in that order. The combined industrial energy demand of these economies is projected to represent more than 70% of the APEC region's total industrial demand between 2010 and 2035. China will have the highest industrial demand in the region—902.8 Mtoe in 2035—which alone represents 44% of the APEC region's total industrial demand. US industrial demand level on the other hand is expected to have about 16% of the APEC region's total industrial demand throughout the period.

Figure 6.1: Final Industrial Energy Demand by Energy Source, Larger Economies



Source: APERC Analysis (2012)

Figure 6.2: Final Industrial Energy Demand by Energy Source, Smaller Economies

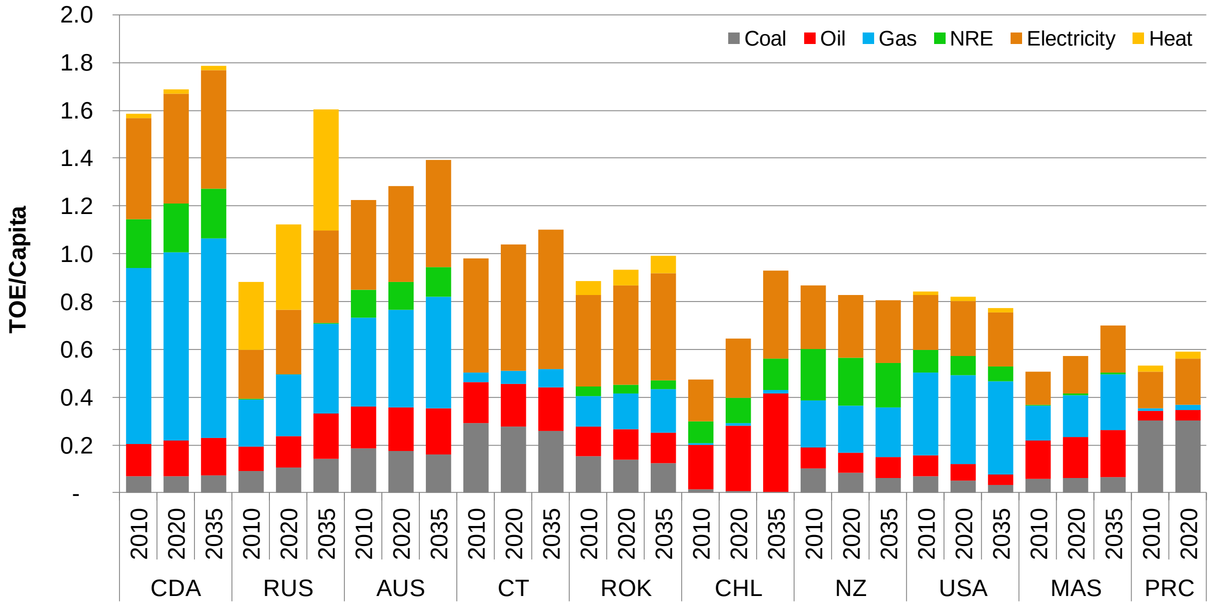


Source: APERC Analysis (2012)

Per Capita Industrial Sector Energy Demand by Economy

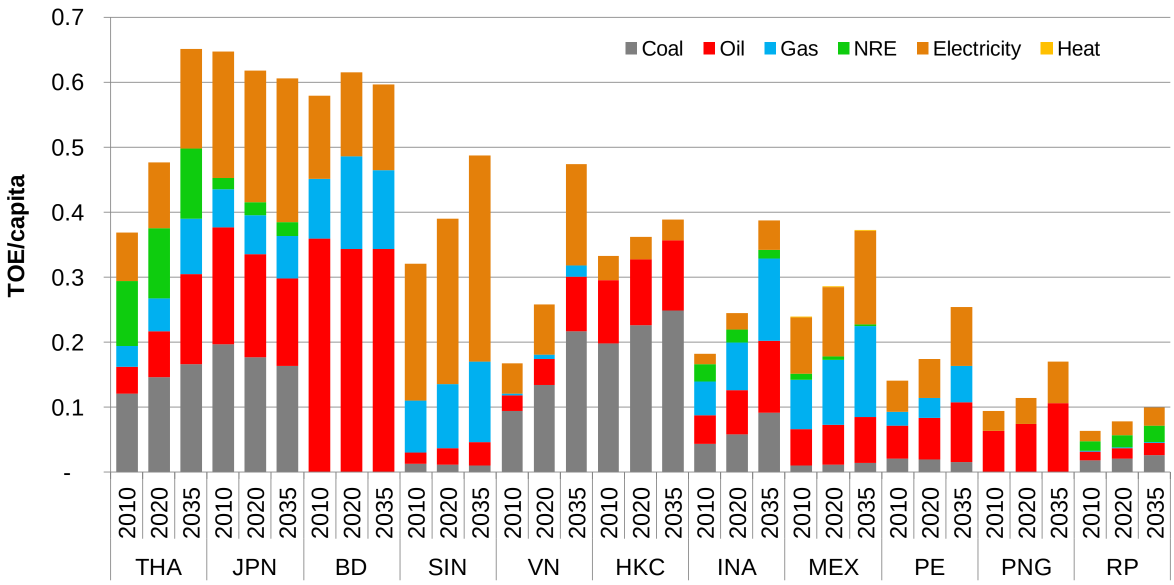
As seen in Figures 6.3 and 6.4, in 2035 Canada, Russia and Australia will have the highest per capita industrial sector energy demand, in that order. With their abundant resources and low population densities, it is likely energy-intensive industries will dominate the industrial structure of these economies over the next 25 years. Chinese Taipei and Korea will also continue to have energy-intensive industries as a core of their economies, albeit fully dependent on imported resources. While oil will continue to be used in moveable industrial applications, growth in industrial demand will be increasingly dominated by a demand for gas, electricity, and (in Russia) district heating ('heat') as the required delivery infrastructures are developed.

Figure 6.3: Per Capita Industrial Sector Energy Demand by Energy Source, Highest Demand Per Capita Economies



Source: APERC Analysis (2012)

Figure 6.4: Per Capita Industrial Sector Energy Demand by Energy Source, Lowest Demand Per Capita Economies



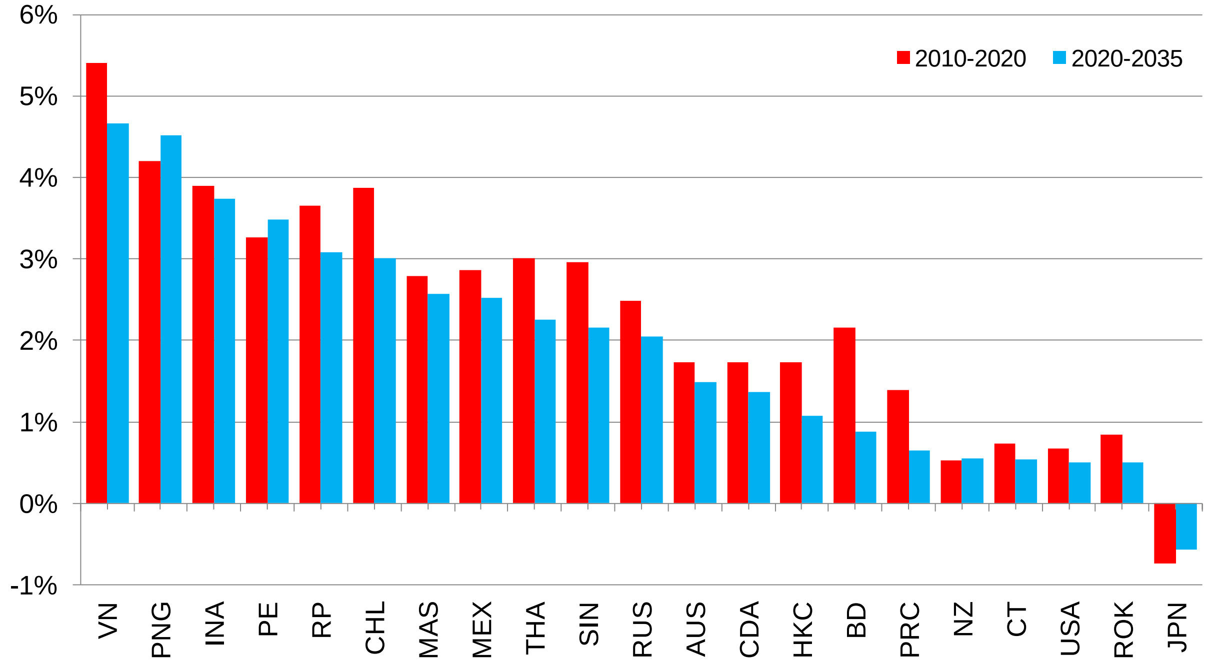
Source: APERC Analysis (2012)

Industrial Sector Growth in Energy Demand by Economy

As shown in Figure 6.5, industrial energy demand is expected to grow most rapidly in APEC's developing economies, other than China. These high levels of growth can be attributed to the rapid industrial development of these economies. Although China's economy is expected to grow rapidly, it is already heavily industrialized and it is likely to have a growth rate more akin to a mature economy.

In the mature economies, industrial demand growth will be slower, as overall economic growth will be slower. These economies will exhibit a structural shift away from energy-intensive industries toward higher value-added industries and services. In particular, Japan's industrial demand is projected to decline by 0.6% over the outlook period, from the 2010 level of 82.9 Mtoe down to 70.7 Mtoe by 2035. This will be the result of Japan's relatively slow economic growth accompanied by an explicit policy of structural change (METI, 2010).

Figure 6.5: Annual Percentage Growth Rates in Industrial Sector Energy Demand by Economy



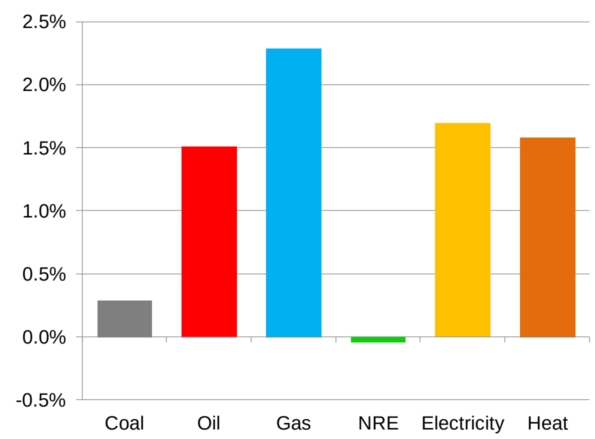
Source: APERC Analysis (2012)

Industrial Sector Growth in Energy Demand by Energy Source

As shown in Figure 6.6, gas is projected to grow the fastest among the energy sources at about 2.3% from 2010 to 2035. This translates to energy demand levels of 231.1 Mtoe in 2010 and 406.8 Mtoe in 2035. Gas is clean, easy to use and energy efficient for many industrial applications. As discussed in Chapter 12, gas will be available in abundant quantities in many APEC economies.

Electricity comes in second with 1.7% growth. It is the only energy source that can generally be used to power electronic and many types of mechanical equipment. Oil comes in third at 1.5%; although oil is expensive, it is the only energy source that can be used with many types of moveable equipment.

Figure 6.6: Annual Percentage Growth Rates in Industrial Demand by Energy Source, 2010–2015



Source: APERC Analysis (2012)

APERC's model projects negative growth for new renewable energy (NRE) in the industrial sector. NRE in the industrial sector consists mainly of biomass used in the pulp and paper and, to a lesser extent, food processing industries, where biomass is a production by-product. Although it is possible new applications for the direct use of NRE in industry may be developed, these are not reflected in APERC's models as there is little encouraging information to go on as yet. Industry can, of course, more easily use NRE indirectly in the form of electricity.

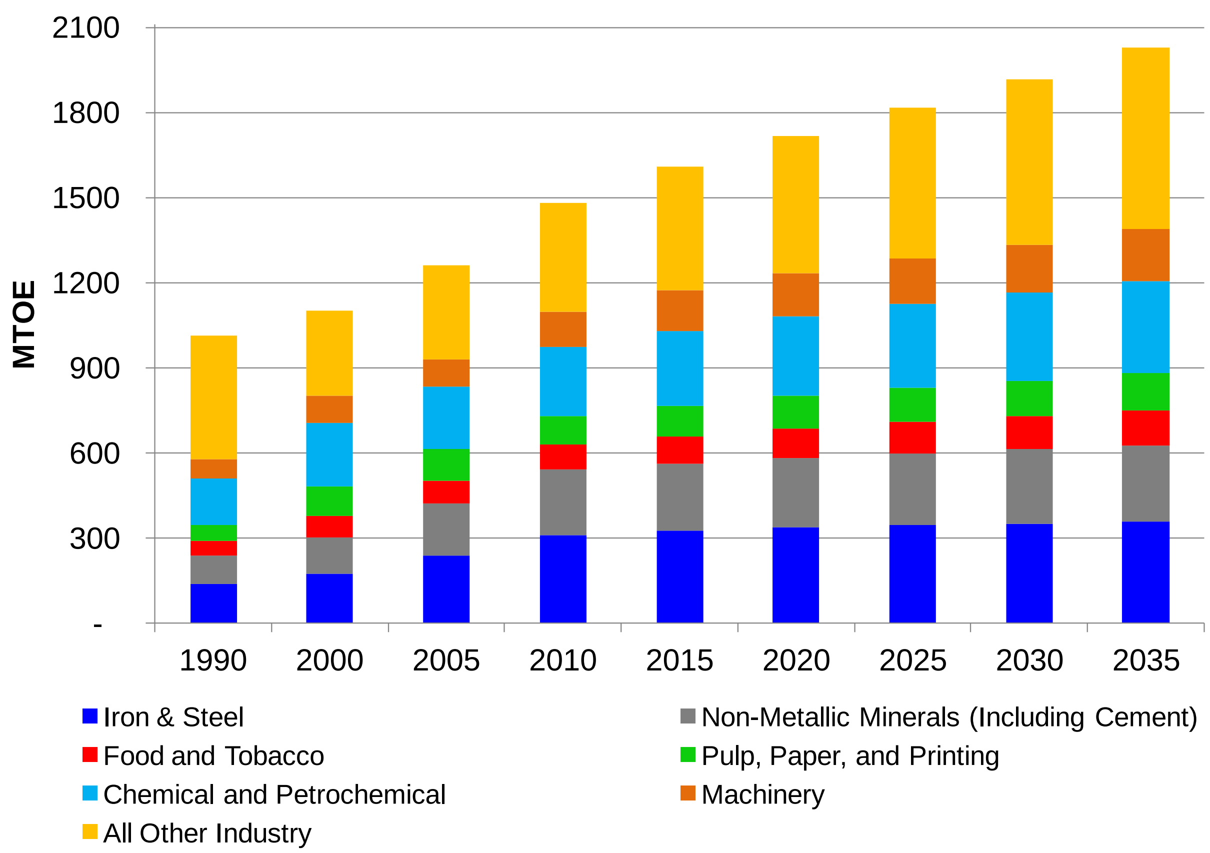
Coal consumption in industry is also projected to grow slowly. It will be used mainly in heavy industrial facilities that either technically need coal or can afford the personnel and equipment needed to manage its use. As discussed above, these industries are likely to grow slowly in many APEC economies. In addition, it is worth noting that 78% of the industrial coal demand in the APEC region in 2010, and 74% in 2035, is in China. China is an economy with an intensive focus on improving industrial energy efficiency (see the sidebar 'Industrial Energy Intensity, China and the United States' at the end of this chapter).

APEC's Energy Demand by Industry Type

Figure 6.7 shows APEC's projected industrial energy demand by industry. Over the outlook period, APEC's developing economies will reach a more mature stage of development. Industries supplying the materials necessary for basic infrastructure, such as steel and cement, will make way for high-tech industries. Thus, the region's industry structure will become less energy intensive. The growth rate of industrial energy consumption will gradually slow, while most of the increase in industrial energy demand will occur in the less energy-intensive industries.

Some economies do not collect data on energy demand by specific industries. This means the 'All Other Industry' category includes not only energy demand by industries other than the six specifically listed in Figure 6.7, but also energy demand in economies where industrial energy demand is not broken out by specific industry.

Figure 6.7: APEC's Final Industrial Energy Demand by Industry Type

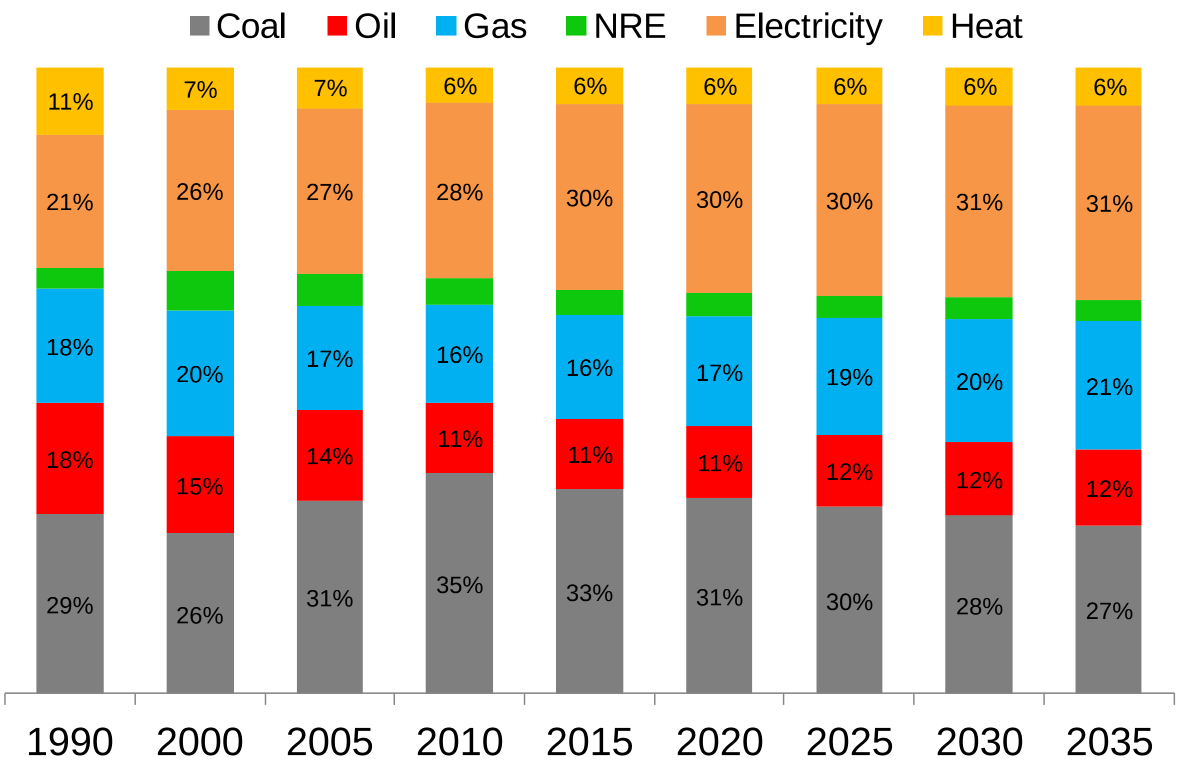


Source: APERC Analysis (2012)

Industrial Sector Market Shares by Energy Type

Figure 6.8 shows the projected market shares for each energy type in the industrial sector. Coal will lose some of its share in the energy mix to natural gas and electricity as the heavy industries intensively using coal, such as iron and steel and cement, reach saturation. Gas and electricity will replace coal as high quality energy sources for high-tech industries. Oil products including liquefied petroleum gas (LPG) will gradually be replaced by gas and electricity pending the development of their delivery networks. NRE will decline modestly unless technologies are developed for its extensive direct use in industry.

Figure 6.8: APEC's Final Industry Energy Demand, Percentage Share by Fuel Source



Source: APERC Analysis (2012)

APERC'S INDUSTRIAL SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

APERC's industrial demand models are based on an econometric approach. That is, equations are specified relating energy demand to other 'dependent' variables such as industry output and energy prices. The coefficients of the equations are then estimated statistically, based on historical data. Given the projections of the dependent variables, one could then use the estimated equations to make projections of future energy demand.

APERC was fortunate to have access to a database of potential dependent variables and their projected future values over the outlook period compiled by IHS Global Insight (Global Insight, 2012). IHS Global Insight is one of the world's leading economic data and forecasting services. Global Insight's database covered 19 of the 21 APEC economies (all but Brunei Darussalam and Papua New Guinea). For the remaining two economies, basic data on historical and projected GDP was available from the US Department of Agriculture, Economic Research Service (USDA ERS, 2012).

Ideally, one would build an industrial energy demand model that is consistent across industries and economies. However, due to data limitations, this was not feasible. Since the data limitations in many ways shaped the model, they deserve noting.

Data on total industry energy demand by type of energy is available from the IEA's World Energy Statistics (IEA, 2011) for all APEC economies except Papua New Guinea. The level of detail varies greatly. For some economies, data on specific industries may be available only for certain industries or for certain types of energy (such as electricity). The data also varies greatly in quality, and in some cases there were values that appeared questionable.

Global Insight provided an extensive database of historical and projected sales by specific industries in each economy. In some cases, APERC researchers modified the projected values to reflect their knowledge of policies and resource constraints that Global Insight may not have considered. Global Insight also provided historical and projected macroeconomic data on each economy, including GDP, employment, and various price indexes.

Data on historical energy prices is available from the IEA publication Energy Prices and Taxes (IEA, 2012a) and other sources. However, the level of coverage varies greatly by economy. Even where coverage is good, it does not necessarily give a clear picture of what is happening to the energy prices faced by individual industrial customers. These energy prices may depend on where the customer is located within the economy, the precise energy product used, and what type of tariffs, regulations, taxes, or contractual conditions apply.

Because of these data limitations, each economy had to be modelled individually. Ideally, at least seven specific industries would be modelled in each economy: iron and steel; chemicals and petrochemicals; non-metallic minerals (including cement); machinery; food and tobacco; pulp, paper and printing; and all other. But, for some economies, it was necessary to further aggregate industries. Also, the models had to be customized to the quality of the data available. What worked for one economy did not necessarily give satisfactory results for another.

In general, APERC focused on modelling energy intensities (that is E/Y, where E = energy consumption and Y = industry sales) for each economy, specific industry, and energy type. Energy intensity was generally modelled as changing over time, with changes in energy prices, and with the growth of the industry or the economy. If one can formulate a projection of energy intensity, it is simply a matter of multiplying it by projected industry sales to obtain a projection of energy demand. The merit of this approach is that it can be used to analyze future changes in industrial structure and energy intensity separately.

A risk of using any econometric model is that coefficients obtained through econometric analyses only show the historical trend, while innovative technology may bring a drastic change in the future. Thus, the energy intensity model is built combining results of econometric analyses and supplementary studies on sub-sector energy trends in each economy. Shifts in the choice of energy types among those available also had to be considered separately.

INDUSTRIAL ENERGY INTENSITY, CHINA AND THE UNITED STATES

As part of the process of developing the industrial energy demand models described above, APERC did some comparisons between industrial energy intensities in APEC's two largest economies, China and the United States (US). The results raise some interesting questions about the competitiveness of the two economies. A summary of the results is shown in Table 6.1.

Table 6.1: Energy Intensity in China and the United States

	Energy Intensity (kilogram oil equivalent/USD)		
	1990	2009	2010
Iron and steel			
China - Based on 2005 Real USD	0.897	0.381	0.368
United States - Based on 2005 Real USD	0.184	0.239	0.200
China - Based on 2005 PPP USD	0.377	0.160	0.155
Chemical and petrochemical			
China - Based on 2005 Real USD	0.696	0.186	0.168
United States - Based on 2005 Real USD	0.157	0.133	0.136
China - Based on 2005 PPP USD	0.293	0.078	0.071
Non-metallic minerals			
China - Based on 2005 Real USD	3.446	0.693	0.580
United States - Based on 2005 Real USD	0.130	0.309	0.334
China - Based on 2005 PPP USD	1.451	0.292	0.244
Machinery			
China - Based on 2005 Real USD	0.371	0.030	0.029
United States - Based on 2005 Real USD	0.020	0.025	0.024
China - Based on 2005 PPP USD	0.156	0.013	0.012
Food and tobacco			
China - Based on 2005 Real USD	0.457	0.055	0.049
United States - Based on 2005 Real USD	0.017	0.044	0.047
China - Based on 2005 PPP USD	0.193	0.023	0.021
Paper, pulp and printing			
China - Based on 2005 Real USD	0.777	0.113	0.102
United States - Based on 2005 Real USD	0.044	0.081	0.089
China - Based on 2005 PPP USD	0.327	0.048	0.043
Others			
China - Based on 2005 Real USD	0.379	0.059	0.052
United States - Based on 2005 Real USD	0.071	0.022	0.023
China - Based on 2005 PPP USD	0.160	0.025	0.022
Total			
China - Based on 2005 Real USD	0.638	0.118	0.106
United States - Based on 2005 Real USD	0.069	0.054	0.056
China - Based on 2005 PPP USD	0.268	0.050	0.045

Sources: *World Energy Statistics* 2011 © OECD/IEA 2011, Global Insight (2012) and The World Bank (2008)

For each specific industry, the first row labeled "China – Based on 2005 Real USD" shows energy intensity in China, measured as kilograms of oil equivalent per 2005 real US dollars (USD) of sales. To get the sales figures, sales in real 2005 Chinese Yuan (CNY) were converted to 2005 real USD at the 2005 CNY to USD exchange rate. The second row labeled "US – Based on 2005 Real USD" shows the comparable figures for the US.

It can be seen that, in 1990, every Chinese industry was far more energy intensive than its US counterpart. However, between 1990 and 2009, China's industrial energy intensities decreased dramatically in every industry. This improvement probably reflects both the huge scale of industrial development and modernization that took place in China over this period, as well as China's comprehensive and assertive policies for promoting industrial energy efficiency. For a description of these policies, see the APEC study Understanding Energy in China: Geographies of Energy Efficiency (APERC, 2009).

What happened to energy intensity for US industry during this period depended on the specific industry—for some industries it went down, but for others it went up. Overall, the gap between China's industrial energy intensities and those of the US narrowed considerably. Because 2009 was a year of deep recession in the US, especially for energy-intensive industries, figures are also shown for the year 2010, based on the International Energy Agency's (IEA's) statistics that became available shortly before the release of this outlook (IEA, 2012b). Compared to 2009, the 2010 results show a continued decline in energy intensity in China and a mixed impact on energy intensity in the US.

There is another way to do the comparison between China and the US. The third row labeled "China – Based on 2005 PPP USD" shows energy intensity in China measured as kilograms of oil equivalent per 2005 purchasing power parity (PPP) USD of sales. To get these sales figures, sales in real 2005 CNY were converted to 2005 USD at the 2005 PPP rate. The PPP rate tells how many CNY it would take in China to buy the same amount of goods and services as one USD would buy in the US. The World Bank has compiled data on 2005 PPP rates for most economies (The World Bank, 2008).

When comparing energy intensities across economies, PPP is arguably superior to using exchange rates. Ideally, any comparison of energy intensities between two economies would compare the energy required to produce identical goods and services in both economies. However, the goods produced by the same industry in two economies will never be identical, so a perfect comparison is impossible. Since PPP dollars are calculated to buy the same amount of goods in every economy, using them to calculate energy intensities should provide a better approximation to the energy required to produce identical goods.

In 2005, CNY 1 was worth 2.375 times more when converted to USD at PPP rates compared to when converted at market exchange rates. That is, one CNY would buy 2.375 times more in China than it would buy if it was converted to USD at the market exchange rate and the dollars spent in the US. Therefore, to convert the Chinese energy intensities from a real 2005 USD basis to a PPP 2005 USD basis, one can simply divide by 2.375. Of course, no adjustment is needed to the energy intensities for the US, since by definition one USD in the US always has a purchasing power parity of one USD.

Comparing the US energy intensities in the second row to the Chinese energy intensities based on PPP values in the third row, we see that China's industrial energy intensities in 2009 are actually lower than those for the US in every industry except 'Others'. In 2010, China's energy intensity is lower in every industry. It would thus appear that China has already surpassed the US in the efficiency by which its industry uses energy, at least when energy intensity based on PPP is used as the measure.

Many factors can distort comparisons of energy intensities between economies. We have already mentioned the impact of the different mix of goods produced in the two economies. There are also issues related to the types of energy used (electricity, for example, can be used more efficiently than coal) and the quality of the data. Nevertheless, this data suggests that by using energy more efficiently, China's industry may be gaining a competitive advantage over US industry. This development should be of concern to both policymakers and industrial managers in the US.

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7 NON-ENERGY SECTOR DEMAND

APEC NON-ENERGY DEMAND

'Non-energy demand' refers to demand for fuels that are used as raw materials and not consumed as a source of energy or transformed into another fuel. This would include the manufacture of products such as bitumen (used in road asphalt and various building materials), lubricants, solvents, paraffin waxes, and ammonia (used for making fertilizers). It would also include feedstocks for the production of various petrochemicals (IEA et al, 2005, pp. 29 and 67). Petrochemicals are the building blocks for a wide variety of products including plastic, paints, adhesives, artificial fibres, and detergents (AFPM, 2012).

Of the four final demand sectors, non-energy demand accounts for the smallest share of the APEC final energy demand, about 10% in 2010. However, it is projected to grow under business-as-usual (BAU) assumptions at a similar rate to total industry energy demand, about 1.3% per year. Specifically, consumption is projected to grow from 479 Mtoe in 2010 to 662 Mtoe in 2035.

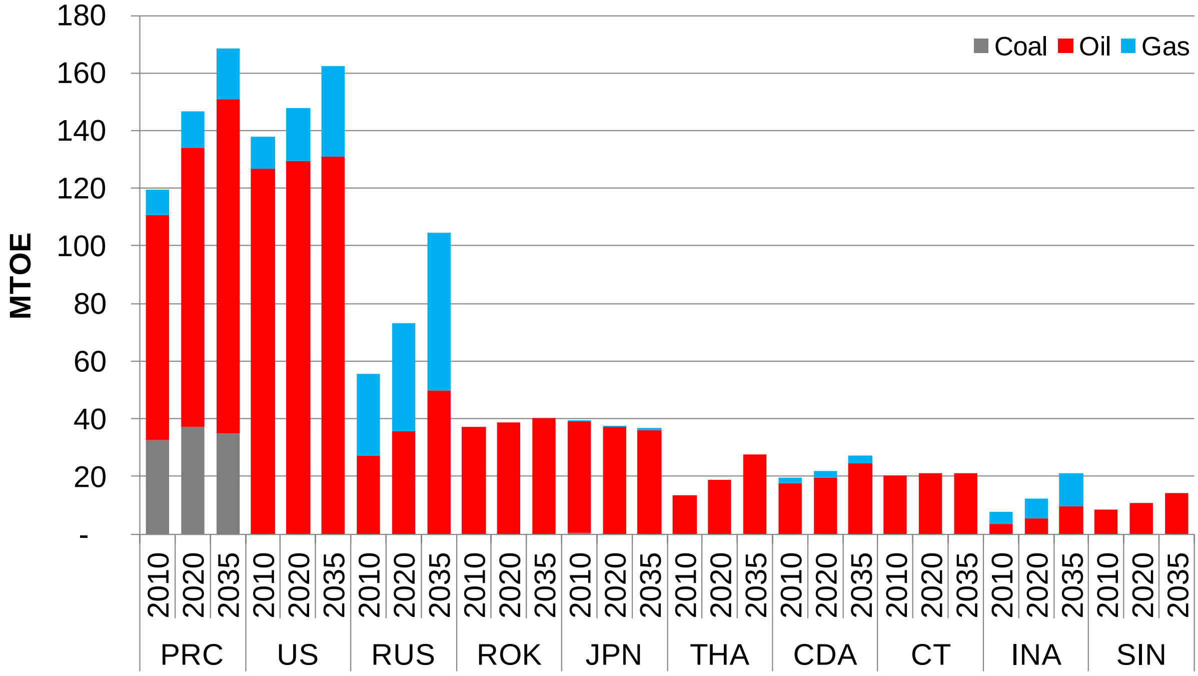
Non-Energy Demand by Economy

Figures 7.1 and 7.2 show the projected non-energy demand by energy type for each APEC economy during the outlook period, from 2010 to 2035. The large difference in vertical axis scales between the two graphs demonstrates the considerable difference in non-energy demand between larger and smaller non-energy consuming economies.

The economies that will likely post the highest non-energy use by 2035 are China, the United States and Russia. The combined non-energy use of these three economies represents over 60% of the total non-energy consumption of the APEC region.

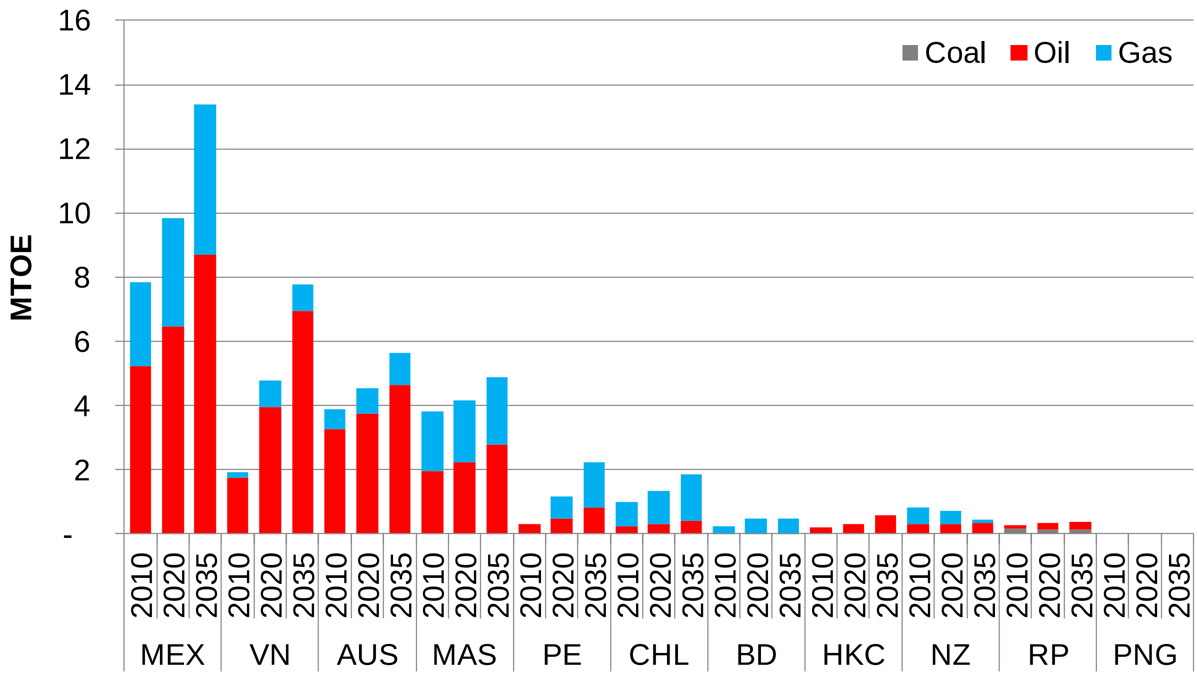
Oil meets the largest share of non-energy demand in most APEC economies. However, the gas share is larger than the oil share in Russia, Indonesia, Peru, Chile, and Brunei Darussalam.

Figure 7.1: Non-Energy Demand, Larger Non-Energy Consuming Economies



Source: APERC Analysis (2012)

Figure 7.2: Non-Energy Demand, Smaller Non-Energy Consuming Economies

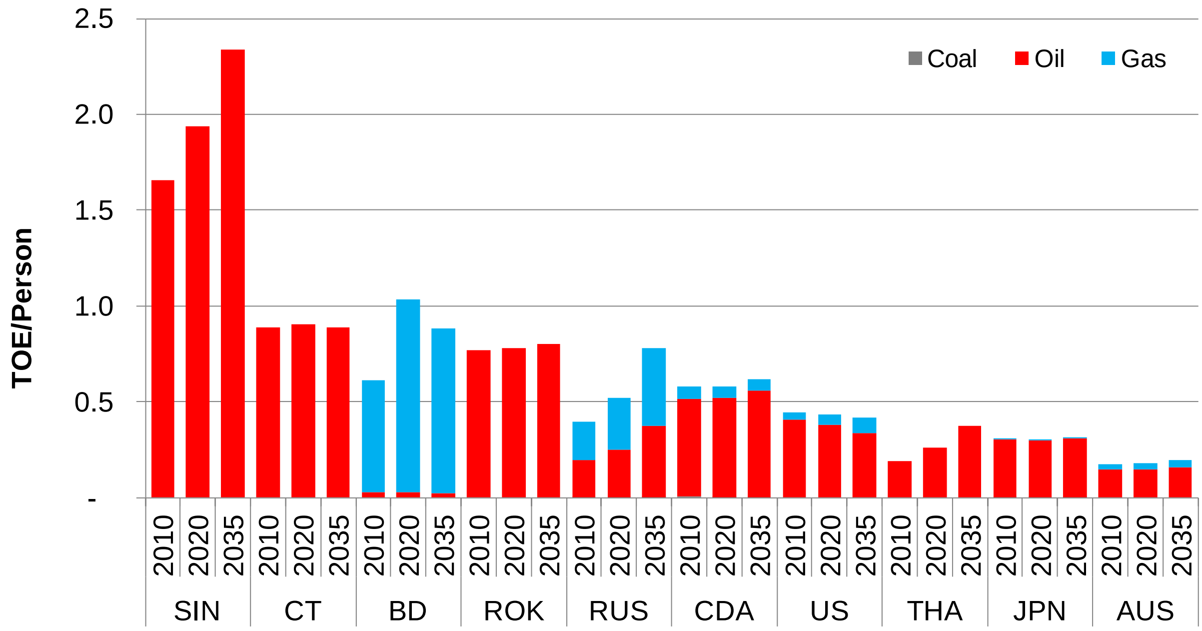


Source: APERC Analysis (2012)

Per Capita Non-Energy Demand by Economy

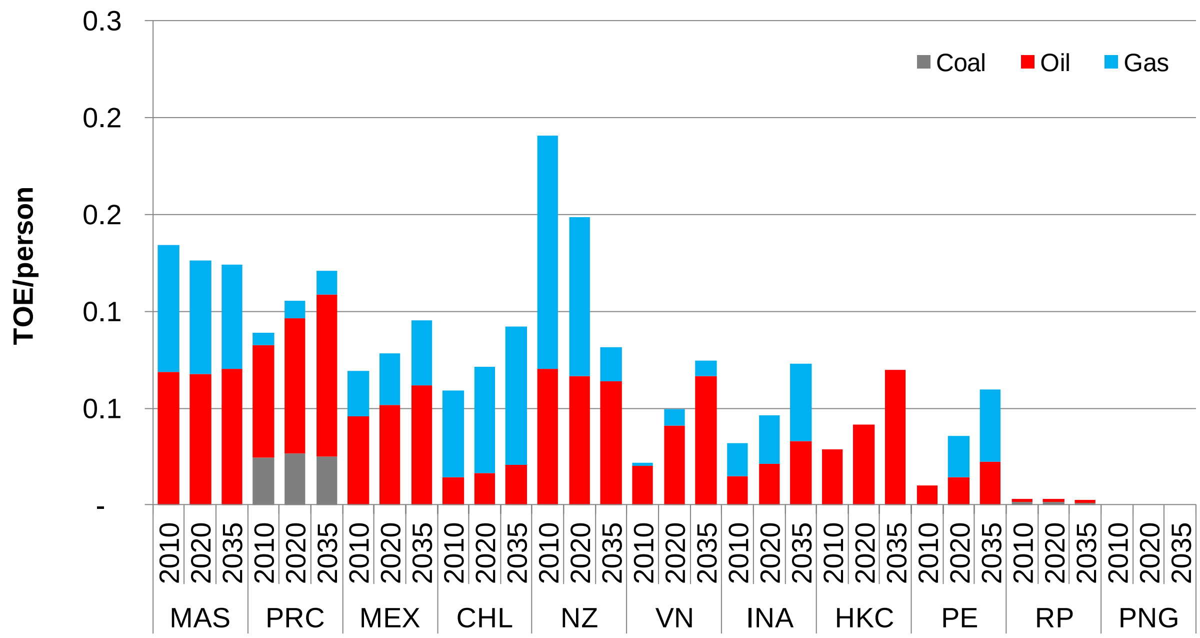
Figures 7.3 and 7.4 show the projected per capita non-energy demand by energy type for each APEC economy during the outlook period, from 2010 to 2035. The economies with the largest per capita demand are those with relatively large petrochemical industries: Singapore, Chinese Taipei, Brunei Darussalam, and Korea.

Figure 7.3: Per Capita Non-Energy Demand by Energy Source, Larger Non-Energy Per Capita Consuming Economies



Source: APERC Analysis (2012)

Figure 7.4: Per Capita Non-Energy Demand by Energy Source, Smaller Non-Energy Per Capita Consuming Economies



Source: APERC Analysis (2012)

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8 RESIDENTIAL, COMMERCIAL, AND AGRICULTURAL SECTOR ENERGY DEMAND

This chapter examines the energy challenges and opportunities in the 'other' sector, which encompasses residential, commercial, agriculture, forestry, fishing and all other services.

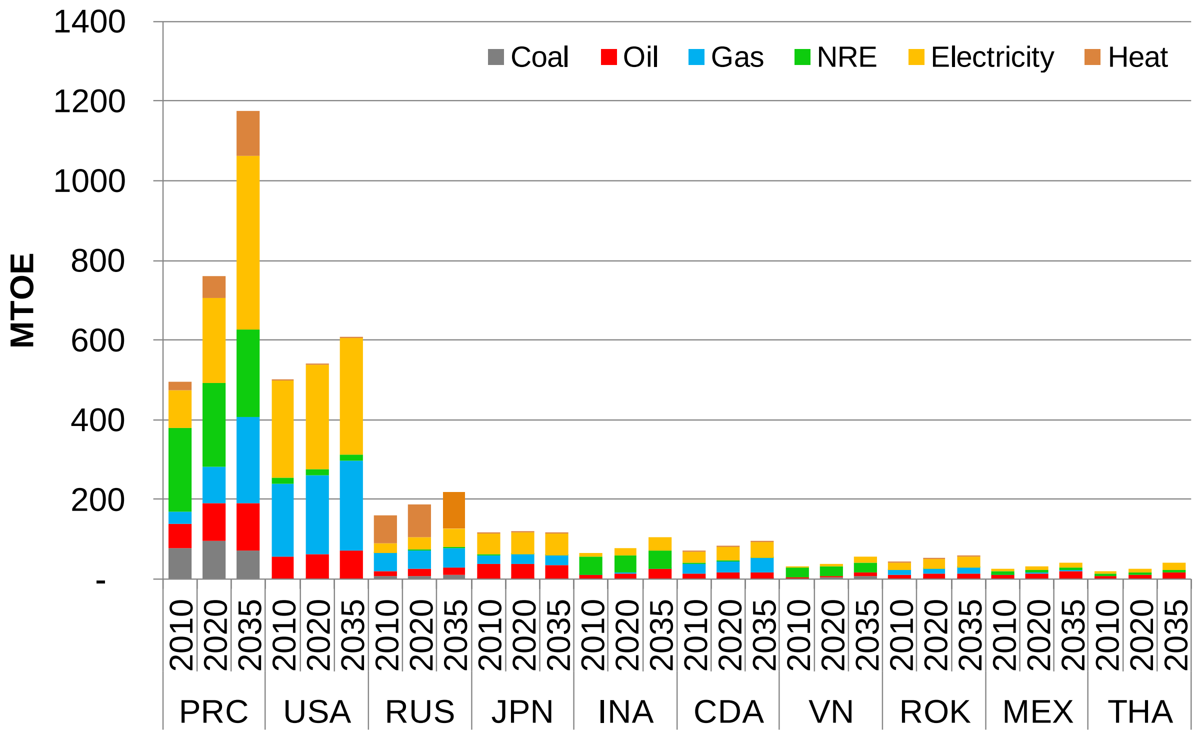
BUSINESS-AS-USUAL 'OTHER' SECTOR ENERGY DEMAND

In 2010, energy use in the 'other' sector accounted for about 33% of the total APEC final energy consumption. The energy sources and the amount of energy used in the 'other' sector vary greatly from economy to economy. Not surprisingly, developed economies had a much higher per capita energy use than did developing economies. Also, electricity and gas were the dominant energy sources in the 'other' sector in developed economies, while some developing economies still relied heavily on biomass and coal. For example, in the United States, where GDP per capita was about USD 42 000, energy consumption per capita in the 'other' sector was 1.61 tonnes of oil equivalent (toe)/capita, with electricity and gas as the main energy sources. In China, on the other hand, where GDP per capita was about USD 6800, energy consumption per capita in the 'other' sector was 0.37 tonnes of oil equivalent/capita, and new renewable energy (NRE), primarily biomass, was by far the largest 'other' sector energy source, with coal ranking number three after electricity.

'Other' Sector Total Energy Demand by Economy and Energy Source

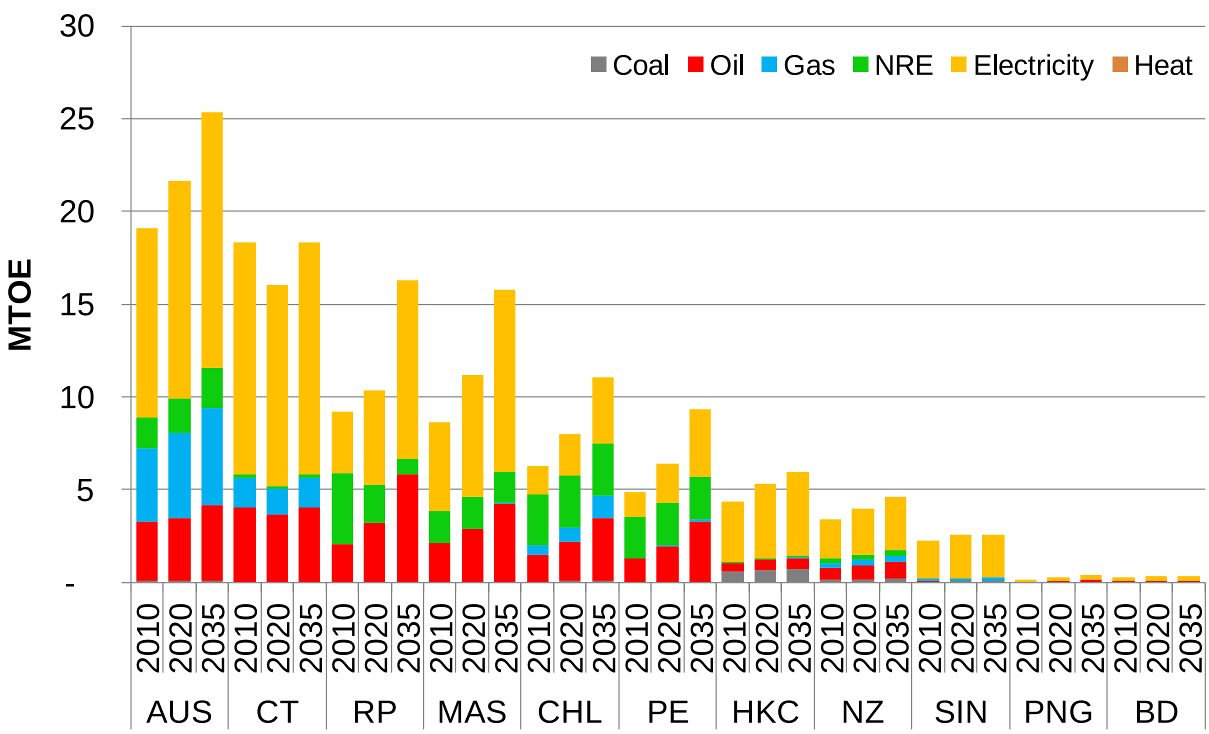
Figures 8.1 and 8.2 show the projected 'other' sector demand in each APEC economy, under business-as-usual. Note, the vertical axes of the two graphs have different scales. Over the period 2010–2035, the total 'other' sector demand is projected to increase from 1593 million tonnes of oil equivalent (Mtoe) in 2010 to 2617 Mtoe in 2035, an average annual increase of 2.0%. By 2035, the 'other' sector will account for about 38% of the total APEC final energy demand. By 2035, China will become the economy consuming the largest amount of energy in the 'other' sector (1177 Mtoe). This will account for about 45% of the total APEC 'other' sector energy demand. The US will be second, with 607 Mtoe (about 23%).

Figure 8.1: Other Sector Energy Demand by Energy Source, Higher Other Sector Demand Economies



Source: APERC Analysis (2012)

Figure 8.2: Other Sector Energy Demand by Energy Source, Lower Other Sector Demand Economies

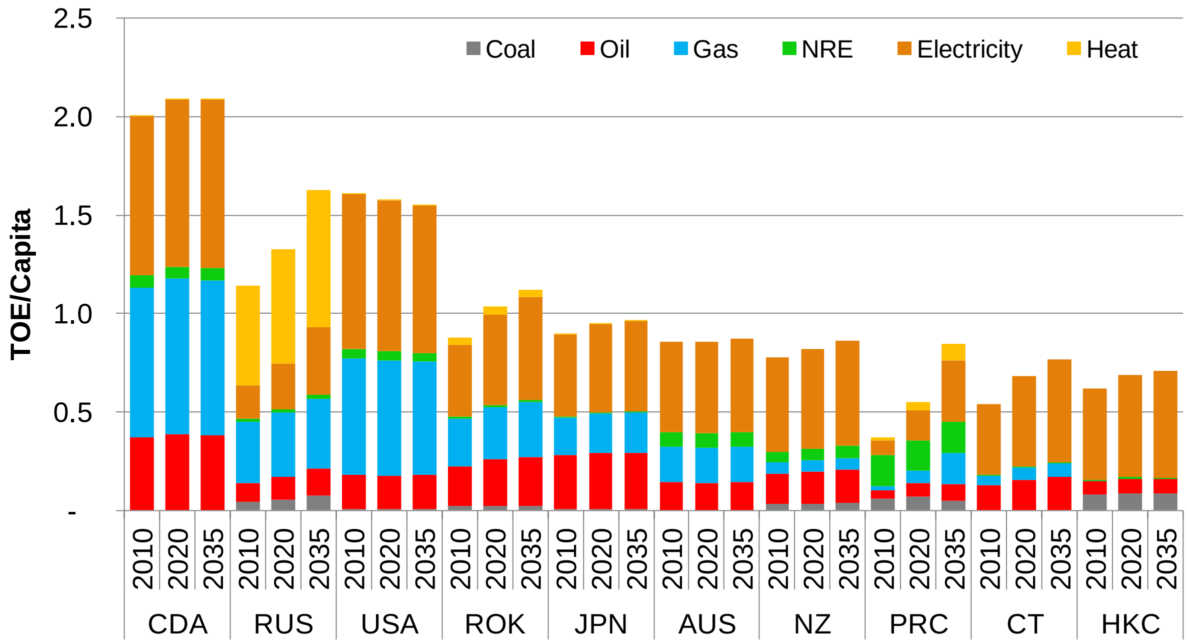


Source: APERC Analysis (2012)

'Other' Sector Per Capita Energy Demand by Economy and Energy Source

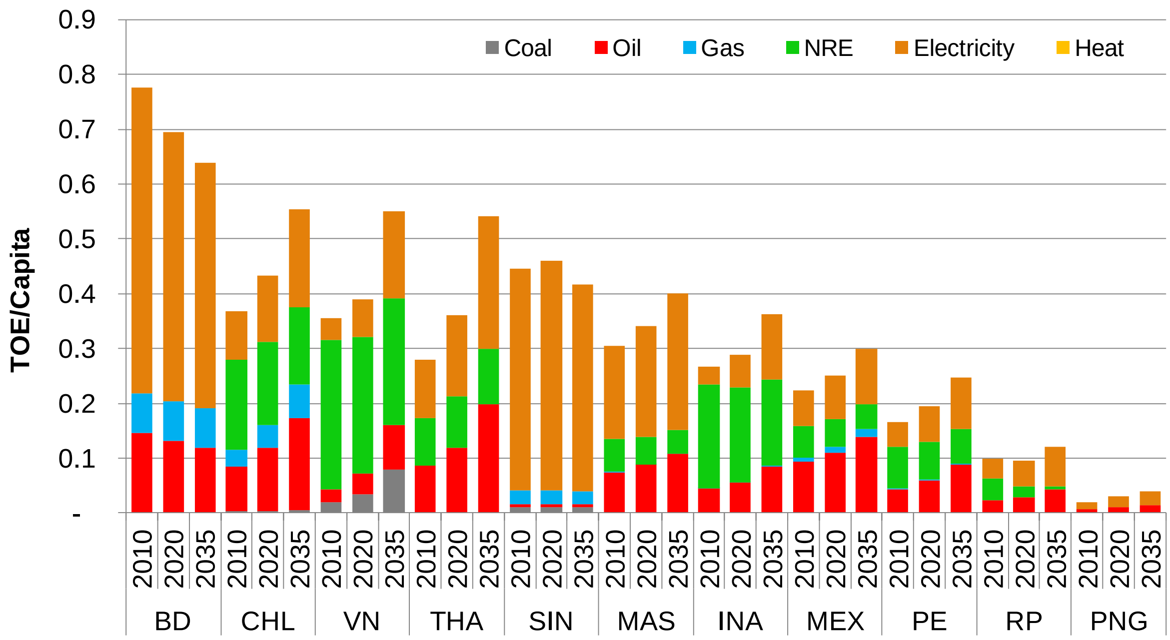
Figures 8.3 and 8.4 show 'other' sector energy demand on a per capita basis. It can be seen that, in 2035, the US will still be using far more energy per capita in the 'other' sector (at 1.55 toe/capita) than China (0.85 toe/capita).

Figure 8.3: Per Capita Other Sector Energy Demand by Energy Source, Higher Other Sector Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 8.4: Per Capita Other Sector Energy Demand by Energy Source, Lower Other Sector Demand per Capita Economies

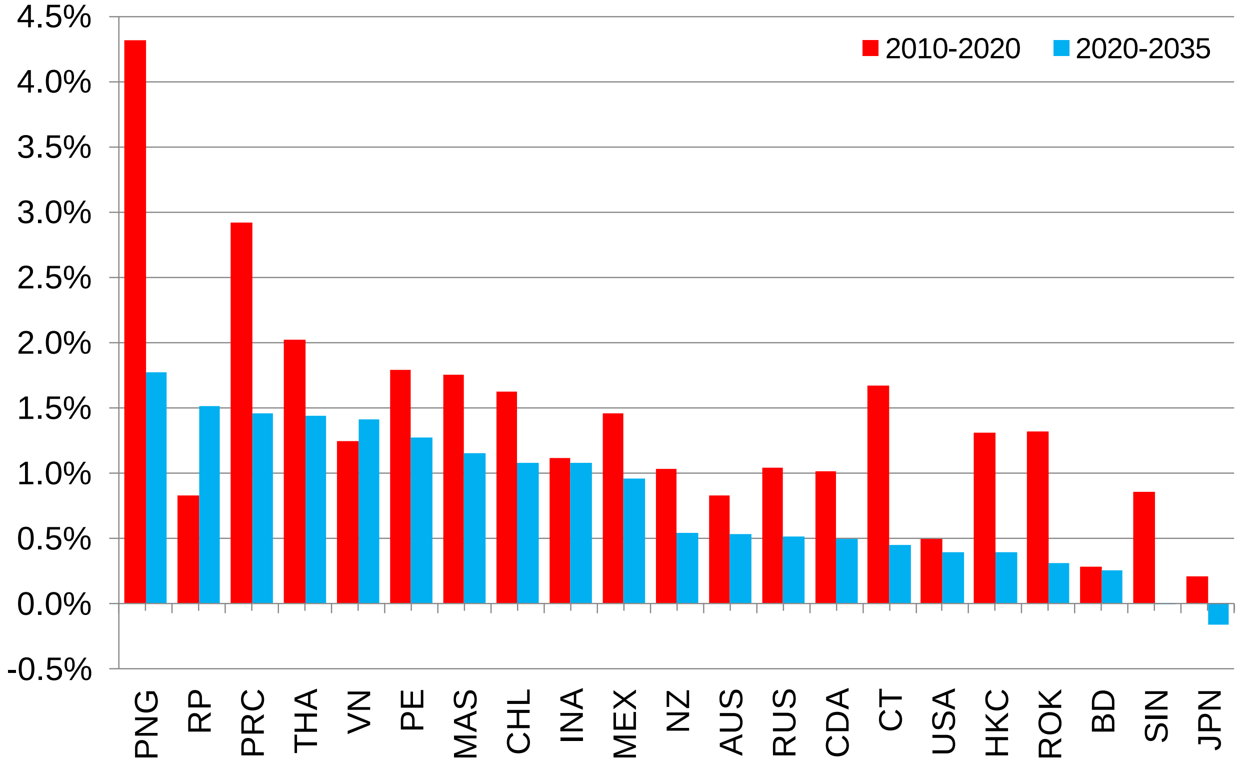


Source: APERC Analysis (2012)

'Other' Sector Percentage Growth in Energy Demand by Economy

Figure 8.5 shows the projected growth rates in the 'other' sector energy demand. The higher growth rates tend to be in the developing economies.

Figure 8.5: Annual Percentage Growth Rates in Other Sector Energy Demand by Economy



Source: APERC Analysis (2012)

APEC 'Other' Sector Total Energy Demand by Energy Source

Figure 8.6 shows the total APEC 'other' sector energy demand by energy source. Among these sources, electricity is projected to be consistently the largest between 2010 and 2035. Electricity demand will grow at an average annual rate of 2.8% over the outlook period, driven by increasing income levels and growing activity in the commercial sector. These factors will result in an increasing requirement for air conditioning, space and water heating, lighting, and home appliances. The expansion of rural electrification and the wider use of air conditioning and refrigerators in China and South-East Asia is a significant factor contributing to an increased demand for electricity in the residential sector. By 2035, China will account for 42% of the total APEC 'other' sector electricity demand, while the US will account for 28%.

Natural gas is projected to be the second-largest 'other' sector energy source between 2010 and 2035. Gas demand will grow at an average annual rate of 2.3%. Rapid growth in natural gas demand is expected as income levels expand and the extensive development of gas infrastructure continues. This will allow gas to replace non-commercial biomass for heating and cooking. 'Other' sector natural gas demand in China, in particular, is expected to grow at about 8.5% a year.

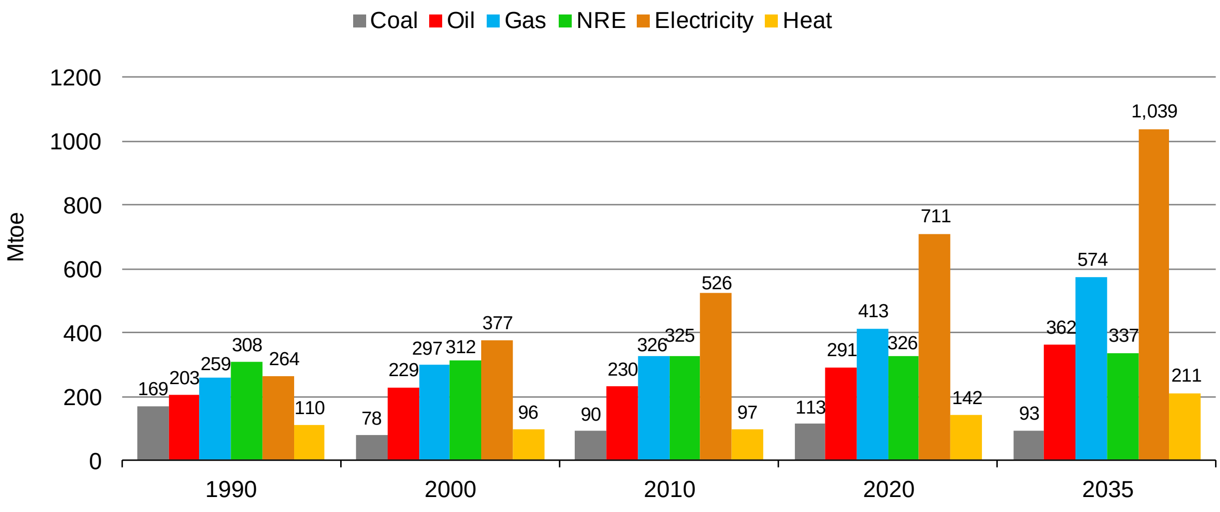
The demand for oil products, which is dominated in the 'other' sector by LPG (liquefied petroleum gas), will be at a more modest rate of 1.8% a year. The growth in demand for oil products will be held back by their relatively high prices and by the loss of some markets to natural gas, due to the expanded coverage of gas distribution networks.

The demand for heat (mainly district heating systems) is projected to be the fastest growing of any form of 'other' sector energy, at 3.2% a year. District heating is potentially a very efficient energy source, since relatively low-temperature heat from power plants and industrial facilities that would otherwise be wasted can be used for space and water heating in nearby buildings. China and Russia, which already have extensive district heating systems, are projected to represent about 98% of the total APEC 'other' sector heat demand in 2035.

Coal demand is expected to have the lowest growth among the commercial fuels in the 'other' sector, at 0.1% annually. Coal will be increasingly replaced by electricity, natural gas and LPG. In 2035, China will remain the largest 'other' sector coal consumer in the APEC region, consuming about 75% of the total 'other' sector coal demand.

Commercial fuels will increasingly replace biomass in the 'other' sector. However, while the biomass share of 'other' sector energy demand will decline overall, its use is expected to persist in rural areas, especially in China and South-East Asia, as a fuel for cooking and water heating. In regard to other NRE sources, there will also be some growth in the demand for solar water heating in the 'other' sector; however, it is not expected to be large compared to biomass. The net result will be a more or less stable demand for NRE in the 'other' sector over the outlook period.

Figure 8.6: APEC Total Other Sector Energy Demand by Energy Source



Source: APERC Analysis (2009)

'OTHER' SECTOR CHALLENGES AND SOLUTIONS

Growth of about 64% in the 'other' sector energy demand between 2010 and 2035 will have a number of favourable consequences. In many economies it will bring healthier living conditions, bring greatly improved standards of living, give children more time to pursue education, and give women more time to pursue both education and income earning opportunities.

It does, however, pose some challenges. These challenges include those related to greenhouse gas emissions, security of energy supply, and price risks for fossil fuels. There are also significant issues in the residential sector related to poverty and affordability. Although people will increasingly have access to electricity and commercial fuels, even in rural areas, many people may still not be able to afford to use very much of them.

All APEC economies recognize these issues, and are working to address them. Approaches to consider include:

- greater use of low-carbon energy sources, such as solar water heaters and the cleaner, more efficient use of biomass
- improved energy efficiency, such as higher energy-efficiency standards for buildings and appliances (see below), and a phase-out of incandescent light bulbs
- targeted assistance for those who would otherwise be facing energy poverty.

Most energy in the 'other' sector is either consumed by building systems (heating, cooling, hot water, lighting) or by appliances and other equipment in the buildings. APERC has been working with APEC developing economies to improve 'other' sector energy efficiency in both these areas through two phases of the APEC-sponsored Cooperative Energy Efficiency Design for Sustainability (CEEDS) project.

Phase 1 of CEEDS (2009–2010) addressed Appliance Energy Efficiency Standards and Labeling (APERC, 2010). Phase 2 of CEEDS (2010–2011) addressed Building Energy Codes and Labeling (APERC, 2011). In each phase, economy delegates worked with internationally recognized experts and APERC researchers to quantify potential energy savings, and to identify characteristics of an effective program. The next two sections discuss the potential energy savings identified in each phase.

Appliance Energy Efficiency Standards and Labeling

As discussed in Chapter 4, consumers often lack the information needed to make an informed trade-off between the initial purchase price of an appliance and the long-term operating costs, which are often primarily energy costs. This may be because comparative information on actual energy usage by different appliances is difficult to obtain, because the consumer lacks the skills to analyze this information, or because the consumer lacks the time to do the analysis of what is, for individual consumers, a relatively small cost difference. As a result, consumers tend to focus on the initial purchase price, and appliance manufacturers tend to focus on lowering the initial purchase price of their products.

For both consumers and society, these 'cheap' appliances may actually be quite expensive in the long run (ECS, 2009). Consumers themselves are burdened over the long term with excessively high energy costs, while society as a whole is burdened by excessively high investments in energy supply infrastructure, threats to energy security, and environmental damage.

Energy efficiency standards and labels break this cycle. Energy efficiency standards prescribe a minimum energy performance for specific types of appliances. Energy efficiency labels summarize key information consumers should know about the energy performance of an appliance. Standards keep the most inefficient and obsolete appliances off the market; labels encourage consumers to go beyond the standard and purchase even more efficient products.

Six developing economies participated in CEEDS Phase 1 on appliance energy efficiency standards and labeling: Chile, China, Malaysia, the Philippines, Thailand, and Viet Nam.

To understand the energy saving potential of appliance energy efficiency standards within these six economies, APERC undertook an analysis of energy saving potential in collaboration with the Collaborative Labeling and Appliance Standards Program (CLASP) and Lawrence Berkeley National Laboratory (LBNL). The model assumed cost-effective standards, achievable with existing technology, were adopted immediately in each economy for six types of appliances, as well as for fluorescent lamps, incandescent lamps, and standby power (power use while switched off) for electronic equipment.

The deployment of the new equipment was then modelled in each economy each year. The savings grow larger each year as the old inefficient appliances are replaced with models that meet the standards. By 2030, most appliances in service meet the standards. Table 8.1 shows the percentage energy savings by economy by type of equipment compared to business-as-usual.

These are obviously significant savings. The full analysis (APERC, 2010) also included a discussion of the total energy savings by economy by type of equipment, which is not reproduced here. Advances in technology over this period, which would allow a further tightening of the standards, as well as the additional benefits from labeling programs could add to these savings.

Table 8.1: Estimated Potential Percentage Energy Savings from Appliance Energy Efficiency Standards by Economy

	Fan	Fluorescent Lamps	Incandescent Lamps	Laundry	Refrigeration	Air Conditioner	Standby	Television	Rice Cooker
Chile	32.2%	NA	39.4%	33.7%	41.7%	26.2%	78.6%	35.4%	NA
China	36.4%	21.7%	41.6%	46.9%	43.3%	37.7%	79.9%	26.9%	29.7%
Malaysia	32.4%	17.1%	39.4%	42.5%	49.5%	20.1%	78.7%	35.4%	29.7%
Philippines	40.3%	9.6%	39.4%	3.7%	49.8%	17.1%	78.4%	35.4%	29.7%
Thailand	31.9%	9.6%	39.4%	41.9%	49.3%	19.0%	78.8%	35.4%	29.7%
Vietnam	40.0%	17.0%	39.4%	17.3%	50.8%	25.0%	78.4%	35.4%	29.7%

Source: APERC Analysis (2012)

Building Energy Codes And Labeling

Consumers and businesses seeking to buy or rent building space face the same informational challenges as appliance consumers discussed above. Building developers, therefore, face the same pressures as appliance manufacturers to keep the initial cost of buildings down, even when the result is higher total costs over the life of the building. The result is a similar under-investment in energy efficiency.

Although it is possible to improve the energy efficiency of buildings through retrofits after they are built, there are at least three additional factors that work strongly against such retrofits:

- First, and perhaps most importantly, it is usually far easier and cheaper to make buildings energy efficient at the time they are designed and built, rather than through later retrofits.
- Second, in the case of rental buildings, the landlord generally must make the investments to improve energy efficiency, but the tenant generally pays for the energy and will reap the benefits of the landlord's investment.
- Third, even in the case of owner-occupied buildings, the owner may not be confident of owning the building long enough to recover the investment through energy savings and, because of the informational challenges mentioned above, may not be confident of recovering the investment when the building is sold.

These three factors make energy efficiency building retrofits hard to justify.

So buildings need to be initially designed and built in an energy-efficient manner. If they are underinvested in energy efficiency at the time they are built, they are likely to stay that way. Because the life of a building is quite long—typically several decades or more—an energy inefficient building will lock-in wasteful energy use for decades to come (Laustsen, 2008).

Building energy codes and labeling can break this cycle. It is especially critical to do so in developing economies, where urbanization and building construction is proceeding at a rapid pace. In addition to energy and environmental benefits, energy efficient residential buildings can help to alleviate energy poverty without the need for on-going subsidies.

Six developing economies participated in CEEDS Phase 2 on building energy codes and labeling: China, Indonesia, Malaysia, Mexico, Thailand, and Viet Nam.

To understand the energy saving potential of building energy codes within these six economies, APERC undertook an analysis of energy saving potential using eQUEST building simulation software developed under the auspices of the California Public Utilities Commission (EDR, 2012).

Using the eQUEST software, APERC analyzed the energy saving potential of implementing the International Energy Conservation Code 2009 as tailored to the climate in each economy, to four building types common in each economy. Typical efficiency provisions included wall insulation, air-tightness, window insulation, window solar properties, lighting power density, ventilation system efficiency, pump and fan controls (VSD), high-efficiency chillers and boilers, and efficient motors for fans and pumps.

The International Energy Conservation Code 2009 is a model building code developed by the International Code Council (ICC). The ICC is a membership association which develops codes for the construction of residential and commercial buildings. It is dedicated to building safety, fire prevention and energy efficiency. Most US cities, counties and states choose to adopt the International Codes developed by the ICC. The International Codes also serve as the basis for the construction of US federal properties around the world, and as a reference for many economies outside the US (ICC, 2012).

The US Department of Energy Building Technologies Program has analyzed the International Energy Conservation Code 2009 for single family and multi-family homes and determined it would "yield positive benefits for US homeowners and significant energy savings for the nation" (USDOE, 2012).

Table 8.2 shows the resulting energy savings compared to business-as-usual for each building type in each of the six economies. Again, the energy savings are significant. The full analysis (APERC, 2011) also included a discussion of the total energy savings by economy by type of equipment, which is not reproduced here.

Because the turnover of buildings is relatively slow, even in developing economies, it would take a number of years for building energy codes to have a big impact. Therefore, it is important to implement building energy codes as soon as possible. As with appliance energy efficiency standards, future advances in technology, which would allow a further tightening of the standards, as well as the additional benefits from labeling programs could add to the savings.

Table 8.2: Estimated Potential Percentage Energy Savings from Building Energy Codes by Economy

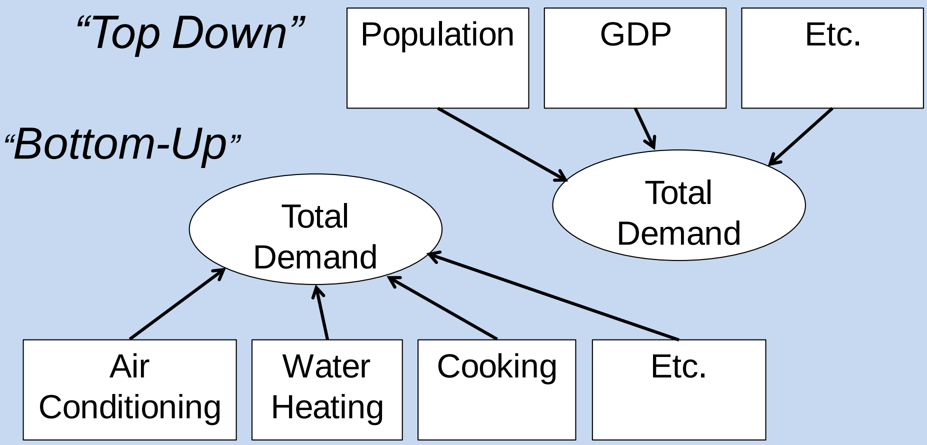
Economy	Building Type	Energy Savings
China	Apartment	16%
China	Office	35%
China	Retail	36%
China	Small Apartment	16%
Indonesia	Apartment	13%
Indonesia	Office	44%
Indonesia	Retail	19%
Indonesia	Single Family House	13%
Malaysia	Apartment	17%
Malaysia	Office	43%
Malaysia	Retail	45%
Malaysia	Terrace Housing	10%
Mexico	Apartment	6%
Mexico	Office	38%
Mexico	Retail	14%
Mexico	Single Family House	15%
Thailand	Apartment	12%
Thailand	Office	29%
Thailand	Retail	28%
Thailand	Single Family House	15%
Viet Nam	Apartment	13%
Viet Nam	Office	38%
Viet Nam	Retail	34%
Viet Nam	Single Family House	19%

Source: APERC (2011, p. 13)

APERC'S 'OTHER' SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

Two general approaches are possible for modelling residential, commercial, or agricultural energy demand, as shown in Figure 8.7. In the 'bottom-up' approach, separate sub-models are developed for each energy application and these are aggregated into the total residential demand. In the 'top-down' approach, energy demand is modelled based on aggregated statistics for the economy. The bottom-up approach is preferable, as it tells a more detailed story of what is happening to energy demand, and more easily allows the modelling of alternative policies that may affect specific energy applications, such as improving the efficiency of certain appliances. However, it requires detailed data on each energy application, which may not be available in many economies.

Figure 8.7: General Approaches to Modelling 'Other' Sector Energy Demand



APERC developed both kinds of models. However, because of data limitations, the bottom-up approach was used only for the residential sector and only for those economies with adequate data: Australia, Canada, Chinese Taipei, Japan, Korea, New Zealand, Russia, and Singapore. This section, therefore, focuses on the 'top-down' approach that was used elsewhere, and specifically focuses on residential demand modelling.

To model demand in the residential sector, APERC sought an approach that could:

- be consistent across economies
- work with the limited data available for many APEC economies
- use knowledge of what is happening in all APEC economies to project the demand in specific APEC economies.

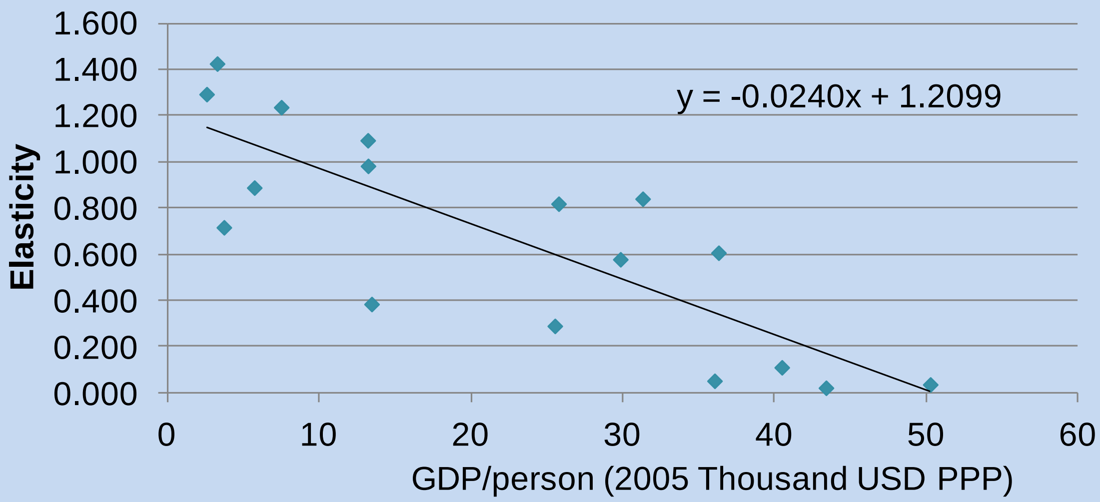
Economic literature (Judson et al., 1999) suggests that:

1. Per capita GDP is the major driver of residential energy demand.
2. The rate at which residential energy demand per capita increases as GDP per capita increases (the income elasticity) declines as GDP per capita increases.

The second conclusion is intuitively quite reasonable, especially for the residential sector. When a poor economy first starts to grow wealthier, among the first things its residents seek to buy are basic home appliances, such as commercial fuel cooking equipment, hot water heaters, refrigerators, washing machines, air conditioners, and televisions. As a result, the residential energy demand of an economy in the early stages of industrialization rises rapidly. A common flaw in residential demand modelling for developing economies is to assume this rapid rate of demand growth will continue indefinitely into the future. It does not. Once people get wealthy enough that they already have basic home appliances, further increases in income tend to be spent in other, less energy-intensive ways.

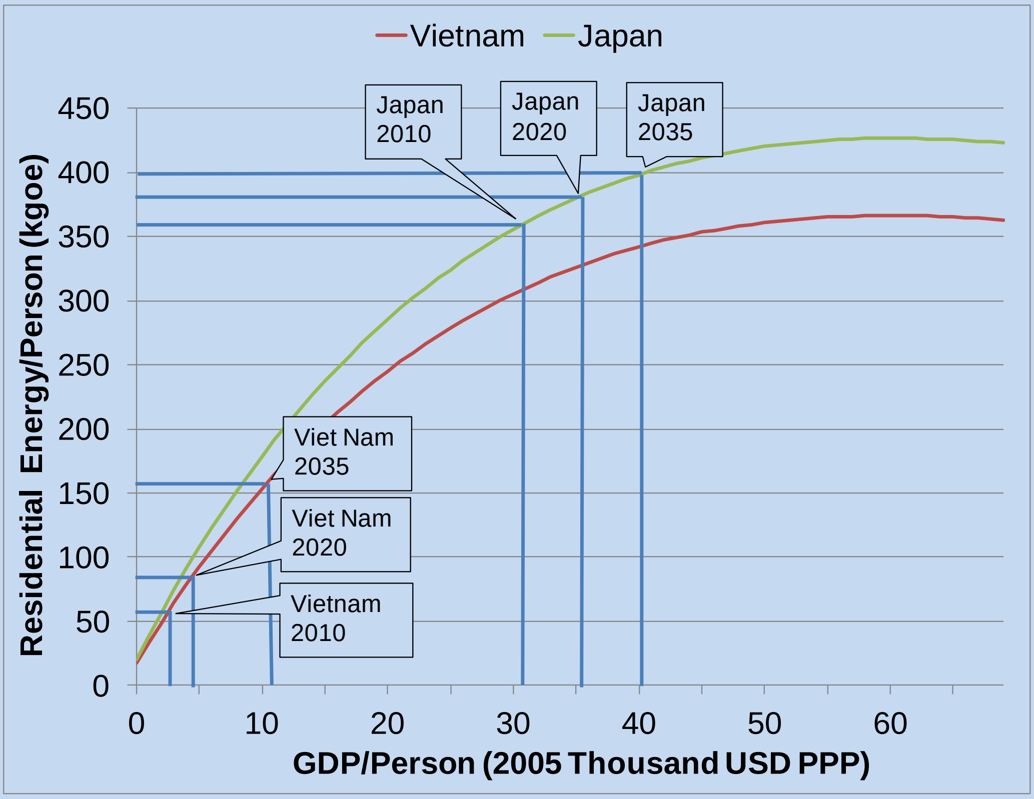
APERC modelled this relationship between the income elasticity of residential energy demand/person and GDP/person based on historical data, as shown in Figure 8.8. The results indicated the income elasticity of residential energy demand is greater than one for poorer economies (that is, a 1% increase in income results in a more than 1% increase in residential energy demand), but drops off rapidly as income rises.

Figure 8.8: Relationship Between Income Elasticity of Residential Energy Demand and GDP/Person by Economy



Using a bit of calculus, the elasticity relationship shown in Figure 8.9 can be used to construct a general relationship between per capita income and residential energy demand/person. Such a curve can be fitted to an individual economy by forcing it to pass through the economy's 2010 residential energy demand per capita and GDP per capita. If one has an estimate of future GDP per capita for the economy, the future residential energy demand per capita can then be simply read off the curve. Figure 8.9 shows an example for Japan and Viet Nam (which does not reflect the actual numbers used in APERC's final residential demand projection for these economies). Note, Viet Nam's residential energy demand/person, although much lower than Japan's, is increasing much more rapidly with GDP/person.

Figure 8.9: Residential Energy Demand Projection Example: Japan and Viet Nam



Note: kgoe = kilograms of oil equivalent

This section is a short summary of Chen and Samuelson (2012), which should be consulted for more detailed information on APERC's 'other' sector demand modelling.

IMPROVING ENERGY EFFICIENCY WITH RESIDENTIAL FUEL CELLS

Fuel cells use an electrochemical process—not moving parts—to generate electricity and heat from gaseous or liquid fuels. Fuel cells can be built in almost any size, and therefore have many potential applications in the energy sector. Perhaps the best known of these is as a source of electricity to power hydrogen vehicles, as discussed in Chapter 5. Another application is as a small scale source of electricity and domestic hot water that could be installed in individual residences. The fuel source for residential fuel cells would most likely be natural gas, but could also be hydrogen, biogas, propane, or liquid fuels.

The main advantage of fuel cells in a residential application would be their high level of efficiency. A modern residential fuel cell could produce electricity from gas with an efficiency of about 40%—comparable to many of today's utility generation plants—but, in addition, could produce hot water from the waste heat with an efficiency of up to 50% (Tokyo Gas and Panasonic, 2011). This would allow an overall efficiency far higher than even today's most efficient utility combined cycle gas turbine generating units, which are in the 55–60% range before transmission losses (Sano, 2010, Figure 3).

Additional advantages of residential fuel cells stem from the fact they are a form of distributed electricity generation, which could eliminate electricity transmission losses and enhance the security and robustness of the energy grid. Small power plants like these can be easily turned on or off remotely, making them amenable to integration into a future smart grid. They are almost noiseless and, when running on natural gas, produce emissions of CO_2 only.

In the future, residential fuels cells could also potentially integrate well with residential solar and wind installations. These renewable electricity sources could be used to electrolyze hydrogen from water during the hours when electricity demand is low; the hydrogen could then be used to generate electricity in a fuel cell during peak electricity demand hours. Such an arrangement could overcome the intermittency limitations of solar and wind power, while providing true zero-emission electricity and hot water.

The greatest barrier to the widespread commercialization of residential fuel cells is their high initial cost. For example, in Japan a 750 W Panasonic Ene-Farm fuel cell is currently sold for about USD 35 000 (JPY 2 761 500) (Tokyo Gas and Panasonic, 2011). This stationary fuel cell will provide about 50% of the electricity needed by a typical Japanese household, and save the household about USD 600 to USD 750 a year on electricity and gas costs compared to buying the electricity from the grid and buying gas for hot water only. The estimated life of the fuel cell unit is only about 10 years, so the initial purchase price cannot be recovered. However, there is substantial room for cost reductions. Various Japanese research and demonstration programs are aiming to reduce the initial cost to around JPY 500 000 by later in this decade (JX Nippon Oil & Energy Corporation, 2011; Daily Yomiuri, 2012), which could offer a payback period of as little as eight years.

While this target cost may still seem high, there may be additional benefits. The hot water could be circulated in the floor of the building to also provide comfortable and economical space heating, allowing the system to be more fully utilized. As these systems are upgraded to allow off-grid operations in the event of blackouts, they could provide even more value and peace of mind to homeowners.

One potential early application for residential fuel cells might be on small islands and in other off-grid communities, which exist in nearly every APEC economy. Here the fuel cells might run on propane or liquid fuels, but could offer substantial efficiency gains over the expensive and inefficient diesel generators commonly used in such locations today.

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9 ELECTRICITY DEMAND AND SUPPLY

HISTORICAL TREND

Electricity demand in the APEC region grew robustly between 1990 and 2009 at an average annual rate of 3.3% per year, from 5720 terawatt-hours (TWh) in 1990 to 10 528 TWh in 2009. Rapid growth was observed particularly in developing Asian economies. Viet Nam experienced the highest average annual growth rate from 1990 to 2009 (14.2%), followed by China (10.2%), Malaysia and Indonesia (both 8.6%), as shown in Table 9.1.

In 1990, developed OECD-member economies including Australia, Canada, Japan and the United States (US) accounted for 69% of the APEC region's total electricity consumption, with the US alone consuming 46%. However, by 2009, the total share consumed by these economies had decreased to 50%; this was due mainly to increasing electricity demand in China and other developing South-East Asia economies. China's share of the APEC region's total electricity demand has increased from 8% in 1990 to 29% in 2009, as calculated from Table 9.1.

Table 9.1: APEC's Electricity Demand by Economy, in TWh

Economy	Final Electricity Demand (TWh)			Average Annual Percentage Change	
	1990	2009	2035	1990-2009	2009-2035
Australia	129	214	318	2.7%	1.5%
Brunei Darussalam	1	3	4	6.3%	0.5%
Canada	418	477	701	0.7%	1.5%
Chile	15	54	128	6.8%	3.4%
China	482	3065	8765	10.2%	4.1%
Hong Kong, China	24	42	56	3.0%	1.2%
Indonesia	28	135	546	8.6%	5.5%
Japan	750	934	957	1.2%	0.1%
Korea	94	406	573	8.0%	1.3%
Malaysia	20	96	206	8.6%	3.0%
Mexico	100	201	402	3.7%	2.7%
New Zealand	28	38	50	1.6%	1.1%
Papua New Guinea	2	3	11	3.5%	5.0%
Peru	12	30	82	5.0%	4.0%
Philippines	21	51	157	4.7%	4.4%
Russia	827	686	1278	-1.0%	2.4%
Singapore	13	36	51	5.5%	1.3%
Chinese Taipei	77	202	312	5.2%	1.7%
Thailand	38	135	339	6.9%	3.6%
United States	2634	3643	4544	1.7%	0.9%
Viet Nam	6	77	385	14.2%	6.4%
APEC Total	5720	10528	19864	3.3%	2.5%

Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

BUSINESS-AS-USUAL ELECTRICITY OUTLOOK RESULTS

ELECTRICITY DEMAND

Electricity demand is expected to continue to grow between 2009 and 2035, at a rate of 2.5% per year. By region, North America, especially the US, is projected to contribute significantly to demand for electricity. Electricity demand in the US is projected to reach 4544 TWh in 2035 or about 22.9% of APEC's total electricity demand in 2035. However, China's expected high economic growth rate will mean its electricity demand will surpass all other APEC economies by the end of the outlook period—it is expected to reach 8765 TWh or 44% of APEC's total electricity demand in 2035, as shown in Table 9.1.

Table 9.2 shows electricity demand as a share of projected total final energy demand (TFED) for each APEC member economy. Electricity's share of TFED is expected to increase for all economies during the outlook period, with the exception of Brunei Darussalam and Singapore. For these two economies, a growing demand for other fuels (especially natural gas feedstock in Brunei Darussalam and oil feedstock in Singapore) will cause electricity's share to decline.

Table 9.2: APEC's Electricity Demand as a Percentage of Total Final Energy Demand (TFED)

(Percentage)

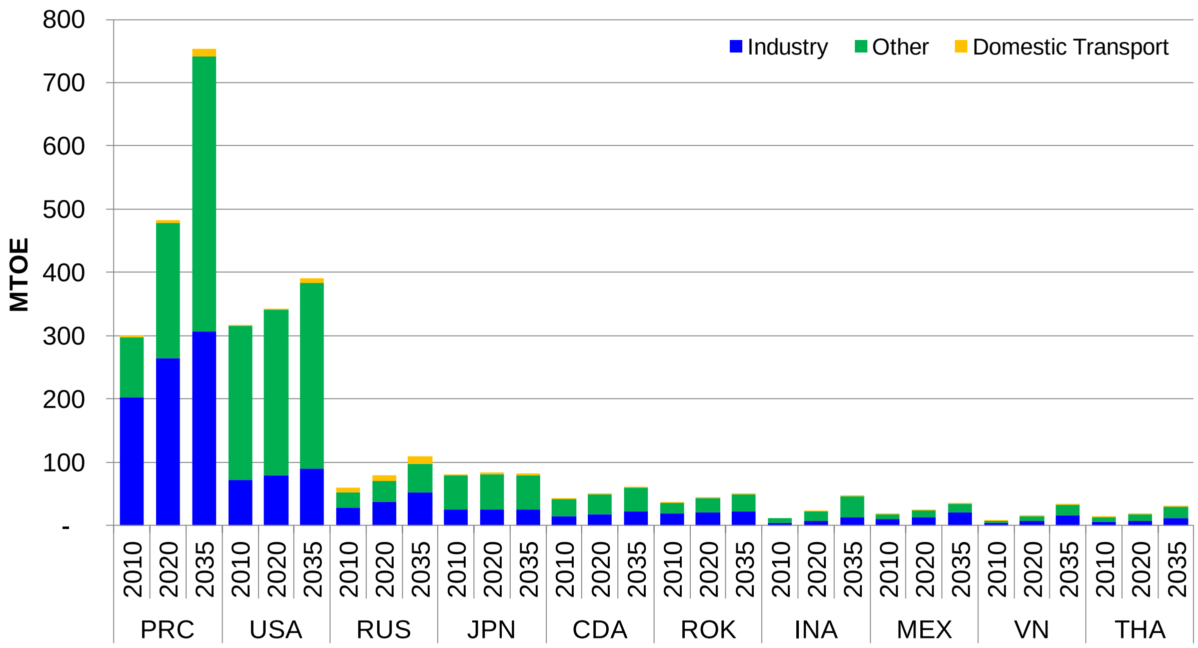
Economy	1990	2009	2035
Australia	20	24	27
Brunei Darussalam	25	31	19
Canada	23	21	32
Chile	12	21	26
China	6	18	28
Hong Kong, China	39	40	42
Indonesia	3	8	15
Japan	21	26	31
Korea	13	24	28
Malaysia	12	21	26
Mexico	10	16	18
New Zealand	24	26	31
Papua New Guinea	26	24	31
Peru	12	18	23
Philippines	9	19	28
Russia	11	14	17
Singapore	22	22	19
Chinese Taipei	22	28	34
Thailand	11	15	20
United States	18	21	24
Viet Nam	2	12	24
APEC	14	20	25

Source: APERC Analysis (2012)

Final Electricity Demand by Sector

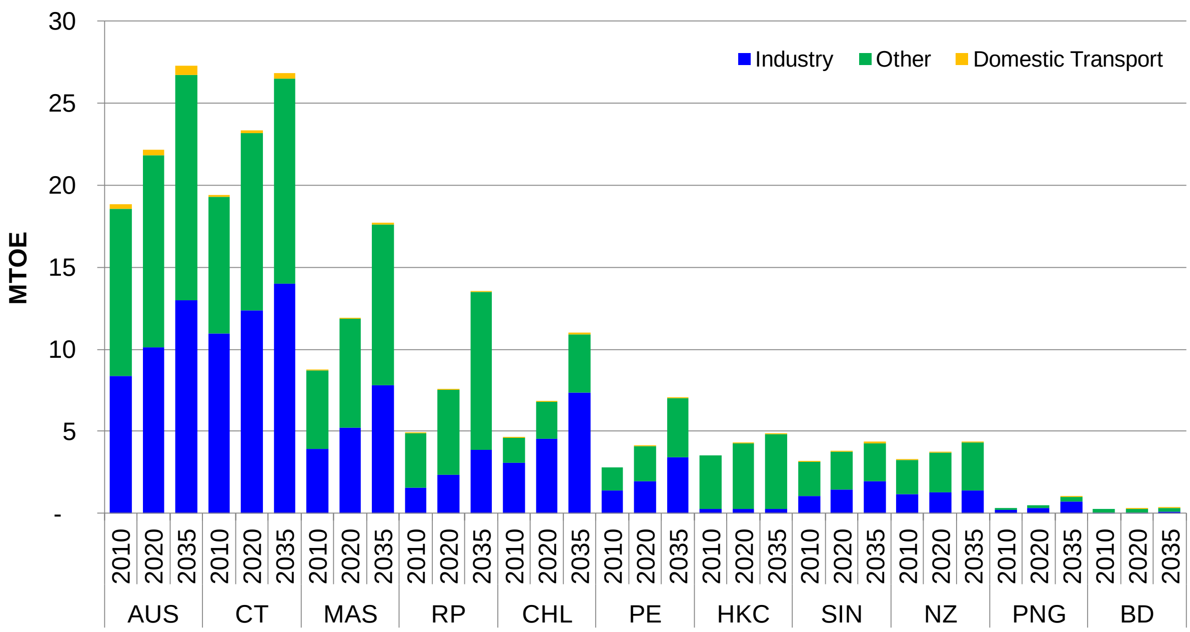
Projections for final electricity demand by sector for each APEC economy are shown in Figures 9.1 and 9.2. Note the difference in the scales of the vertical axes in the two figures. Total electricity demand is projected to increase in all APEC economies from 2010 to 2035.

Figure 9.1: Projected APEC Electricity Final Demand by Sector, Higher Final Demand Economies



Source: APERC Analysis (2012)

Figure 9.2: Projected APEC Electricity Final Demand by Sector, Lower Final Demand Economies



Source: APERC Analysis (2012)

For most APEC economies, by 2035, more than half of the electricity demand will be from the 'other' sector—this includes the residential, commercial and agricultural sub-sectors. The exceptions are Russia, Mexico, Chinese Taipei, Chile and Papua New Guinea. In these economies, more than half the electricity final demand will be from the industry sector.

The rise in electricity demand in the 'other' and industry sectors will be underpinned by increasing trends in both population and economic growth rates. Another important factor will be the continuing shift to electricity from primary energy sources. For instance, in the 'other' sector, primary fuels like traditional biomass, coal and kerosene are still used for cooking, lighting and space heating in some of the less developed areas of the APEC region. With better access to electricity, it is expected these primary fuels will be supplemented or displaced by electricity. At the same time, rising incomes and improving standards of living will drive the demand for electrical devices, which in turn will spur electricity demand in the 'other' sector, particularly in developing Asian economies like China and Indonesia.

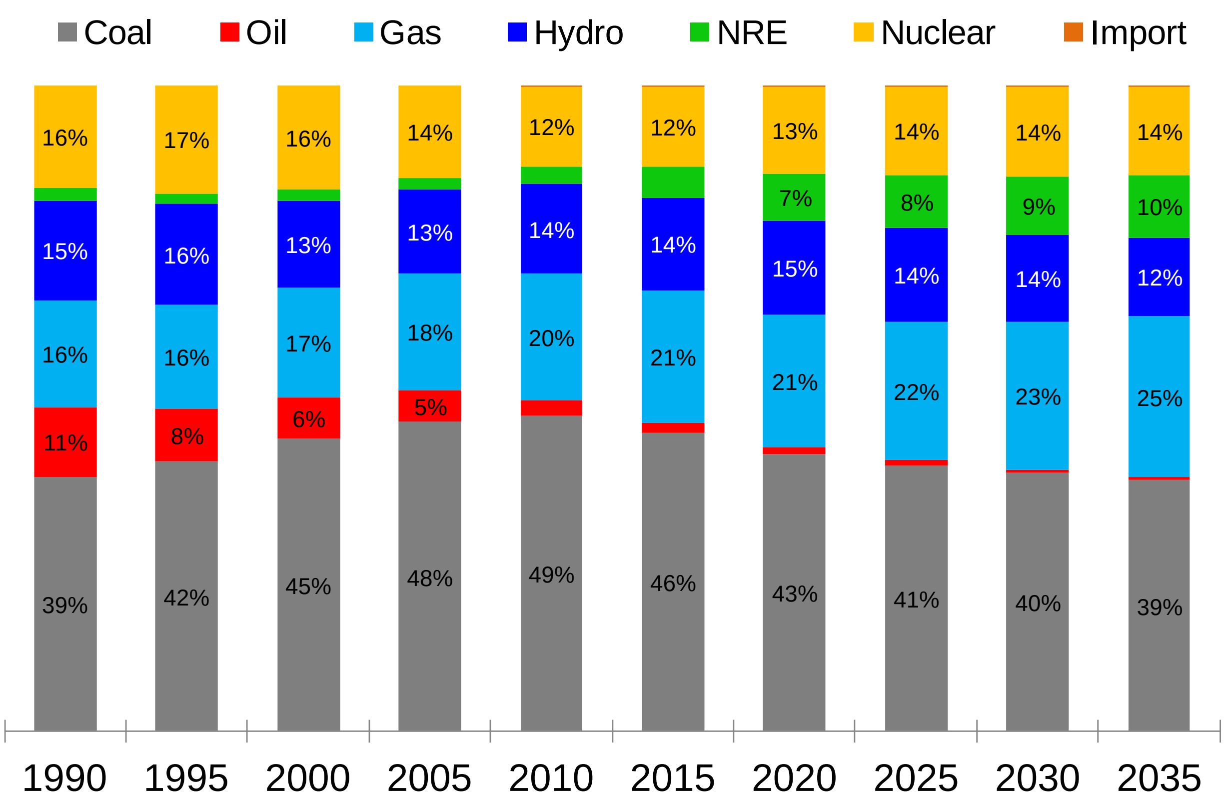
For the domestic transport sector, although the share for each economy is small (less than 5% for all economies with the exception of Russia) the total electricity demand will increase from 2010 to 2035 for all economies. This increase can reflect either one of two major developments, or a combination of both. The first is a transportation modal shift from private vehicles to electrically-powered public transport. The second is the penetration of more vehicles that use electricity instead of oil as their energy source.

ELECTRICITY SUPPLY

Electricity supply across the APEC region is expected to grow at an average annual rate of 2% between 2010 and 2035. Figure 9.3 shows APEC's historical and future electricity generation mix in percentage terms.

Nuclear shares will remain fairly consistent throughout the outlook period. New renewable energy (NRE)—that is renewable energy other than hydro—and gas will show increasing trends, while coal and oil will show significant decreases. Please refer to Chapter 2 for a detailed discussion of projected electricity supply by energy source in absolute quantities.

Figure 9.3: APEC's Electricity Generation Mix (1990–2035)



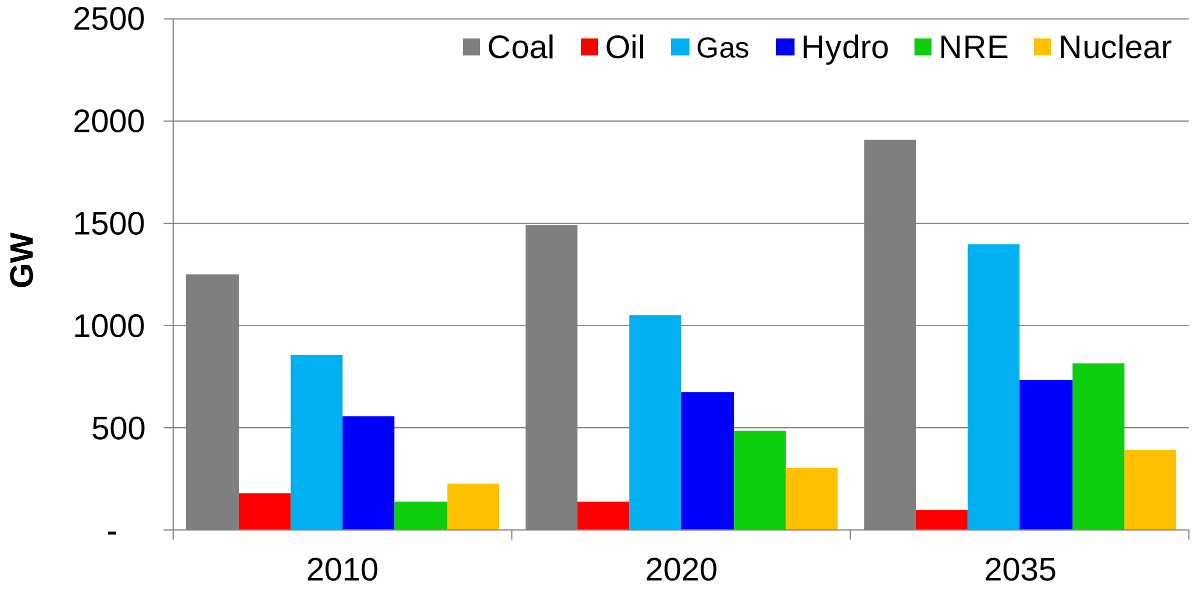
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Electricity Generating Capacity by Energy Source

Figure 9.4 shows the projected electricity generating capacity by energy source. To meet the projected increase in total electricity demand, total generating capacity in the APEC region is projected to almost double over the outlook period, from 3212 gigawatts (GW) in 2010 to 5340 GW in 2035. As new generating capacity is added, the supply mix is expected to change, driven by a number of factors. Some of the more vital drivers are as listed below:

- available energy resources — which includes both indigenous resources and available imports, and can be either fossil fuels, renewable energy resources or nuclear
- fuel costs and capital investment costs, and the ability to secure funds for both
- available technologies and infrastructure, and the feasibility of implementing new technologies
- government policies — especially policies related to energy security, environmental regulations and emissions targets
- public acceptance of certain resources that may be perceived as either "risky" (nuclear) or "dirty" (coal).

Figure 9.4: APEC's Projected Electricity Generation Capacity by Energy Source



Source: APERC Analysis (2012)

Over the outlook period, oil prices are expected to continue to increase while coal prices are expected to remain stable and relatively low, as coal is an energy resource with abundant deposits worldwide. On the other hand, with more unconventional gas resources like shale gas and coal bed methane being produced, gas prices will probably begin to decrease—especially in Asia. Gas prices in North America are already low although they are expected to trend upward in the coming years but it is unlikely they will reach the same level as oil prices. For these reasons, coal and gas capacities will continue to be the dominant electricity resources in the APEC region.

Coal, however, generates more greenhouse gases (GHG) than any other fossil fuel and causes more severe local air pollution. Even under business-as-usual (BAU) assumptions, concerns about climate change may limit the growth of coal-fired generating capacity.

Coal-fired generating capacity is expected to grow at an average annual rate of 1.7%, while the share of generating capacity that is coal fired will decrease, from 39% in 2010 to 36% in 2035. The decrease in share is mainly due to growing concerns about the detrimental effects of emissions from coal-fired generation, and a general shift from coal-fired generation capacity togas, NRE and nuclear generation capacities.

Oil-fired electricity generation is expected to continue its historical decline during the outlook period. It will be maintained only in areas where no other fuels are readily available, such as on small islands and other remote off-grid communities. This is due primarily to high fuel costs, security of supply risks and environmental considerations. Oil-fired generating capacity APEC-wide is projected to decrease at an average annual rate of 2.5%. The share of generating capacity that is oil fired will also decrease significantly from 6% in 2010 to 2% in 2035.

Natural-gas-fired combined-cycle gas turbines (CCGT) are very efficient at converting gas to electricity, have little impact on the local environment, can be built quickly, have a fairly low initial capital cost, and have fewer GHG emissions than coal. Additionally, older steam turbines (which may use coal, oil or natural gas as fuel) will be replaced by the more efficient CCGTs, thus increasing CCGT capacity in the APEC region. Nonetheless, the combined share for all natural-gas-fired generating capacity (which includes CCGTs, open-cycle gas turbines and steam turbines burning gas as fuel) will likely experience a slight decrease in share of capacity from 27% in 2010 to 26% in 2035.

Hydro is an attractive option as it has no fuel costs and low GHG emissions (see Chapter 15), but its further development will be hindered in many APEC economies by a lack of suitable sites. Hydro generating capacity is expected to grow at an average annual rate of 1.1%, but the hydro share of generating capacity will slowly decrease from 17% in 2010 to 14% in 2035.

A number of initiatives are being undertaken by APEC member economies to promote the rapid development of NRE under our BAU assumptions. Therefore, the installed capacity of NRE is expected to increase at the fastest rate of any generation energy source, 7.3% per year from 2010 to 2035. The NRE share of generating capacity will increase significantly from 4% in 2010 to 15% in 2035.

The Fukushima Nuclear Accident of March 2011 has somewhat changed the nuclear outlook in the APEC region. Higher safety standards, increasing costs and construction times, as well as eroding public acceptance of nuclear energy power plants mean the APEC economies will become more cautious in expanding their nuclear generation capacity. Our nuclear generating capacity projection has been revised to reflect this situation, especially in Japan and Chinese Taipei. In this new climate, nuclear energy is projected to grow at a slower rate of 2.2% annually, and the nuclear share of generating capacity will remain constant at about 7% throughout the outlook period.

To reduce GHG emissions and to control costs, APEC economies are expected to focus on energy efficiency and conservation measures that include reducing transmission and distribution losses, as well as increasing the efficiency of electricity generation from fossil fuels.

Our BAU projections indicate that average coal generation efficiency will increase from 36% in 2010 to 42% in 2035, and average gas generation efficiency will increase from 44% to 50%. Similarly, we expect that overall electricity losses will be reduced by about 29% from 2008 to 2035. For this outlook, electricity losses are defined as the difference between the amount of electrical energy entering the system (electricity generated and imported) and the demand. These losses may include power dissipated from transmission and distribution lines, transformers and measurement systems (also known as transmission and distribution losses) as well as internal losses and auxiliary consumption in the power generation stations. Further discussions on improvements in generation, transmission and distribution efficiencies are included in a later section of this chapter.

Electricity Generation Capacity by Economy

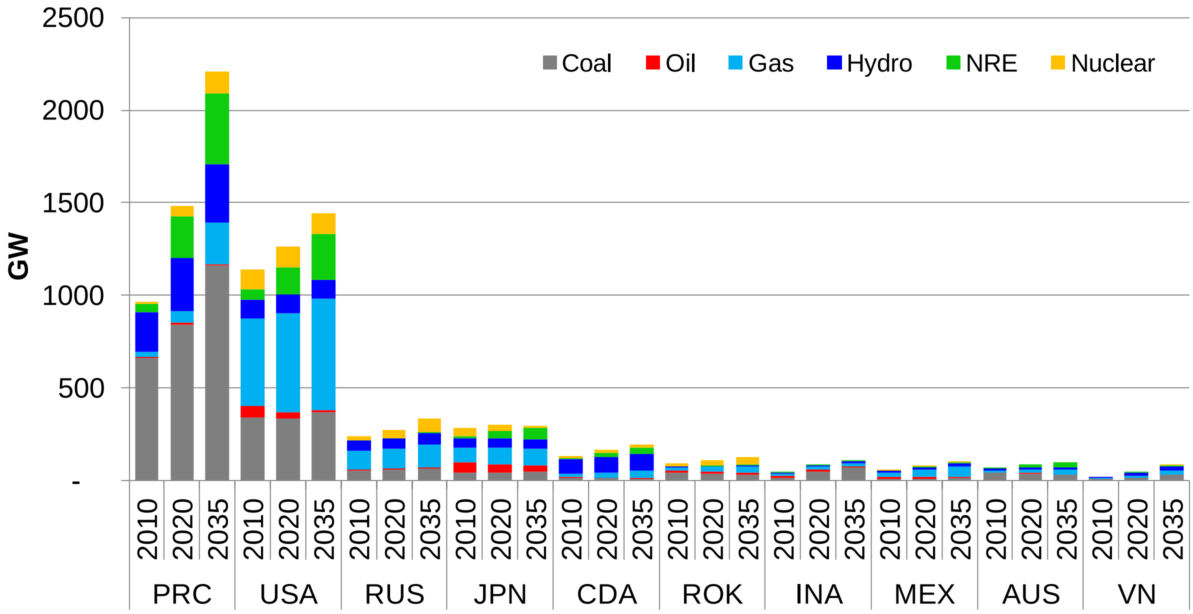
In 2010, the largest installed generation capacity was in the US. Its total capacity, of over 1130 GW, was dominated by gas (42%) and coal (30%). China's 2010 installed capacity was the second highest, at 966 GW, of which coal was 68% and hydro was 22%. However, by 2035, China's installed capacity is expected to exceed that of the US, reaching 2211 GW compared to the US's 1444 GW. After these two economies, Japan and Russia will have the next largest installed capacities, in both 2010 and 2035.

By 2035, thermal generating capacities are still dominant in most APEC economies. The exceptions are Canada, New Zealand and Papua New Guinea where hydro generating capacities are more prominent. Several of APEC's Asian economies are expected to introduce nuclear generating capacity by 2035; these include Thailand and Viet Nam, while Chinese Taipei and Japan are expected to reduce their nuclear generating capacity over the outlook period.

As technologies for harnessing NRE improve, economies with suitable resources are projected to further develop their NRE capacities to improve energy security and to mitigate environmental emissions problems. As a result, several economies will experience a substantial increase in NRE penetration. In Australia, for example, NRE's share of generating capacity will increase from 4.6% in 2010 to 31% in 2035—this will consist mostly of wind generation capacities. Please refer to Chapter 15 on Renewable Energy Supply for a more complete discussion of renewable energy power installations in the APEC region.

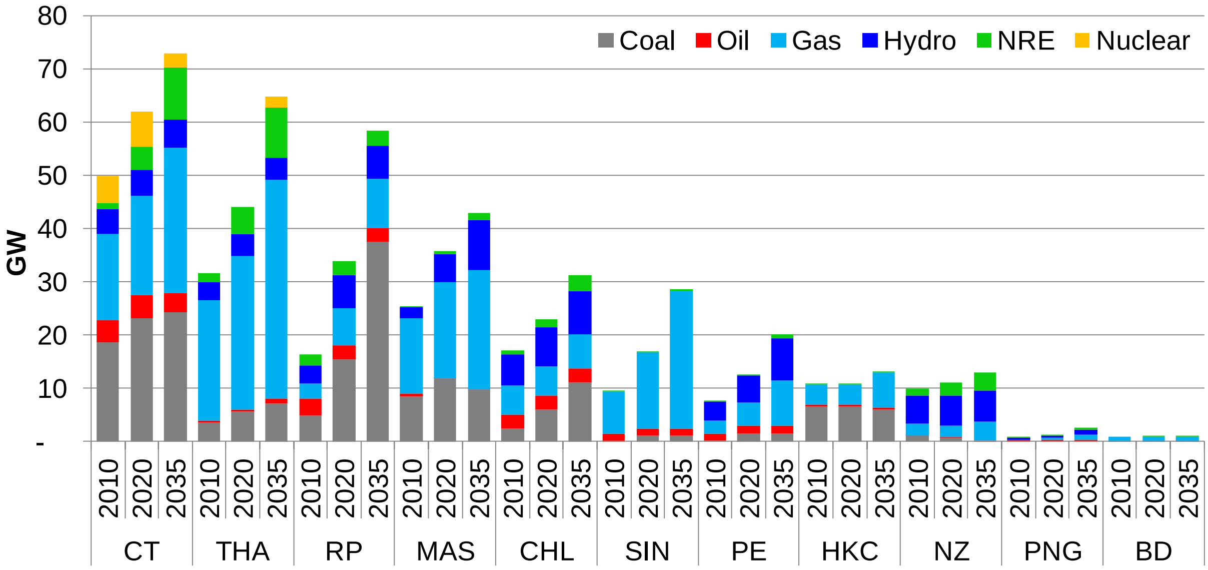
Figures 9.5 and 9.6 show the installed generation capacities by energy source and economy. Note the two graphs have different scales on the vertical axes.

Figure 9.5: Projected Generating Capacity by Economy and Energy Source, Economies with Larger Capacities



Source: APERC Analysis (2012)

Figure 9.6: Projected Generating Capacity by Economy and Energy Source, Economies with Smaller Capacities

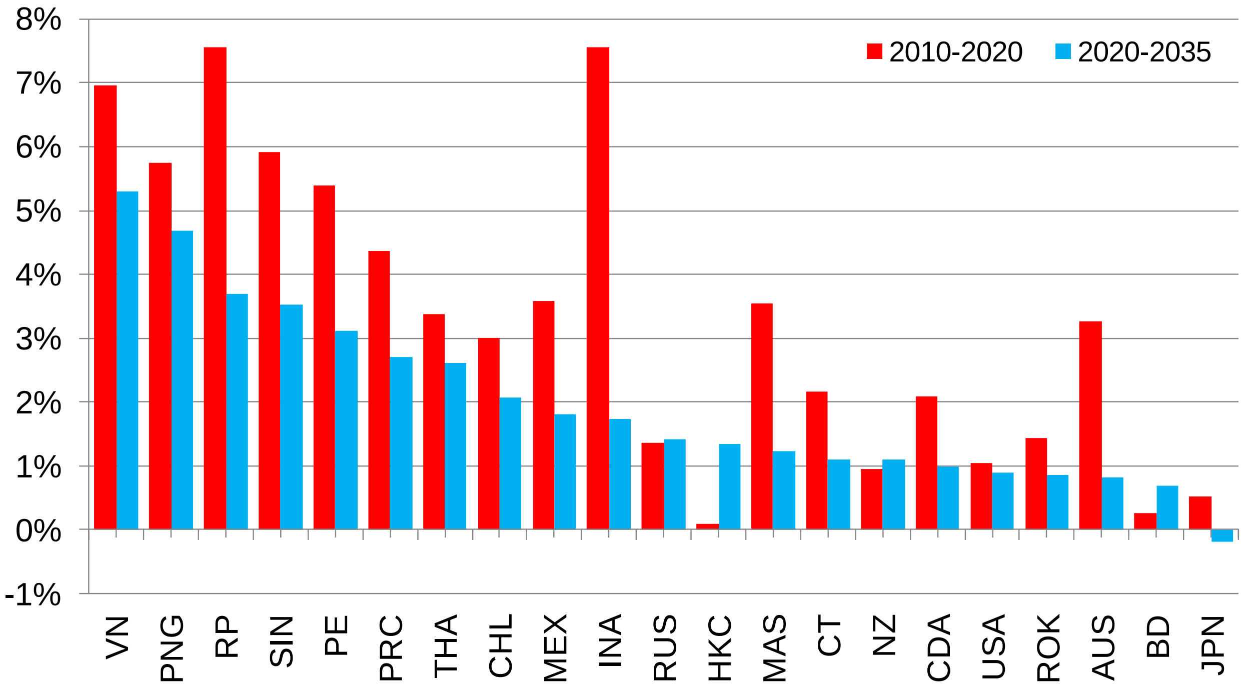


Source: APERC Analysis (2012)

Figure 9.7 shows the annual growth rates for generating capacity across all APEC economies during the first 10 years compared to the final 15 years of the outlook period.

With the exception of four economies (Hong Kong, China; Russia; New Zealand; and Brunei Darussalam), it is projected that capacity build-up will be more aggressive during the earlier years of the outlook period. Electricity growth rates are generally higher overall for developing Asian economies like Viet Nam, the Philippines and Indonesia, where there is much room for growth and massive generation capacity will be necessary to meet the rapidly growing demand. For developed, high-income economies like Japan and Brunei Darussalam where demand growth is slower, there will be more focus on maintaining and improving existing infrastructure.

Figure 9.7: Annual Growth Rates of APEC Economies' Generation Capacities between 2010–2020 and 2020–2035



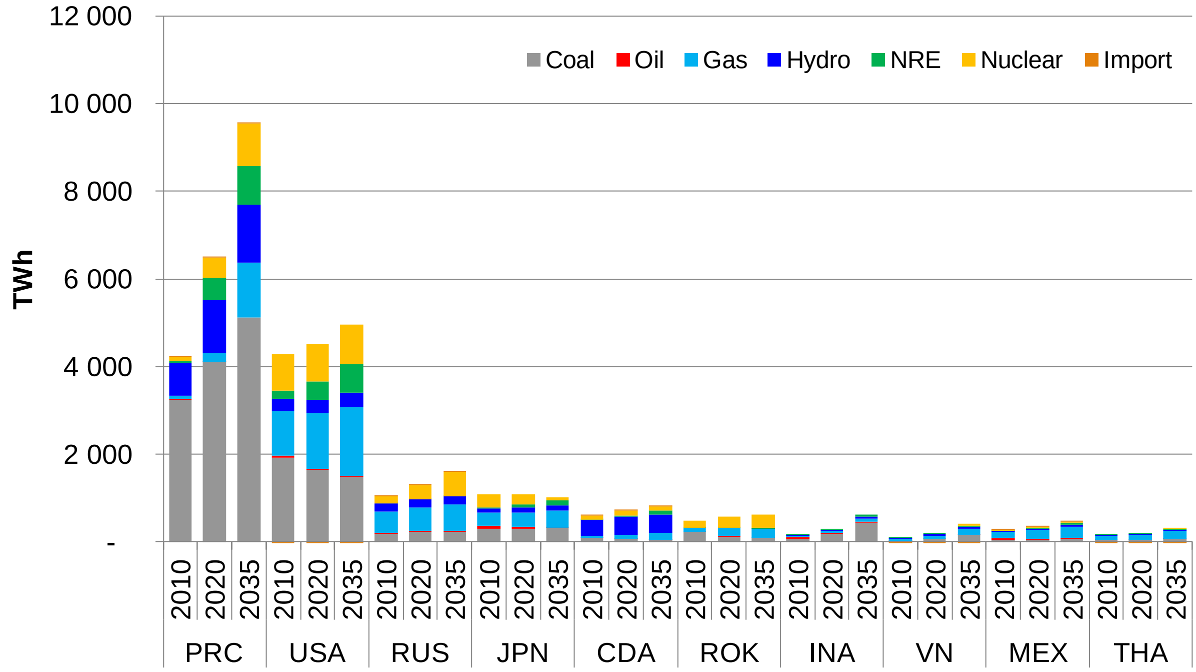
Source: APERC Analysis (2012)

Electricity Generation Supply by Economy

Figures 9.8 and 9.9 show the electricity supply for each APEC economy by energy source for the years 2010, 2020 and 2035. Again, note the vertical axes of the two graphs have different scales. The results are very much in line with the graphs of generating capacity by economy presented in Figures 9.5 and 9.6 above.

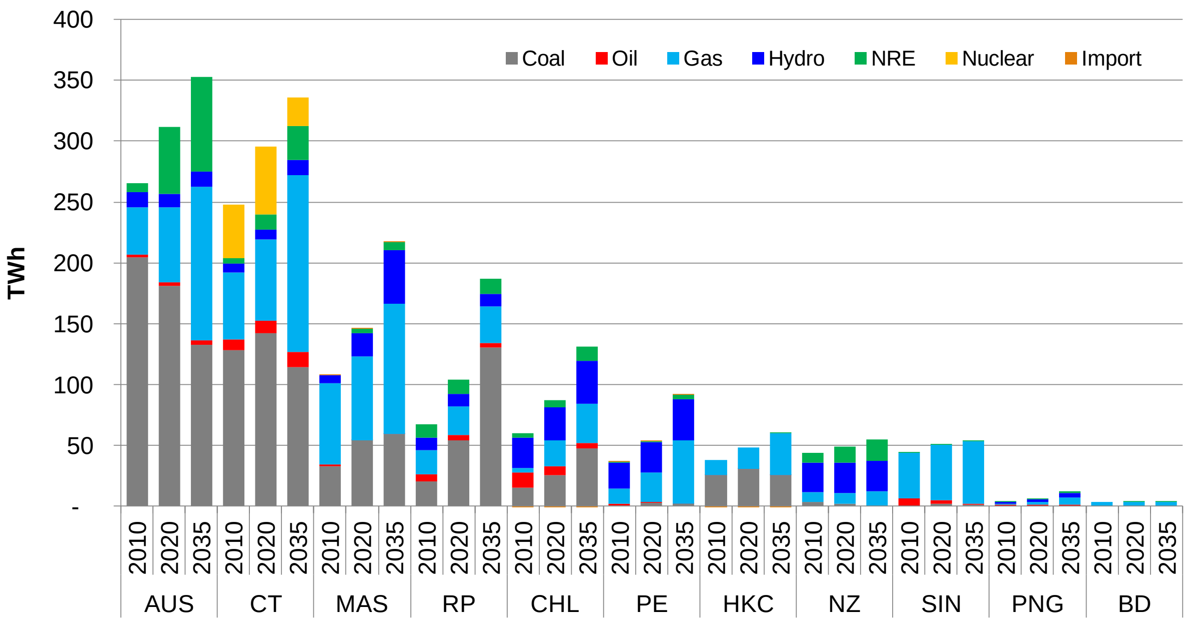
China and the US once again dominate the APEC region: the two economies will account for over 60% of total electricity generation supply over the outlook period. At the other end of the spectrum are the smaller-sized economies: Singapore, Papua New Guinea and Brunei Darussalam.

Figure 9.8: Electricity Generation Supply by Economy and Energy Source, Larger Generating Economies



Source: APERC Analysis (2012)

Figure 9.9: Electricity Generation Supply by Economy and Energy Source, Smaller Generating Economies

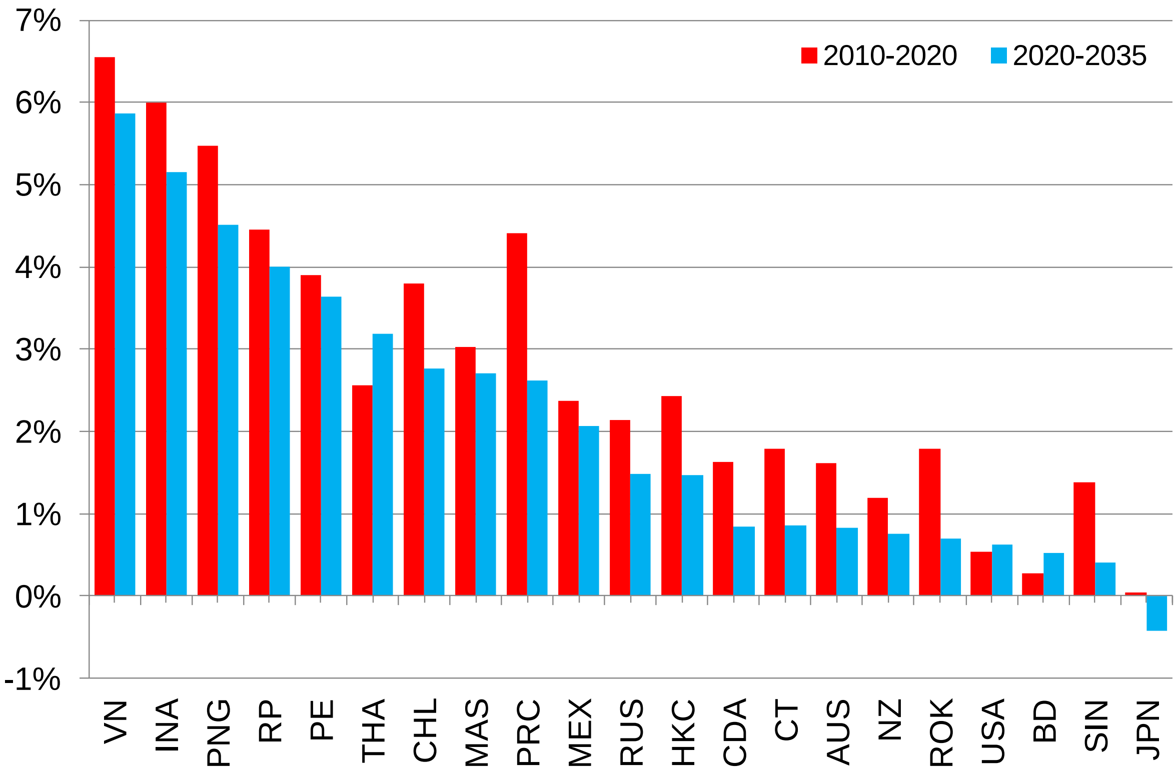


Source: APERC Analysis (2012)

Figure 9.10 shows the electricity supply growth rates for the APEC economies. There is a marked trend of higher generation growth in the earlier 10 years of the outlook period compared to the later 15 years. The exceptions to this trend are China, the US and Brunei Darussalam.

The slower electricity generation growth rate in the APEC region for the later years can probably be attributed to the increasing maturity of most APEC economies, as developing economies tend to have faster GDP growth rates and therefore faster electricity demand growth rates. This increasing maturity is also accompanied by a shift from energy-intensive industry to a less energy-intensive high-value added industry and services.

Figure 9.10: Annual Growth Rates of APEC Economies' Electricity Generation Supply between 2010–2020 and 2020–2035



Source: APERC Analysis (2012)

ACCESS TO ELECTRICITY

Rural electrification is quite properly a key development objective for those economies that have not yet achieved nearly universal access to electricity. Rural electrification not only significantly enhances the quality of life of people living in rural areas, but it can also bring significant economic benefits. Studies show that providing communities with access to electricity has significant positive impacts on household income, expenditure, and the educational achievement of children. It can also lead to significant reductions in poverty (Khandker et al., 2012; World Bank, 2009).

Table 9.3 shows that most APEC economies have already achieved this critical development milestone. The successes of China and Viet Nam in the last decade in providing 99% and 98%, respectively, of their populations with access to electricity in 2009, are especially impressive.

Table 9.3: APEC Economies' Access to Electricity

Economy	Percentage of Population	Percentage of Household
Australia[a]	100	100
Brunei Darussalam[b]	99.7	n/a
Canada[a]	100	100
Chile[c]	98.5	n/a
China[c]	99.4	n/a
Hong Kong, China[a]	100	100
Indonesia[d]	n/a	67.2
Japan[a]	100	100
Korea[a]	100	100
Malaysia[c]	99.4	n/a
Mexico[e]	97.3	n/a
New Zealand[a]	100	100
Papua New Guinea[f]	n/a	12.9
Peru[c]	85.7	n/a
Philippines[g]	n/a	73.7
Russia[h]	100	100
Singapore[c]	100	100
Chinese Taipei[a]	100	100
Thailand[i]	n/a	86.8
United States[a]	100	100
Viet Nam[j]	97.6	98.5

n/a= not available

Sources: [a] APERC Analysis (2012), [b] BDEPD (2010), [c] World Bank (2012), [d] IDGEEU (2011), [e] MSener (2010), [f] PNG (2010), [g] PNGCP (2011), [h] RME (2012), [i] TDEDE (2010) and [j] VGSO (2009)

Only five APEC economies still had access-to-electricity rates less than 95% in the most recent year for which data is available (generally 2009): Indonesia at 67.2% of households, Papua New Guinea at 12.9% of households (PNG, 2010, p. 77), Peru at 85.7% of the population, Philippines at 73.7% of households, and Thailand at 86.8% of households. These economies are moving aggressively to provide increased access, and we expect nearly universal access by 2035, although Papua New Guinea's goal is 70% access by 2030 (PNG, 2010, p. 77).

POTENTIAL FOR ENERGY EFFICIENCY IMPROVEMENTS IN THE ELECTRICITY SUPPLY SYSTEM

Energy efficiency improvements can greatly enhance energy security, reduce costs, and help protect the environment. In an electricity supply system, improving energy efficiency refers to minimizing the primary energy used in producing each unit of electricity consumed. This utilisation can be broadly divided into two categories. The first is the power generation category which encompasses converting primary energy into electricity. The second is the transmission and distribution of electricity category which consists of energy that is used in transporting electricity between sources of supply and the ultimate end-users.

Energy Efficiency in Electricity Generation

About one-third of the APEC total primary energy supply is used to generate electricity, and from this amount, more than 70% are from fossil fuels (In 2009, about 2006 million tonnes of oil equivalent (Mtoe) of fossil fuels were used for electricity generation, out of 2662 Mtoe of total energy supplied for electricity generation and 7005 Mtoe of total primary energy supply). Of the primary fossil fuels used for electricity generation, less than 40% of their energy content is actually converted to electricity (767 Mtoe of electricity produced from 2006 Mtoe of fossil fuels in 2009). The remainder is lost in the transformation process. Therefore, there is a great potential for energy savings in the APEC region by improving the thermal efficiency of fossil-fuel electricity generation. For APEC economies, this can be achieved through either retro-fitting or refurbishing existing capacity to improve efficiency, or by installing new generation capacity with higher efficiencies (APERC, 2008, p. 32).

Thermal generation plant efficiency deteriorates with time but it is possible to offset this aging process with timely investment in refurbishment and retrofitting measures (IEA, 2010, p. 22). There is a broad range of technical possibilities since entire parts of a plant are subjected to replacement or reconditioning. Measures that can lead to energy savings include improvements in a plant's heat recovery system (economisers) and heat transfer (including condensers); better energy management supported by the variable control of energy consuming devices (such as pumps and fans), better combustion control, and the use of more efficient turbine blades (when blade replacement is necessary).

It is also possible to completely refurbish a plant. One example of a complete refurbishment measure is generation plant repowering, in which a coal-fired generation plant is converted into a gas-fired generation plant. Another example is converting a simple open-cycle gas turbine into a combined-cycle gas turbine. Both examples will improve the overall efficiency of the plant, since the latest combined-cycle gas turbine technology, the H-Class, is capable of achieving efficiency of over 60% compared to the 39–47% efficiency of a typical coal steam turbine or the 35–40% efficiency of a typical open-cycle gas turbine (Siemens, 2012; Eurelectric, 2003).

The refurbishment and retrofitting measures described, in conjunction with the implementation of best practices in generation plant operation and maintenance, would likely improve a generation plant's performance and efficiency, as well as extend its lifetime.

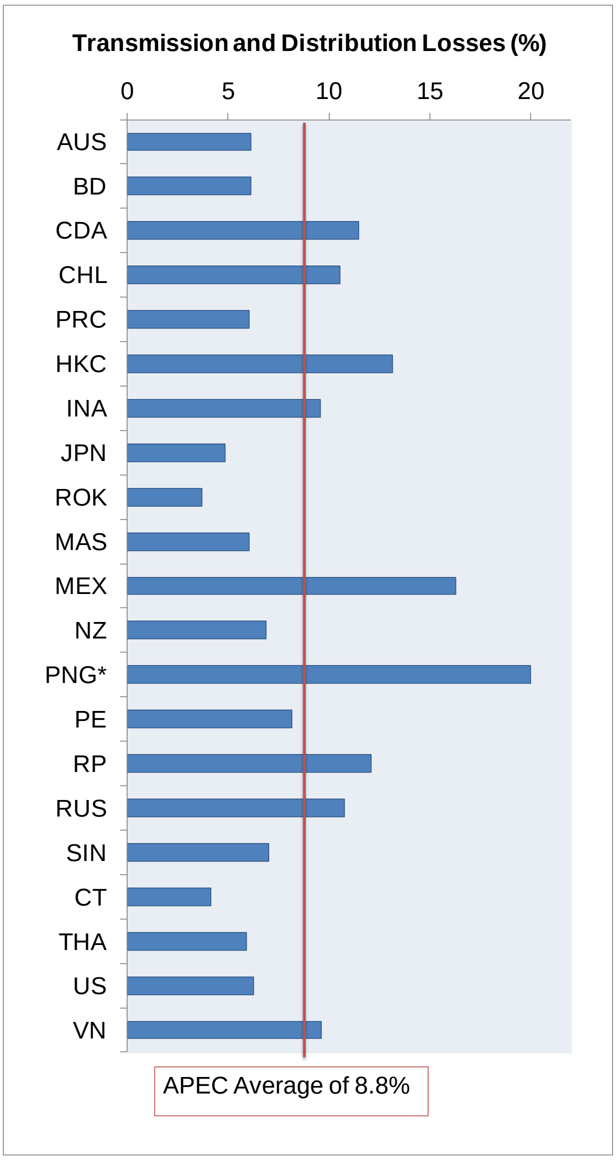
Of course, new generation capacity will also be needed either to replace obsolete existing capacity or to meet the needs for additional electricity in those economies where electricity demand is growing despite efforts to improve end-user energy efficiency. Choosing the generation technology to be used is a major investment decision. It requires a complex decision-making process, taking into account various technical, economic and environmental factors that will best suit the economy's needs.

The variety of options available for new capacity additions is especially broad for coal-fired generation. There are currently several new technological options that are being developed or are commercially available that offer high-efficiency and low-emissions relative to conventional coal-fired technology. These are discussed in the sidebar 'Improving the Efficiency of Coal-Fired Electricity Generation' in Chapter 13. Given the climate change challenges facing the APEC region, as discussed in Chapter 16, all new generation capacity should ideally be low-carbon: renewable, nuclear, or fossil-fuel with carbon capture and storage (CCS). However, if an economy must build non-CCS coal-fired capacity, these advanced technologies for coal-fired generation can significantly reduce emissions, as well as fuel costs, and deserve careful consideration.

Energy Efficiency in Transmission and Distribution

Transmission and distribution (T&D) losses are defined as the share of electricity losses between sources of supply (generating stations), and the ultimate end-users. In 2009, the T&D losses among APEC economies ranged from 3.7% (Korea) to about 20% (Papua New Guinea), with an average of about 8.4% for all APEC economies.

Figure 9.11: APEC Economies T&D Losses in 2009



Sources: *World Energy Statistics 2011* © OECD/IEA 2011 and *PNG (2011)

T&D losses can be attributed to both technical and non-technical losses, where technical losses are related to the dissipation of energy in conductors and equipment while non-technical losses are caused by pilferage and meter-related issues (Bhalla, 2000). Technical losses can be reduced by installing more energy efficient equipment in the T&D network.

Several technological improvements that would improve efficiency in T&D networks are tabulated in Table 9.4. The better management of grid electricity flow will also boost efficiency. This can be achieved through load forecasting, optimal load flow planning, loss minimization and reactive power management (Pezzini et al., 2011).

Table 9.4: Energy Efficient Technologies for T&D Networks

Equipment	Energy Efficiency Technology
Cables	Superconductors, HVDC lines, Underground Distribution Lines
Power flow control	Flexible AC Transmission System (FACTS) devices, Phase Shifting Transformers (PTS)
Transformers	High energy efficiency classes, Amorphous Metal Distribution Transformer (AMDT)
Substations	Gas-Insulated Substations (GIS)

Sources: Pezzini et al. (2011) and ABB (2007)

Smart Grids

The APEC region's grids are constantly evolving. Energy resources are becoming increasingly heterogeneous with the introduction of distributed technologies like intermittent renewable energy generation, plug-in electrical vehicles, combined heat and power (CHP) and energy storage facilities. Modern electrical and electronic devices are much more complex, being more sensitive to voltage or frequency fluctuations in electricity supply.

To meet these new challenges, several APEC economies are planning to update their grids with sophisticated 'smart grid' technologies. The smart grid concept is set to restructure the traditional T&D network from one that is centralized and producer-controlled to one where control is more distributed, automated, and consumer-interactive. Digital technologies and communications are used to coordinate the actions of intelligent devices and systems throughout the electricity power network.

Smart grid monitoring applications, automation and control functions will provide more flexibility to integrate distributed energy resources with their varied characteristics into the T&D system. The same smart grid applications can also enhance overall T&D system efficiency with real-time system performance optimization and increased asset utilization.

The importance of smart grid technology in the APEC region is emphasized in The Fukui Declaration from the Ninth Energy Ministers Meeting in June 2010 (APEC, 2010) which states that "smart grid technologies, including advanced battery technologies for highly-efficient and cost-effective energy storage, can help to integrate intermittent renewable power sources and building control systems that let businesses and consumers use energy more efficiently, and they can also help to enhance the reliability of electricity supply, extend the useful life of power system components, and reduce system operating costs".

This declaration was reinforced with instructions to the Energy Working Group (EWG) "to start an APEC Smart Grid Initiative (ASGI) to evaluate the potential of smart grids to support the integration of intermittent renewable energies and energy management approaches in buildings and industry" (APEC, 2011). ASGI comprises four main elements:

1. Survey of Smart Grid Status and Potential.
2. Smart Grid Road Maps.
3. Smart Grid Test Beds.
4. Smart Grid Interoperability Standards.

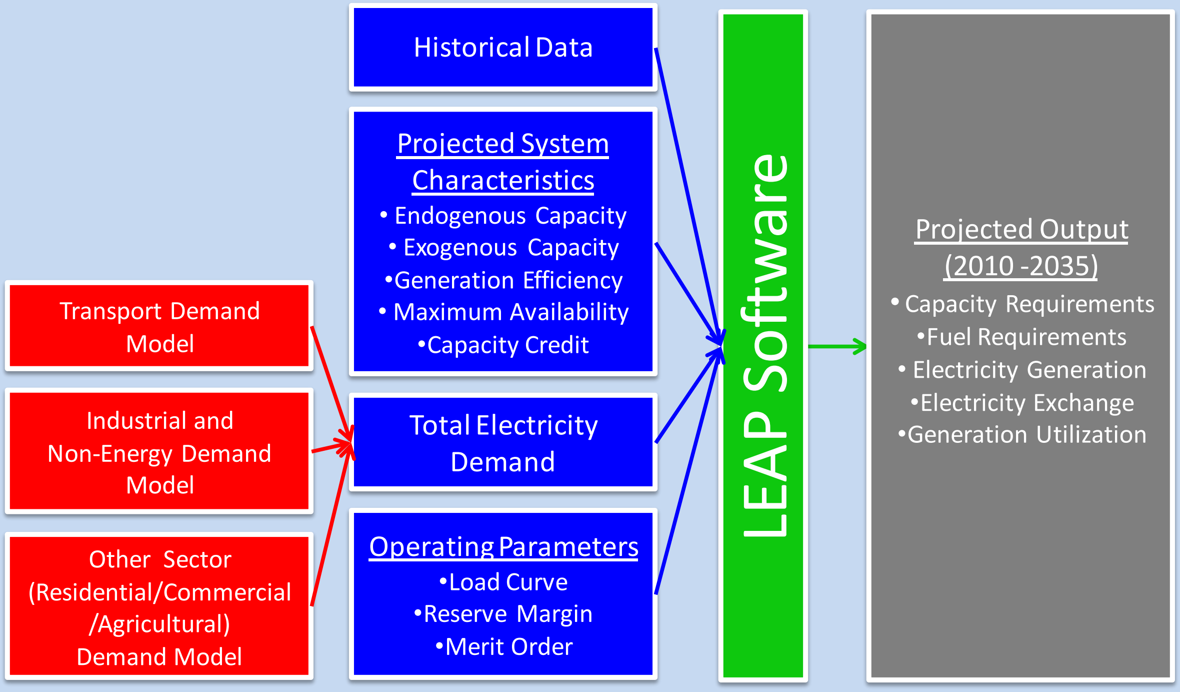
As of 2011, APEC member economies are in various states of smart grid development, including conducting demonstrations and engaging in joint projects with other economies (APEC, 2011). The Knowledge Sharing Platform (KSP), established in the EWG-41 Meeting in May 2011, is a tool for collecting and sharing best practices for creating energy smart communities. The KSP website is the best resource for the latest information on smart grid initiatives and projects in APEC economies (APEC, 2012).

APERC'S ELECTRICITY SUPPLY MODEL AND HOW IT WORKS

Because of the complexities involved in modelling electricity supply, APERC uses an off-the-shelf model known as the LEAP (Long-Range Energy Alternatives Planning) system developed by the Stockholm Environment Institute (SEI, 2012). LEAP is a flexible planning tool used in many organizations worldwide. Although LEAP is a complete energy supply and demand modelling system, APERC has elected to use LEAP only for modelling electricity supply. Other parts of the APEC Energy Demand and Supply model were developed by APERC and are described in other chapters of this volume.

LEAP simulates decision-making in the electricity supply sector based on the inputs shown in Figure 9.12 below. The outputs extracted from LEAP simulations are listed in the same figure.

Figure 9.12: APERC's Electricity Supply Model



Two types of generation capacities are defined in LEAP. 'Exogenous capacity' is generation capacity that either already exists or which the modeller believes is sure to be built. 'Endogenous capacity' is additional generation capacity that LEAP can choose to build if required by the system. Both types of generation capacities are defined in terms of key variables, including fuel type and generation efficiency, maximum availability, and percentage capacity credit. For exogenous generation, the year in which the capacity will be retired is also defined.

Total demand for electricity in each year is a model input that comes from summing the electricity demand results from each demand sector model. For this outlook, the demand sector models are the Industrial and Non-Energy Demand Model, the Transport Demand Model and the Other Sector Demand Model. These demand models are described elsewhere in this volume.

LEAP requires the modeller to specify a load curve for the economy, which defines how this demand fluctuates throughout the day and throughout the year. LEAP is thus able to effectively estimate a demand for electricity during each hour of the year. The modeller also supplies a merit order, which defines the order in which various types of generation capacities are to be used. In general, renewable generation is used first since it has no fuel cost, next the efficient base-load generation (usually coal or combined-cycle gas turbine) is used, and, when these types are not sufficient, a less efficient peaking unit such as an open-cycle gas turbine is used. Based on this information, LEAP decides how to dispatch the generation in each hour of the year.

Over the longer term, LEAP must also decide what new generation should be added. The user supplies a required level of reserve capacity for the economy. In years when this reserve requirement cannot be met during the hour of peak demand, LEAP adds capacity from the modeller-specified endogenous capacity. The modeller specifies an addition order for each increment of endogenous capacity, allowing LEAP to add endogenous capacity according to this pre-specified order until it can meet the reserve requirement in that year.

In this way, LEAP simulates electricity supply for an economy in each year of the outlook period. It then sums up and reports the results in each year, including fuel requirements for each fuel, the amount of electricity generated by each fuel type, the required capacity additions, and the use of each type of generation.

In setting up the model inputs for each economy, APERC researchers considered the energy resources available in the economy and the economy's policies and plans for generation capacity additions.

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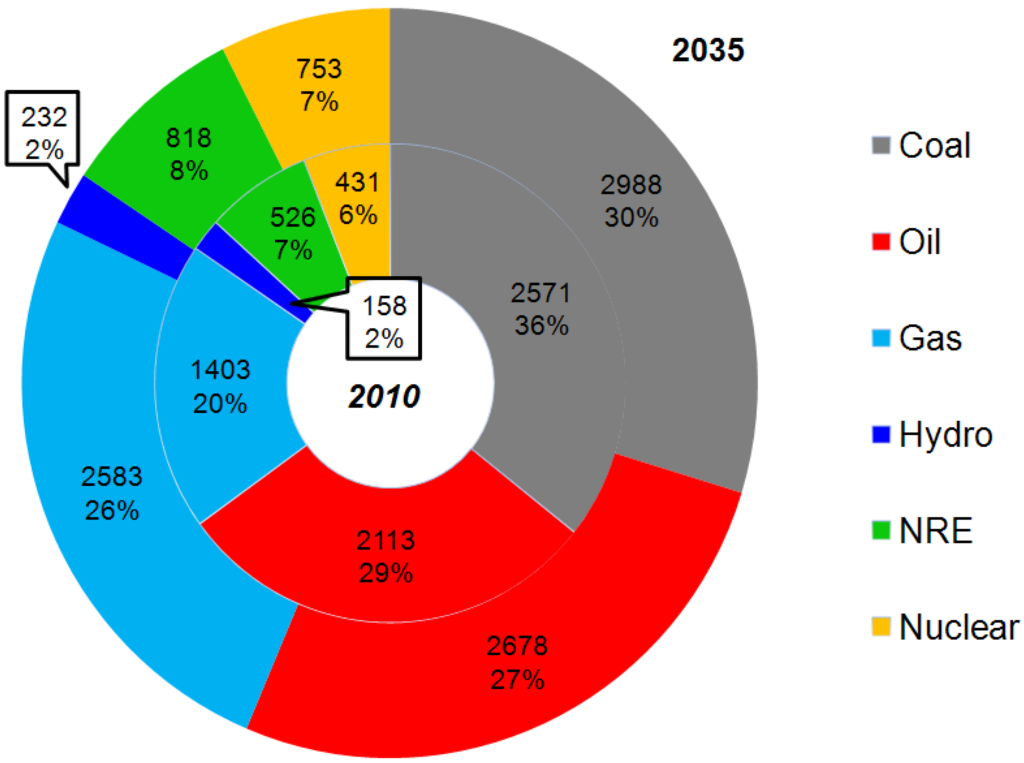
10 PRIMARY ENERGY DEMAND AND SUPPLY

APEC contains some of the world's largest energy producers, but also some of the world's largest energy importers. Most coal, gas and nuclear fuels used in the APEC region are sourced within the region, while a considerable share of oil is sourced from outside APEC. Overall, APEC's 2010 oil production was equivalent to nearly three-quarters of its primary oil demand.

This chapter discusses the outlook for the primary energy supply in the APEC region. 'Primary energy' refers to energy in its original form, before the conversion of primary fuels to electricity and before the conversion of crude oil into petroleum products.

Given that demand must equal supply, the term 'primary energy demand' can be used almost interchangeably with 'primary energy supply'. However, customary usage appears to favour 'primary energy supply', so that term is used in this chapter. Primary energy supply includes energy from both domestic and imported sources.

Figure 10.1: Total Primary Energy Supply, in Mtoe and Percent, 2010 and 2035



Source: APERC Analysis (2012)

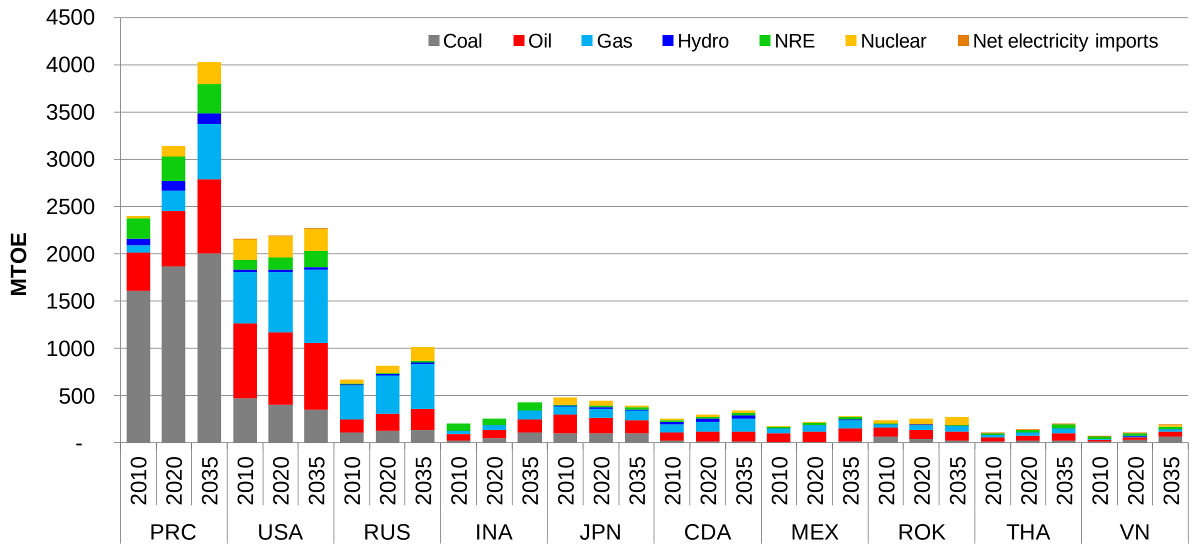
TOTAL PRIMARY ENERGY SUPPLY

APEC's total primary energy supply amounted to about 7204 Mtoe in 2010. Under business-as-usual (BAU) assumptions it is projected to grow 40% to reach 10 057 Mtoe by 2035. This amounts to an average annual growth rate of 1.3%.

Of all the energy sources that compose primary energy supply, gas will be the fastest growing in both absolute and percentage terms in the outlook period. Gas will grow 84%, while nuclear will grow 75%, new renewable energy (NRE) will grow 55%, hydro will grow 46%, and oil will grow 27%. The slowest growing primary energy supply source will be coal, which is expected to grow about 16%. As discussed in Chapter 14, despite concerns about nuclear energy's safety in light of the accident at Japan's Fukushima Daiichi Nuclear Power Plant in 2011, APERC's analysis of member economy's policies suggest that nuclear development in the APEC region will continue under BAU scenario. Only in Japan and Chinese Taipei is nuclear power production projected to decline.

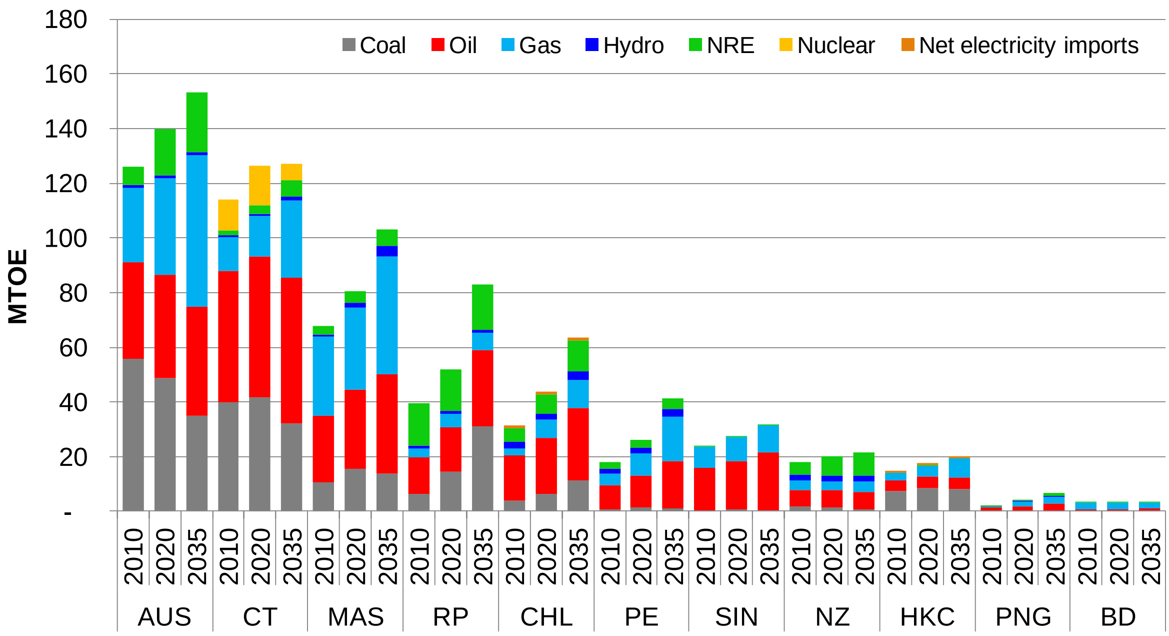
As shown in Figure 10.1, projections indicate that by 2035 the total APEC primary energy supply will be made up of coal (30%), oil (27%), gas (26%), NRE (8%), nuclear (7%) and hydro (2%). The most significant changes from 2010 will be within the fossil fuels—coal will decrease its share considerably while gas will expand its contribution. Nuclear and NRE are also likely to increase their role in the primary energy supply by 2035. Many APEC economies are striving to lower their CO_2 emissions by shifting away from coal and oil in favour of gas, NRE and nuclear.

Figure 10.2: Primary Energy Supply by Energy Source, Higher Primary Energy Supply Economies



Source: APERC Analysis (2012)

Figure 10.3: Primary Energy Supply by Energy Source, Lower Primary Energy Supply Economies



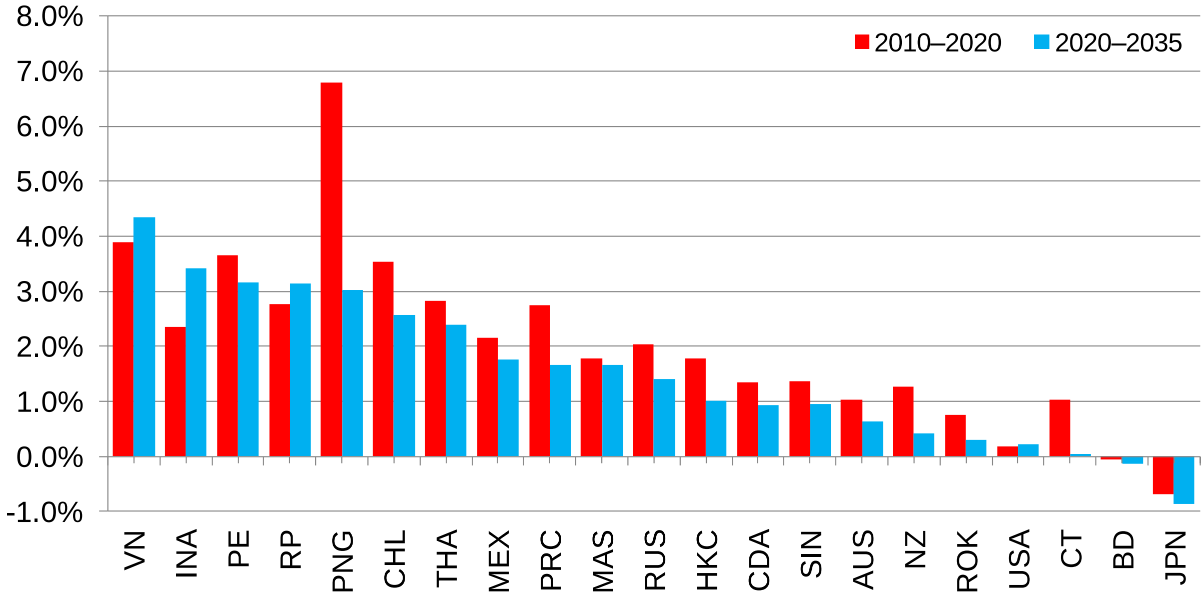
Source: APERC Analysis (2012)

On an economy basis, China, the US and Russia will represent more than two-thirds of APEC's primary energy supply by 2035. Figures 10.2 and 10.3 show the projected primary energy supply by economy—note the different scale used in the two figures.

Figure 10.4 presents the estimated primary energy supply growth rates for all APEC economies. The largest increases are expected in developing economies, particularly in Viet Nam, Indonesia, Peru, the Philippines, and Papua New Guinea.

Estimates of primary energy supply growth in China and other developing economies are lower. Growth is generally moderate in the developed economies. In Brunei Darussalam and Japan, the primary energy supply will decrease over the outlook period—in Brunei by 2.5% and in Japan by 18%. In the case of Brunei, the replacement of its electricity generation infrastructure with more efficient combined-cycle plants will improve the efficiency of gas utilization, while in the case of Japan, population shrinkage and energy efficiency improvements are the main drivers.

Figure 10.4: Primary Energy Supply Average Annual Growth Rate by Economy, 2010–2020 and 2020–2035



Source: APERC Analysis (2012)

APEC'S GOAL TO RATIONALIZE AND PHASE OUT FOSSIL FUEL SUBSIDIES

Subsidies for fossil fuels have many adverse impacts. For the economies concerned:

- (where subsidies are government funded) they drain government budgets
- (where subsidies take the form of price controls on energy producers) they discourage investment and reduce domestic production
- they encourage wasteful consumption
- consequently, they threaten energy security by reducing fossil fuel exports and/or increasing fossil fuel imports
- they increase CO_2 emissions and local pollution.

They also:

- encourage fuel smuggling
- discourage low-carbon energy investment.

While often justified as assistance for the poor, in practice fossil fuel subsidies disproportionately benefit the middle-class and the rich, who can afford the appliances and vehicles that consume fossil fuels. The IEA estimates that of the USD 409 billion spent on fossil fuel subsidies worldwide in 2010, only USD 35 billion, or 8%, reached the poorest 20% of the population (IEA, 2011, p. 519).

Despite their adverse impacts, fossil fuel subsidies are widespread around the world and in the APEC region. Politically, they are difficult to remove, as the benefits to individual consumers are easy for them to see, while the adverse impacts on society as a whole are less obvious. Intensified educational efforts and greater transparency about the costs of subsidies may be helpful.

There are many ways to measure the cost of fossil fuel subsidies. The IEA has used a 'price gap' approach to measure consumer-oriented energy subsidies. This approach measures the difference between the prices paid by consumers and the full cost of supply. Based on this approach, the IEA has identified fossil fuel subsidies in 11 APEC economies. These are shown in Table 10.1. This approach measures only subsidies that result in prices below those that would prevail in a competitive market. There are numerous other subsidies targeted at encouraging production that are not reflected here, and these exist in additional APEC economies not listed in the table, including Australia, Canada, and the United States (IEA, 2011, p. 511).

Because of their adverse impacts, APEC leaders, beginning with their Singapore Declaration of 2009, have committed the APEC economies to "rationalise and phase out over the medium term fossil fuel subsidies that encourage wasteful consumption, while recognising the importance of providing those in need with essential energy services" (APEC, 2009). The Leaders 2011 Honolulu Declaration added the call for a voluntary reporting mechanism on progress, which they will review annually (APEC, 2011). This mechanism is currently under development by the APEC Energy Working Group.

Table 10.1: Estimated Consumer-oriented Fossil Fuel Subsidies in 2010

Economy	Subsidy as Percent of Full Cost of Supply	Subsidy in USD/person	Subsidy as Percent Share of GDP	Subsidy by Fuel (Billion USD/Year)			
				Oil	Gas	Coal	Electricity
Brunei Darussalam	31.9	840	2.6	0.19	0	0	0.15
China	3.8	16	0.4	7.77	0	2.01	11.54
Indonesia	23.2	66	2.3	10.15	0	0	5.79
Korea	0.4	4	0	0	0	0.18	0
Malaysia	20.0	200	2.5	3.89	0.97	0	0.81
Mexico	12.5	84	0.9	9.34	0	0	0.16
Philippines	7.3	12	0.6	1.10	0	0	0
Russian Federation	22.6	274	2.7	0	16.95	0	22.26
Chinese Taipei	1.8	25	0.1	0.24	0	0	0.34
Thailand	20.7	123	2.7	2.11	0.48	0.44	5.44
Viet Nam	14.4	33	2.8	0	0.23	0.01	2.69

Source: IEA (2012)

MODELLING FOSSIL FUEL PRODUCTION

In our projections of the future supply of fossil fuels in the APEC region, APERC has relied primarily on official government or government-sponsored projections from each economy. For economies where these are not available, APERC sought to find reliable independent sources. However, very few economy governments or independent sources make projections 25 years ahead, so a good deal of judgement on the part of APERC was required for the later years of the projection. Typically, we based projections for the later years on trends in the earlier years and on available estimates of the extent of the economy's resources. These long-term projections are, therefore, subject to a high degree of uncertainty.

Most APEC economies have not been well explored for oil and gas, so the full extent of their resources is not known. Furthermore, oil and gas exploration and production technology continues to improve (see the discussion of unconventional oil in Chapter 11 and unconventional gas in Chapter 12), and by 2035 this progress could allow production of resources not currently considered economic. APERC's oil and gas production estimates should, therefore, be viewed as conservative.

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11 OIL SUPPLY

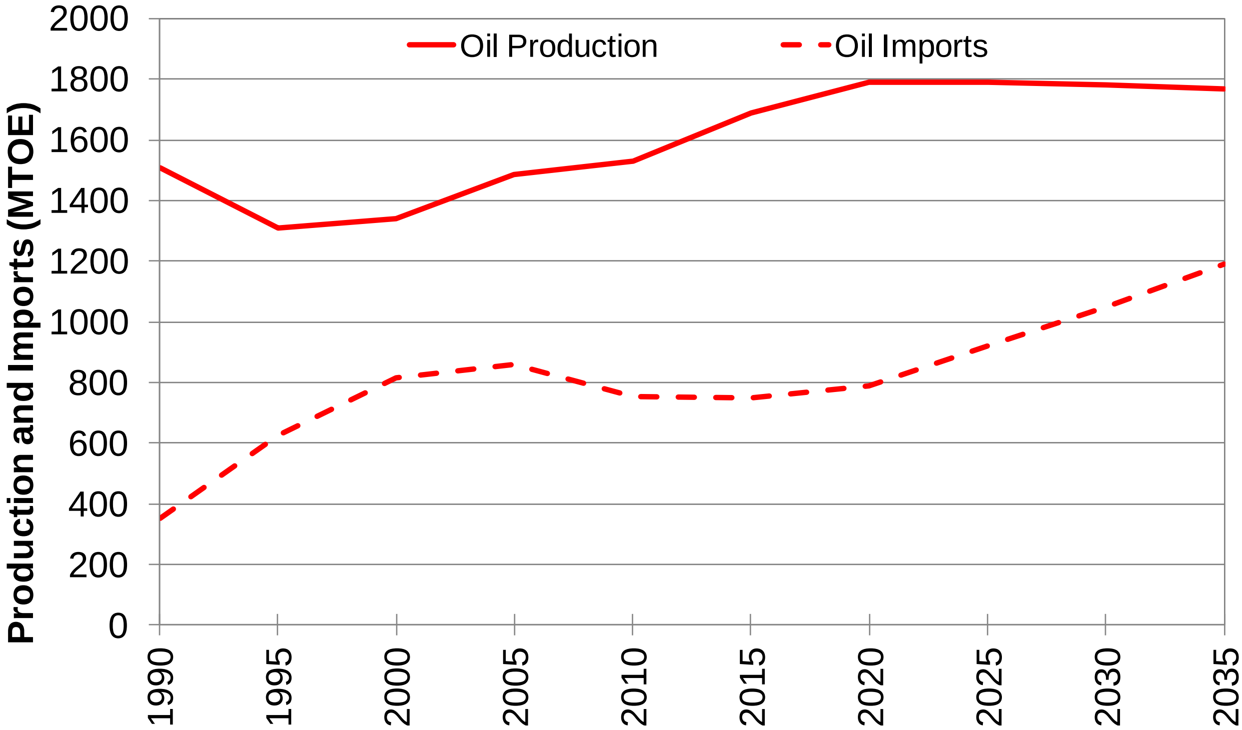
APEC OIL PRODUCTION AND IMPORTS

Since 1990, oil production in the APEC region has increased only slightly, while oil demand has risen significantly. As a result, oil imports into the APEC region have grown faster than oil production. APEC's oil production, including natural gas liquids (NGLs) reached 1498 million tonnes of oil equivalent (Mtoe) in 2009, which accounted for roughly 37% of worldwide production.

As shown in Figure 11.1, oil production in the APEC region is projected to grow to about 1790 Mtoe in the early 2020s and then to roughly level off. On the other hand, APEC's oil demand is likely to continue to grow faster than its oil supply.

As discussed in Chapter 5, rapid oil demand growth is being driven primarily by growing vehicle ownership in the developing economies of the APEC region. As a result, APEC's oil imports are likely to grow 55% between 2009 and 2035. There are, of course, many uncertainties in these projections, especially in the later years when the increased production of unconventional oil could push production upward.

Figure 11.1: APEC Total Oil Production and Net Oil Imports, 1990–2035



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011

Today, technologies for oil exploration and production are evolving quite rapidly. As the existing oil reserves deplete and traditional supplies become scarcer, producers are shifting their targets towards resources that are more costly and technically complex. High oil prices have made this shift possible, stimulating advances in technology that have made many unconventional and frontier resources economic. Resources long considered sub-commercial are now being integrated into the world oil supply; see the sidebar 'The Increasing Importance of Frontier and Unconventional Oil' in this chapter.

Unlike conventional oil, which is predominantly located in a few regions in a few economies, unconventional resources are more widely distributed, which is another incentive for developing them. Since the late 2000s, efforts to develop unconventional oil resources have been especially intensive in the APEC economies in North America. As with unconventional gas, discussed in Chapter 12, the ability to develop these resources in other APEC economies may depend as much on the institutions that make their development possible as it does on the resources themselves. In addition to extensive technology transfer, providing a reasonably stable and transparent system of regulations, taxes, and fiscal terms for oil producers is of critical importance.

THE CHALLENGE OF OIL SECURITY

This increasing dependency on oil imported from outside the region in the business-as-usual (BAU) case means the APEC economies may face at least four kinds of risks to their economies:

1. The availability of oil supplies could be threatened by political events in other regions, such as the Middle East and Africa.
2. The availability of oil supplies will depend on the ability of national and international oil companies in these other oil producing regions to make adequate investments.
3. As oil production becomes more concentrated in a few countries, oil prices will be increasingly influenced by the market power of the producing countries.
4. Increasing amounts of oil will need to be moved longer distances, typically from the Middle East or Africa, which poses additional security risks.

The likely outcomes of the APEC region's import dependency are:

- Continued oil price volatility will be a near certainty.
- There will be significant risks of supply disruptions.
- Both of the above threaten the economic stability of APEC economies and the world.

These conclusions hold even for the APEC economies that are not oil importers, or that are likely to become less dependent on oil imports over the outlook period (such as the United States). In today's globally-integrated economy, a crisis in the oil market affecting oil imports anywhere, will be felt everywhere.

THE INCREASING IMPORTANCE OF FRONTIER AND UNCONVENTIONAL OIL

Frontier and unconventional oil development requires complex technologies, facilities, and processes which differ from those traditionally used by the oil industry. Compared to conventional oil, their cost is higher and their environmental impacts are potentially larger. Nevertheless, their emergence has substantially expanded the scope of hydrocarbons available for mankind. This section provides a brief overview of the opportunities and challenges posed by each type of frontier and unconventional oil.

Deepwater Oil

Generally, the greater the water depth, the greater the efforts required to extract hydrocarbons and hence the larger the investment required. Oil extraction activities at water depths of less than 300 metres (1000 feet) are regarded as shallow water wells and are similar to onshore wells since the continental shelf is still present. On the other hand, wells drilled in water depths from 300 metres (1000 feet) to approximately 1500 metres (5000 feet) are considered deepwater wells. Although this range may differ among producers and economies, these are the boundaries adopted by the industry in the Gulf of Mexico, the most intensive deepwater oil producing area in the world (USEIA, 2009a; USBSEE, 2012). Production beyond the upper limit is regarded as ultra-deepwater, entailing the highest risks and most intricate technical requirements.

Despite this complexity, technological progress is constantly allowing the drilling of oil wells in water of greater depths. While many wells in the Gulf of Mexico and Brazil are producing oil at water depths of 2 kilometres (km), in April 2011 a well was drilled in India at a water depth of over 3.1 km (10 194 feet) (Transocean, 2012). Especially since the early 1990s (USBSEE, 2012), deepwater oil has increased its strategic role in the total oil supply. This is particularly true in the US, where deepwater operations started in the 1970s. The contribution of the deepwater output in the Gulf of Mexico accounted for almost a quarter of US domestic oil production in 2010 (USEIA, 2012b).

In addition to the US, deepwater operations are concentrated in Brazil and West Africa. Deepwater output is estimated to account for as much as 7% of the world's total oil output in 2012, and is expected to rise to nearly 10% by 2020 (BP, 2012). The general consensus is that this contribution is likely to grow over the next few years. In Brazil, for instance, the ultra-deepwater reservoirs at Lula in the Santos Basin hold resources estimated to be 5–8 billion barrels (Petrobrás, 2009); while nearly all of Angola's current production and proved reserves of 9.5 billion barrels lie offshore, mostly in deepwater (USEIA, 2011).

Deepwater oil projects require special technology and infrastructure. Since their costs are greater than those for conventional oil production, they call for significant capital expenditure and expansion of current technical frontiers. As a reference, in the US from 2007 to 2009, the average total costs of offshore oil production were 64% higher than the costs of onshore oil production (USEIA, 2012c). Adding to this complexity, tighter environmental and safety requirements after the 2010 Deepwater Horizon oil spill in the Gulf of Mexico could entail additional costs.

Arctic Oil

The Arctic is one of the world's least explored and exploited oil frontiers. In spite of being regarded as conventional in terms of its geological characteristics, the technical challenges of developing it are huge. This is primarily due to the Arctic's extreme weather and ice, its lack of infrastructure, its logistical limitations and its isolated conditions. Even though the first large field discovered was Russia's Tazovskoye in 1962, the Alaskan North Slope is by far the best known project (USEIA, 2009b). According to a US Geological Survey's assessment of 25 Arctic basins (USGS, 2008), the potential technically-recoverable conventional oil resources are estimated to be nearly 90 billion barrels, which amounts to about three years of global oil demand in 2010. A third of those resources are concentrated in the Arctic Alaska Basin.

The rapid development of the Arctic oil in the US started in the 1970s when significant oil resources were discovered at Prudhoe Bay in Alaska's North Slope. In spite of its high costs and environmental challenges, the energy shocks in the 1970s helped push the project to completion. By 1988 production had reached its peak at 2.2 million barrels per day, accounting for 24% of the US oil production in that year. Although natural decline and the lack of significant further discoveries have resulted in a production drop at an average annual pace of 5.3% from 1988 to 2010, the North Slope still represents nearly all of Alaska's oil output. The state accounted for 11% of the US production in 2010 and it is the second-largest oil producing state after Texas. According to the US Department of Energy (USDOE, 2009a), Alaska's untapped oil resource in its already developed fields has an estimated potential of 6.1 billion barrels. That could expand to roughly 35 billion barrels if restrictions are lifted on exploration and production in the 1.5 million-acre coastal plain designated as the 1002 Area of the Arctic National Wildlife Refuge, the National Petroleum Reserve and the Outer Continental Shelf.

During the second quarter of 2012, Russia's oil company Rosneft reached agreements with several international oil companies to advance its Arctic exploration and production activities, including in its four blocks in the Kara and Barents Seas (Rosneft, 2012b). These blocks have an oil potential amounting to 46 billion barrels. According to current schedules, seismic studies will be done shortly, with the first wildcat well to be drilled by 2015 and full-scale production expected from 2016 or 2017 (Rosneft, 2012a).

Tight Oil

'Tight oil' is a term used primarily to describe oil produced from low permeability shales, the same shales that produce 'shale gas', as described in Chapter 12. Tight oil is sometimes referred to as 'shale oil'. Although it might seem more natural to refer to tight oil as 'shale oil', that term is easily confused with 'oil shale', a term which describes a completely different type of resource (see below). APERC uses the term 'tight oil'. The word 'tight' denotes the characteristic low permeability of the rock in the reservoirs. It is this characteristic which calls for different production methods to extract the oil.

Due to this low permeability, tight oil has historically been unattractive for development, with producers in the US bypassing it to focus on other resources less difficult to develop (USDOE, 2009b, p. 14). It was only in the late 2000s that tight oil was able to be commercially produced by means of a combination of hydraulic fracturing and horizontal drilling.

Technological advances in the last few years, as well as high oil prices, mean conditions are favourable for the expansion of tight oil supply in the US. Since the technology and methods involved in producing tight oil and shale gas are basically the same, at least in the US, tight oil supply is affected by the relative prices of oil and gas. Specifically, gas producers have moved to reservoirs richer in oil as the price of gas has fallen relative to oil. According to recent US Government projections (USEIA, 2012a), tight oil production in the US could grow at an average rate of 8.1% per year under the most optimistic scenario, rising from 0.4 million barrels per day in 2010 to 2.8 million barrels per day (about 140 Mtoe per year) by 2035. This is roughly equivalent to 37% of the total oil output of 7.5 million barrels per day produced in the US in 2010.

As with other unconventional resources, tight oil development presents some challenges. It requires cutting-edge technology and expertise, intensive drilling, the availability of considerable volumes of water to be injected into the wells, and extensive infrastructure and auxiliary services. All these mean tight oil production requires larger capital expenditures in comparison to conventional oil production (IHS, 2011). Rising environmental concerns, mainly to do with the risk of polluting groundwater aquifers and with land disturbance due to drilling activities, might hinder accelerated tight oil development on a global basis (USDOE, 2009b).

In response to these concerns, governments are considering or implementing stricter environmental standards, which could slow the development of tight oil. There are also uncertainties about the ability of other economies to replicate the successful experience of the US. The US has some advantages including a vast resource base, flexible land leasing arrangements, extensive oil development infrastructure and supporting services, and decades of practice and knowledge not present in most other economies. Additional characteristics of the US stimulating the development of tight oil supply are an abundance of small-sized independent oil producers who are willing to take risks, combined with a financial sector eager to fund new ventures (Maugeri, 2012).

Extra-Heavy Oil

Extra-heavy oil is viscous and does not flow easily under normal conditions. Apart from being far more challenging to produce, it yields less high-value products in comparison to lighter crude oil types. Extra-heavy oil reservoirs are located mainly in Venezuela and Russia as well as in the oil sands of Canada.

Oil sands are a solid, extra-heavy type of crude oil composed of a mixture of natural bitumen, sand, water and clay. The largest known deposits are located in the Athabasca oil fields of the Canadian province of Alberta. Sometimes referred to as 'tar sands', this term is considered less appropriate in the industry as oil is the ultimate product obtained from these resources. Since its beginning in 1967, Canada's oil sands production has grown continuously—by 2010 it amounted to 1.6 million barrels per day, accounting for as much as 57% of Canada's total oil production. According to domestic industry projections, oil sands supply is likely to grow 2.3 times by 2030 to reach 5.3 million barrels per day (about 265 Mtoe per year) and represent 85% of Canada's total oil production (CAPP, 2012a).

For oil sands to be economically produced, two methods are employed. For deposits that are deeply buried, a process intensive in energy and water known as in-situ recovery is used. In this process, steam is injected into the ground to soften the bitumen and allow it to flow to the wellbore. Later, it can be converted to synthetic crude (syncrude) at special processing units (upgraders). For resources that lie close to the surface, the oil sands can be mined and processed aboveground. Although both methods are used in Canada, in-situ production accounts for about 80% of the total production (CAPP, 2012b).

Extra-heavy oil and oil sands are expected to become more significant in global oil production. While the extra-heavy oil deposit in the Orinoco Belt of Venezuela is believed to be one of the largest oil reservoirs in the world and constitutes 86% of Venezuela's total oil reserves (PDVSA, n.d.), the share of oil sands in Canada's oil reserves, at 97%, is even higher (CAPP, 2012b). The abundance of these unconventional resources gives both these economies the largest oil reserves in the world along with Saudi Arabia (OGJ, 2011).

Since late 2011, the available pipeline network that transports Canadian oil to the consuming and refining centres in eastern Canada and across the US has reached capacity. This poses a major challenge to the further development of the oil sands. Apart from the large investments required to develop the potential of these unconventional resources, the role of technology in increasing their sustainability will be critical in determining their future contribution. As a reference, technology has enabled a 26% reduction in carbon emissions per barrel of oil produced in 2012 compared to 1990 levels (IPIECA, 2012) and the improving trend is expected to continue.

Oil Shale

Oil shales are sedimentary rocks (mudstones and shales) containing organic matter known as kerogen. Since these rocks have not been buried deep enough and long enough for heat and pressure to transform the kerogen into oil, it is common to find them at shallow depths. This calls for production methods different to those used for conventional oil. Since the main component present in the rock is kerogen, oil shale is sometimes known as 'kerogen oil' (IEA, 2011, p. 120).

The most common method of yielding oil from rock is to retort the rock to very high temperatures (approximately to 450°C) either in place or by having the rock mined first and processed later. Since the in-situ heating and injection of fluids, or the mining, retorting and upgrading of the rock, involves huge amounts of capital and energy, oil prices need to be high for oil shale to cover the investment required and to be considered viable. Studies done for the US Department of Energy (Bartis et al., 2005) found that for a project of this kind to be feasible oil prices would need to be at least USD 70–95 in 2005 terms. For this reason, some economies just burn the mined rock in a similar manner to coal. This is the case in Estonia, where this method provides more than 90% of its electricity generation (EMOE, 2008).

Estimates suggest the global oil shale resources are very large, amounting to at least 4.8 trillion barrels (WEC, 2010, p. 93). One of the richest oil shale deposits is in the Green River area of the US, in the states of Colorado, Utah and Wyoming. Other significant oil shale resources are located in Australia, Brazil, China, Estonia, Jordan and Morocco. However, commercial exploitation was carried out in only a few of those economies in 2010, and mainly on a small scale. In the APEC region, apart from the US there are projects underway in Australia, Canada, China, Russia and Thailand (WEC, 2010).

As well as needing sustained high oil prices to cover its costs, oil shale production is energy intensive. It entails larger emissions of CO_2 than conventional oil production and it may have other significant environmental impacts. Therefore, to promote oil shale production and to increase its integration into the global oil supply, intensive research aimed at lowering its costs and minimising its environmental impacts is needed.

Other Sources of Oil

Apart from the unconventional resources discussed above, other technologies have not been widely commercialized yet, due to their prohibitive costs and adverse environmental impacts. One of these technologies is gas-to-liquids (GTL). This involves the use of natural gas as an input which is then processed to produce heavier hydrocarbons, similar to those obtained from oil refining. In 2011, the application of GTL was limited, with some plants installed in Malaysia, South Africa and Qatar. However, more GTL facilities could be built, especially on the US Gulf Coast and in Russia (IEA, 2011; Shell, n.d).

In the case of coal-to-liquids (CTL), coal is used as a feedstock to produce oil products. The use of CTL is also limited and its employment is favoured in those economies with abundant coal resources. In South Africa, a little less than one-third of its gasoline and diesel demand is supplied from coal (World Coal Organization, n.d.).

The development of these technologies may appear tempting—gas and especially coal reserves are larger and better distributed, and their prices are usually lower on an energy basis compared to conventional oil. Nonetheless, the technology involved in these processes is costly; and the processes themselves are energy intensive due to the loss of heat value in processing, and they require huge amounts of water.

Technology could play a critical role, not only in adding volumes of unconventional oil to the global oil supply, but also in designing solutions to reduce the environmental impacts. To illustrate, one of the processes of enhanced oil recovery aimed at improving the productivity of oil wells, CO_2 injection, could both increase oil production and avoid the release of CO_2 into the atmosphere. But for this practice to be feasible, costs need to be reduced. Although there has been limited use of CO_2 injection in the US and Saudi Arabia (IEA, 2011, p. 132; Hyne, 2001, p. 443), the speed and magnitude of technology developments during the outlook period will influence its further implementation.

OIL PRODUCTION BY ECONOMY

APEC's oil production is expected to grow 15% from 1530 Mtoe in 2010 to 1767 Mtoe in 2035. Nearly all of this growth is expected to come from North America, with the contributions from Canada, the US and Mexico projected to expand by 114%, 42% and 29% respectively during the outlook period. This growth will be driven mainly by the development of their unconventional resources.

The increase in oil production in Canada is expected to be supported by its oil sands, and in the US by its tight oil supply going hand-in-hand with its rapidly-growing shale gas production. In Mexico, the beginning of its deepwater production, the development of new fields, and the use of enhanced recovery methods in mature fields will provide the incremental production.

Outside North America, other economies are also likely to increase their production by 2035. These economies include China, Peru and Australia, although their joint contribution to APEC's growth during the outlook period is expected to be less significant.

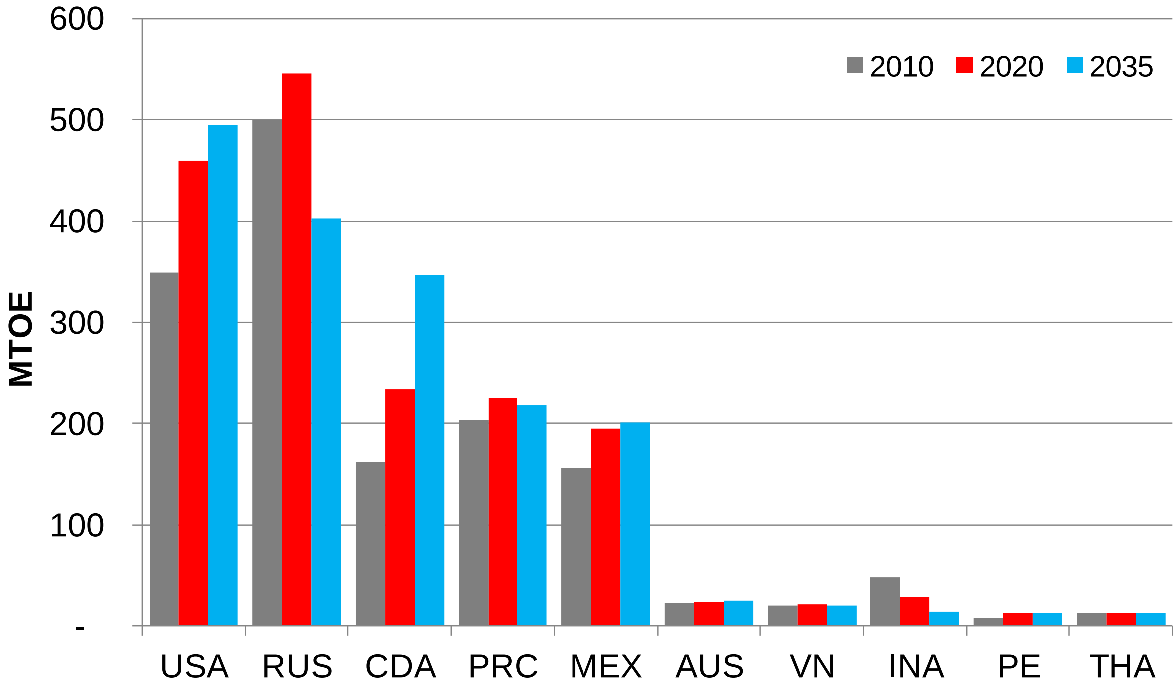
In contrast, oil production is projected to decline in Russia, Indonesia, Malaysia, Brunei Darussalam and the Philippines over the same period. As noted earlier, though, there are large uncertainties in these projections. In the remaining APEC economies, a lack of resources prevents them from developing significant domestic oil production.

In 2010, Russia was APEC's largest oil producer followed by the US, China, Canada and Mexico. By 2035, it is projected the US will lead APEC's oil production, followed by Russia, Canada, China and Mexico, with their joint output representing 94% of the APEC region's production.

Apart from exploration and production activities, the APEC region has a significant role in refining. The largest crude oil refining economies in the APEC region are the US, China, Russia, Japan and Korea, which together represented nearly 80% of the region's distillation capacity and about one-third of the worldwide distillation capacity in 2010.

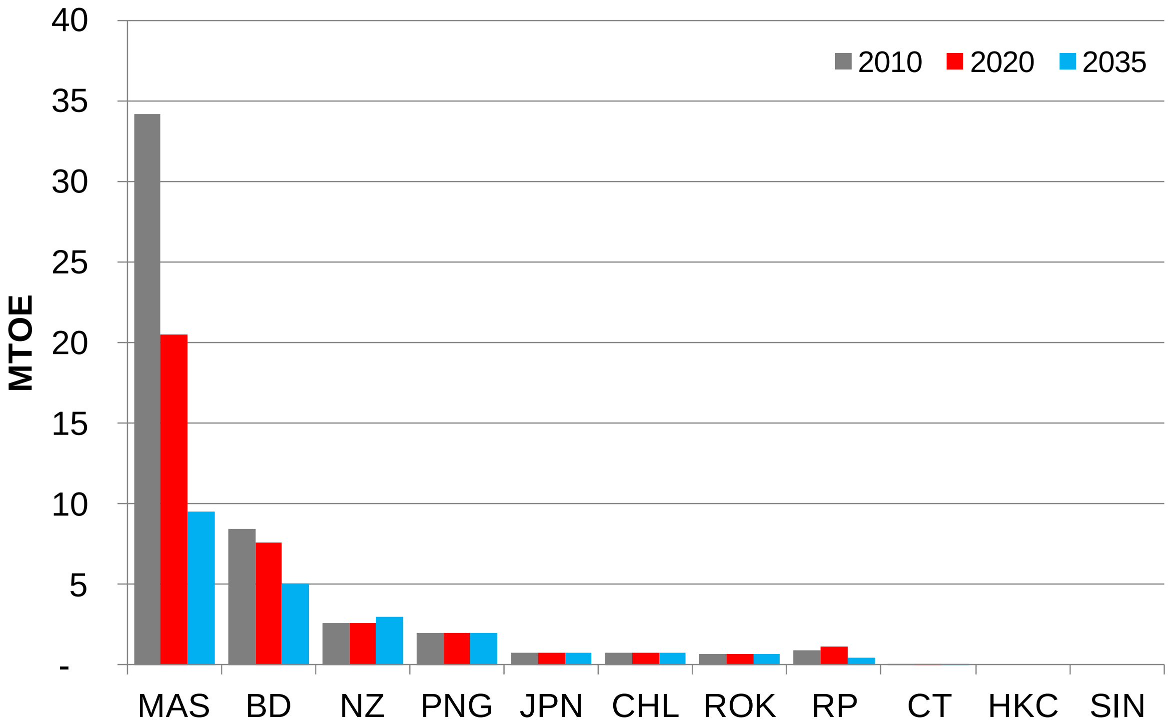
Beyond distillation, the APEC region also has a leading role in other refinery processes. Many refineries are adding capacity to process increasingly heavier crude oil feedstock and to yield more high-value oil products such as gasoline and distillates. In 2010, APEC's refineries accounted for 65% of the global catalytic cracking capacity, 61% of the global hydroconversion capacity (including hydrocracking and catalytic hydrotreating) and 70% of the global coking capacity (OGJ, 2010).

Figure 11.2: APEC's Projected Oil Production in 2010, 2020 and 2035, Higher Oil Production Economies



Source: APERC (2012)

Figure 11.3: APEC's Projected Oil Production in 2010, 2020 and 2035, Lower Oil Production Economies



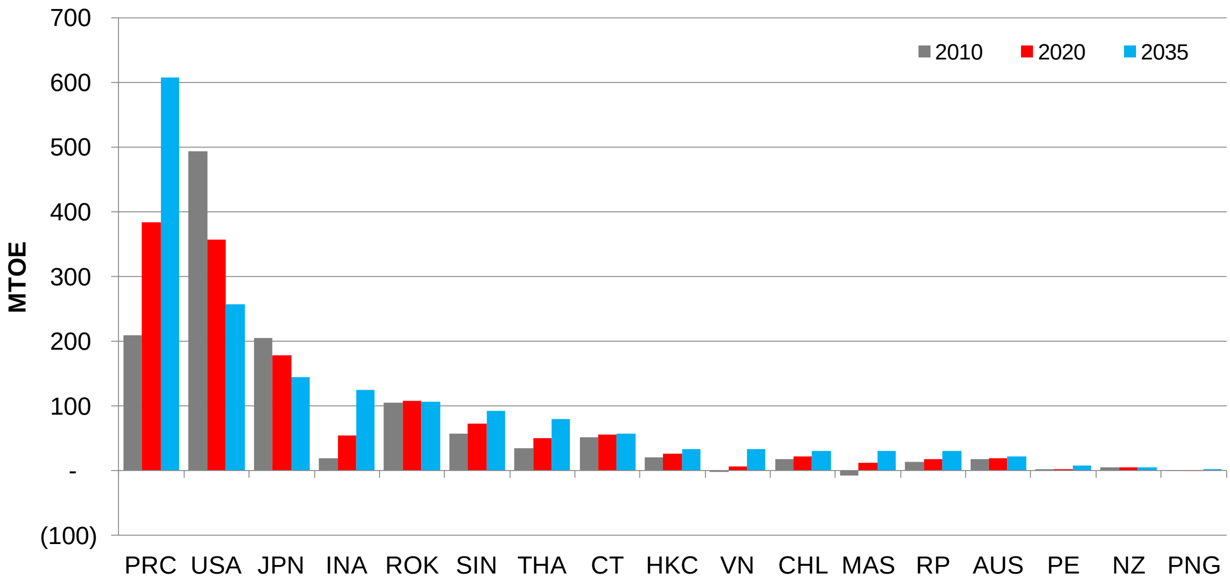
Source: APERC (2012)

INTERNATIONAL OIL TRADE BY ECONOMY

In the BAU case, the APEC region will be a growing oil importer, with its net imports expanding 58% between 2010 and 2035. Much of this growth in imports will be driven by China's rising primary oil demand, which is expected to almost double between 2010 and 2035. Despite the fact China's domestic production is expected to increase during the outlook period, it will be insufficient to meet the growth in demand. It is projected the net oil imports to China will grow 191%, from 209 Mtoe in 2010 to 608 Mtoe in 2035. This will account for almost half of the APEC region's net imports.

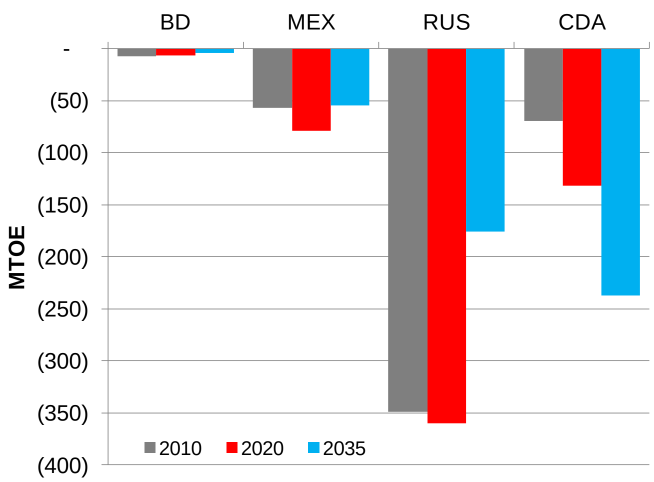
After China, the largest net importers in the APEC region in 2035 are expected to be the US, Japan, Indonesia and Korea, though the US is expected to reduce its oil imports significantly over the outlook period. Viet Nam, Malaysia, and Papua New Guinea will go from net oil exporters in 2010 to net oil importers by 2035. Projections indicate that by 2035 Canada, Russia, Mexico and Brunei Darussalam will continue to be net oil exporters.

Figure 11.4: Net Oil Imports for Net Oil Importing Economies



Note: (Negative) indicates net exports
Source: APERC (2012)

Figure 11.5: Net Oil Imports for Net Oil Exporting Economies



Note: (Negative) indicates net exports
Source: APERC (2012)

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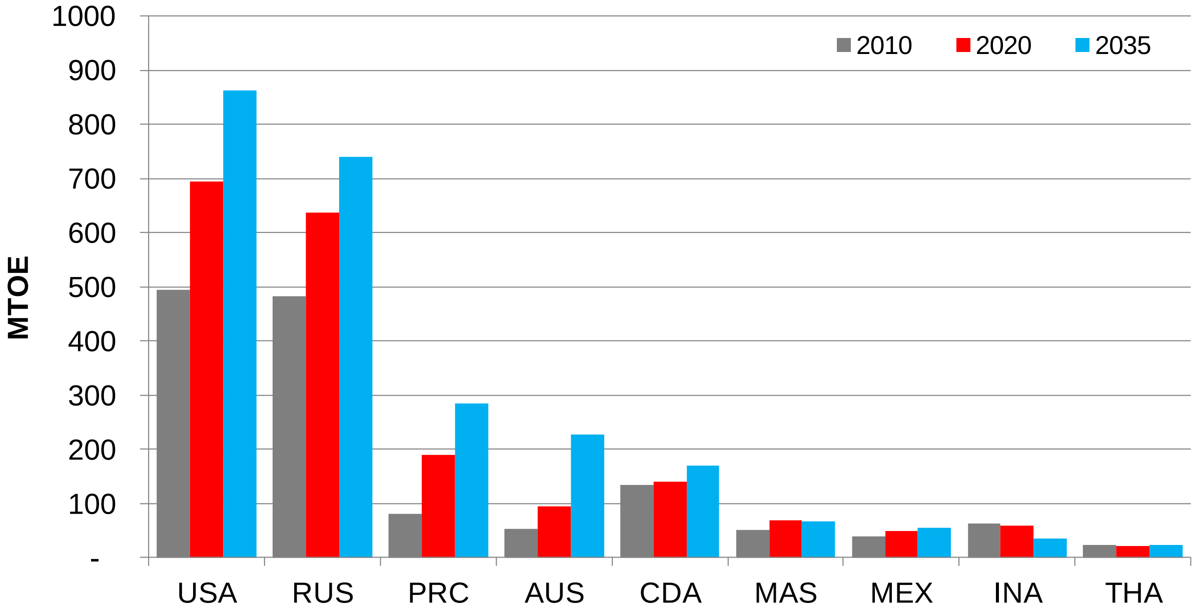
12 NATURAL GAS SUPPLY

GAS PRODUCTION

Production of gas in the APEC region under a business-as-usual (BAU) scenario is projected to grow by 80%, from 1405 Mtoe in 2009 to 2522 Mtoe in 2035. Figures 12.1 and 12.2 show projected gas production by economy. Note the difference in the scales of the vertical axis in the two figures.

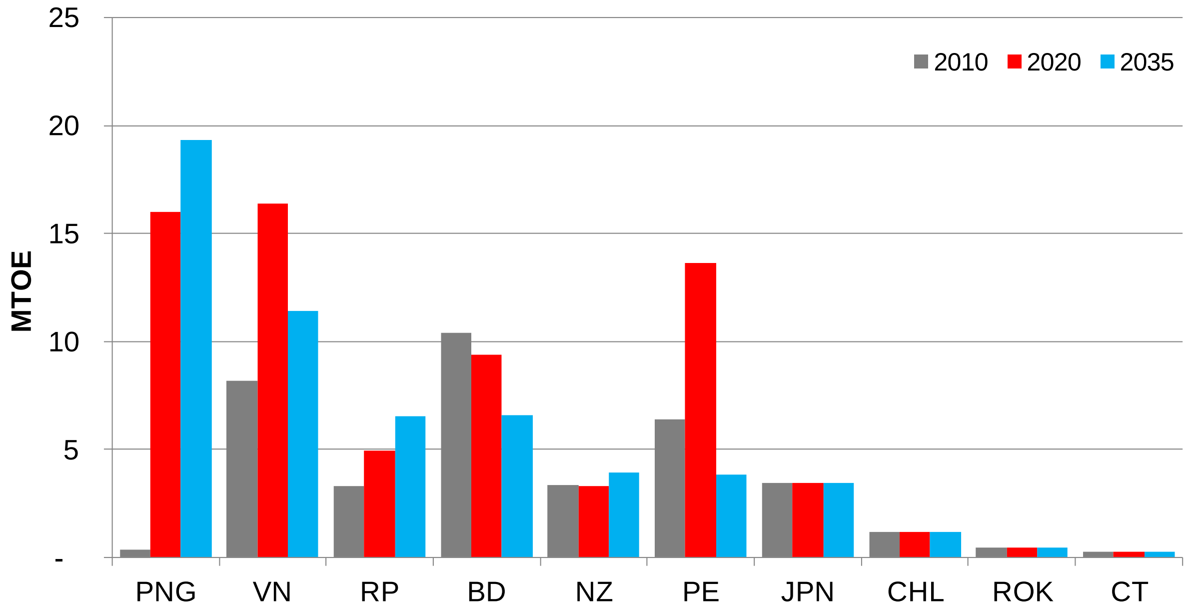
It can be seen that most of the growth in production will occur in four economies: the United States, Russia, China, and Australia. The drivers of growth in each of these economies are somewhat different, but all are contributing to meeting the growing demand for gas worldwide, as gas becomes increasingly recognized as a relatively clean, economical, and easy-to-use fuel.

Figure 12.1: Projected Gas Production, Larger Gas-Producing Economies



Source: APERC Analysis (2012)

Figure 12.2: Projected Gas Production, Smaller Gas-Producing Economies



Source: APERC Analysis (2012)

In Russia, immense resources of conventional gas are available (see Table 12.1) to satisfy both growing domestic demand and export demand. However, much of this gas is in remote locations, so production is expected to move away from mature, existing fields to new and more-difficult-to-develop regions that will require significant investment in infrastructure.

The United States (US) is expected to continue experiencing a boom in the production of unconventional gas, especially shale gas. The growth in unconventional gas in the US is driven by advances in technology, especially horizontal drilling and hydraulic fracturing, which have made it profitable to develop resources that were previously considered to be uneconomic. As discussed in the United States Economy Review in Volume 2, the growth in unconventional gas production in the US is projected to shift the US from a net gas importer to a net gas exporter.

China is seeking to develop its significant conventional and unconventional gas resources, as that economy's rapid economic growth drives rapid growth in domestic demand for energy. Increased gas production will diversify China's energy supply away from coal, while helping to reduce the need for imported energy.

Australia also has significant conventional and unconventional gas resources, some of which are located in areas of that economy that are remote from the domestic pipeline network. Australia is therefore in the process of developing several major LNG projects, which will export gas to growing Asian markets.

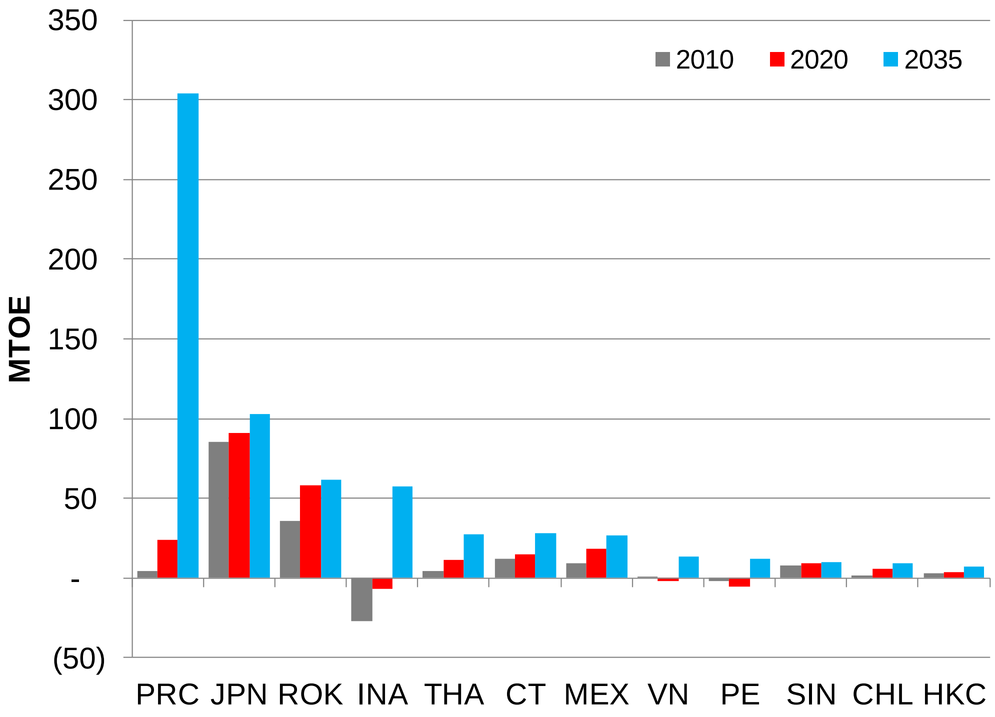
GAS IMPORTS AND EXPORTS

APEC's net gas exports are projected to increase from 48 Mtoe in 2009 to 222 Mtoe in 2020. But after 2020, the trend toward growing exports will reverse and by 2035 APEC could have net imports of 61 Mtoe. These imports and exports are quite small numbers relative to APEC's total gas demand and supply, and are subject to many uncertainties. In general, we can say that APEC will be more-or-less self sufficient in gas during the outlook period.

As shown in Figure 12.3, imports of gas are projected to increase in all importing economies over the outlook period with the exception of the US. The APEC region currently includes some of the largest importers of LNG in the world including Japan, Korea, and Chinese Taipei. China is likely to become an increasingly large importer of gas, utilizing both pipeline transportation from neighbouring economies and LNG. Indonesia is likely to switch from being a net gas exporter to a net gas importer (BP, 2012, p. 28).

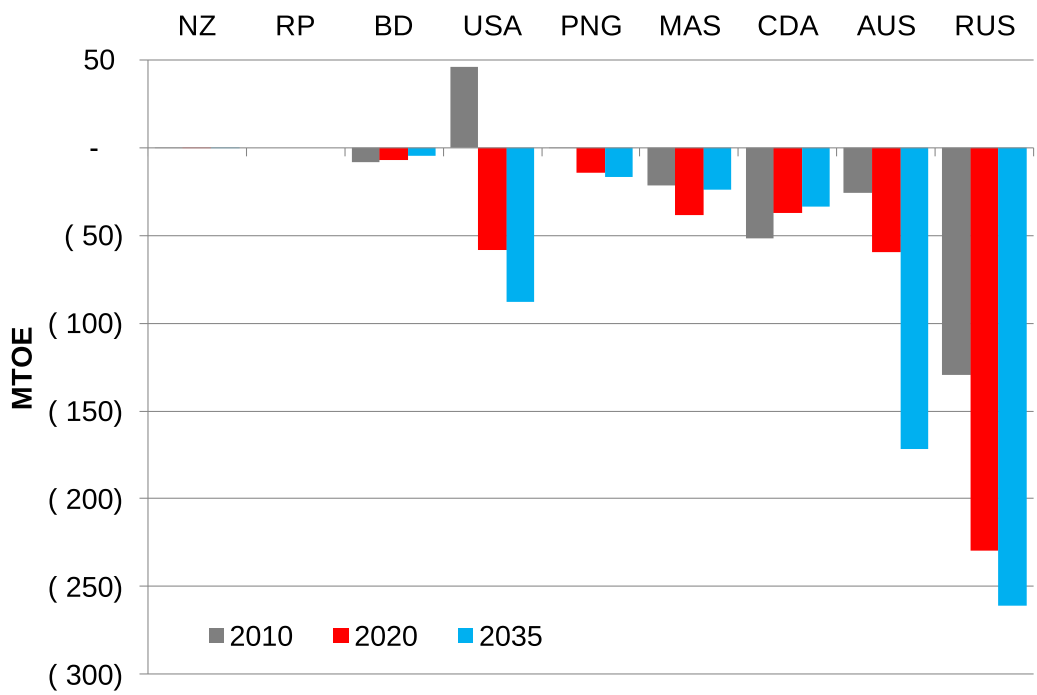
As shown in Figure 12.4, Russia will remain the largest gas exporter in APEC, while Australia will dramatically increase its exports during the outlook period. Canada has historically exported gas by pipeline to the US, but given the booming production in the US, will increasingly turn to overseas exports of LNG. The Philippines and New Zealand are projected not to import or export natural gas.

Figure 12.3: Projected Net Import of Gas in APEC Economies



Source: APERC Analysis (2012)

Figure 12.4: Projected Net Export of Gas in APEC Economies



Source: APERC Analysis (2012)

THE POTENTIAL FOR UNCONVENTIONAL GAS

We have already mentioned the boom in unconventional gas in the US, which includes coal bed methane, tight gas, and especially shale gas. In 2009, 10% of US gas production came from coal bed methane, 31% from tight gas, and 14% from shale gas, implying that more than half of the US gas supply is already coming from unconventional sources. The United States Energy Information Administration projects that in 2035, 6% of US production will come from coal bed methane, 22% from tight gas, and 49% from shale gas (USEIA, 2012, Table A14), implying that more than three-quarters of US gas production will be unconventional by 2035.

A number of other APEC economies are already utilizing unconventional gas resources, especially coal bed methane. In 2011, unconventional gas provided about half of Canada's natural gas supply (70 billion cubic metres (bcm) or about 63 Mtoe). China produced 36 bcm (roughly 32 Mtoe) of tight gas, while Mexico produced about 2 bcm (roughly 2 Mtoe) in 2011. Australia produced 6 bcm (roughly 5 Mtoe) of coal bed methane in 2011 (Moodhe, 2012).

The APEC region is believed to have immense resources of conventional and unconventional gas. Table 12.1 shows estimated technically recoverable resources of conventional gas, shale gas, coal bed methane, and tight gas for those APEC economies whose resources were assessed in the APEC Unconventional Natural Gas Census, as well as Russia. For comparison purposes, 2009 production is also shown and the implied number of years of production at the 2009 production rates. It can be seen that in each case, more than 100 years of production should be available, often considerably more.

Table 12.1: APEC's Technically Recoverable Conventional and Unconventional Gas Resource Base, in Mtoe

Economy	Conventional Gas	Unconventional Gas				Conventional & Unconventional Gas	2009 Production	Years of Production
		Shale Gas	Coal Bed Methane	Tight Gas	Total			
China	5 225	22 150	9 625	na	31 775	37 000	76.7	482
US	30 750	14 475	3 500	13 000	30 975	61 725	532.7	116
Australia	5 700	9 950	10 975	500	21 425	27 125	38.1	712
Canada	8 650	2 250	1 125	4 250	7 625	16 275	147.6	110
Mexico	2 375	7 425	100	na	7 525	9 900	49.1	202
Russia	86 125	1 825	50	na	1 875	88 000	474.9	185

na = not assessed

Sources: Conventional gas: Ejaz (2011, Table 1)—all conventional figures shown are remaining recoverable resources which exclude gas already produced; figure for Australia includes Oceania. Unconventional gas: Moodhe, (2012, slides 9 and 15). 2009 production: BP (2012, p. 24). Original data in trillion cubic feet (Tcf) converted to Mtoe using a conversion factor of 25 Mtoe/Tcf as per BP (2012, p. 44).

Unconventional resource estimates are subject to considerable uncertainty given the limited amount of exploration that has been done in most APEC economies. Table 12.2 shows another set of technically recoverable shale gas resource estimates from a separate analysis by the United States Energy Information Administration. In addition to the economies shown in these tables, Indonesia is known to have significant resources of coal bed methane and shale gas. More modest unconventional gas resources are also known to exist in other South-East Asian economies, Peru, and New Zealand. However, the extent to which these resources are technically recoverable has not been assessed.

Table 12.2: APEC's Technically Recoverable Shale Gas Resource Base, in Mtoe

Economy	Technically Recoverable Shale Gas
China	31 875
US	21 550
Australia	9 900
Canada	9 700
Mexico	17 025
Russia	na
Chile	1 600

Source: USEIA (2011, Table 1). Original data in trillion cubic feet (Tcf) converted to Mtoe using a conversion factor of 25 Mtoe/Tcf as per BP (2012, p. 44).

While the US is experiencing a shale gas boom, and several other APEC economies are developing unconventional gas, the extent to which unconventional gas can be developed throughout the APEC region remains a huge uncertainty. In particular, shale gas has so far been developed on a large scale only in the US.

The shale gas boom in the US has benefitted from unique circumstances that could be difficult to replicate elsewhere. There are questions whether the geology elsewhere is really as attractive as it would appear, and what kind of technology will be required to develop it, which require further investigation.

But perhaps more importantly, the US provides a reasonably stable and transparent system of regulation, taxes, and fiscal terms for gas producers. This includes, on the one hand, an unusual system of privately owned mineral rights, which allows any gas producer to gain land access simply by contracting with the landowner. On the other hand, it also includes another unusual system of privately owned and freely tradable pipeline capacity rights, which allows anyone to access pipeline transportation (or even have it built) simply by contracting for it in the market (see Makholm, 2012). The result is an environment uniquely suited to the entrepreneurial firms who have pioneered shale gas technology. APEC would do well to promote understanding not only of unconventional gas geology and technology, but also of the institutions that could make its development possible.

HIGH GAS SCENARIO

The BAU scenario discussed above does not include significant shale gas development outside North America and includes fairly conservative estimates of production from both conventional and non-shale-gas unconventional resources outside of North America. As discussed above, the conventional and unconventional gas resources of the Asia–Pacific region are immense. And with LNG prices in Asia several times as high as those in North America the economics of gas development outside of North America, as well further gas development in North America for export, should be compelling. For example, in 2011 the average Japanese LNG import price was USD 14.73 per million British thermal units (Btu) compared to an average US Henry Hub price of USD 4.01 per million Btu (BP, 2012, p. 27).

How could development of these resources be better promoted? A first step might be to address some significant barriers to gas development that exist in a number of APEC economies. These include:

- Policies requiring a domestic price of gas below market levels (a form of subsidy), thereby limiting the profitability of gas development and making investment in gas development less attractive.
- Limited technology in some economies for gas development, especially unconventional and deepwater gas development.
- Protective policies restricting the export of gas.
- Policies granting a monopoly on gas development or pipeline access to certain domestic firms, or limiting the participation of foreign-owned firms, or otherwise limiting competition in gas development.
- Slow and cumbersome regulatory approvals and land access processes for gas producers.

APEC could help its member economies to overcome potential constraints on gas production and trade constraints by:

1. Continuing to encourage member economies to rationalize and phase out fossil fuel subsidies in accordance with the APEC Leaders' Declarations; these subsidies can discourage gas development especially when they take the form of price controls on gas producers.
2. Including goods and services for gas industry development in the definition of 'environmental goods and services', and continuing to encourage member economies to reduce existing barriers and refrain from introducing new barriers to trade and investment in environmental goods and services.
3. Encouraging member economies to reform policies that discourage the export of gas or restrict the involvement of foreign firms in gas development.
4. Cooperating to promote best practices in gas industry regulation (safety, environmental protection, economics).

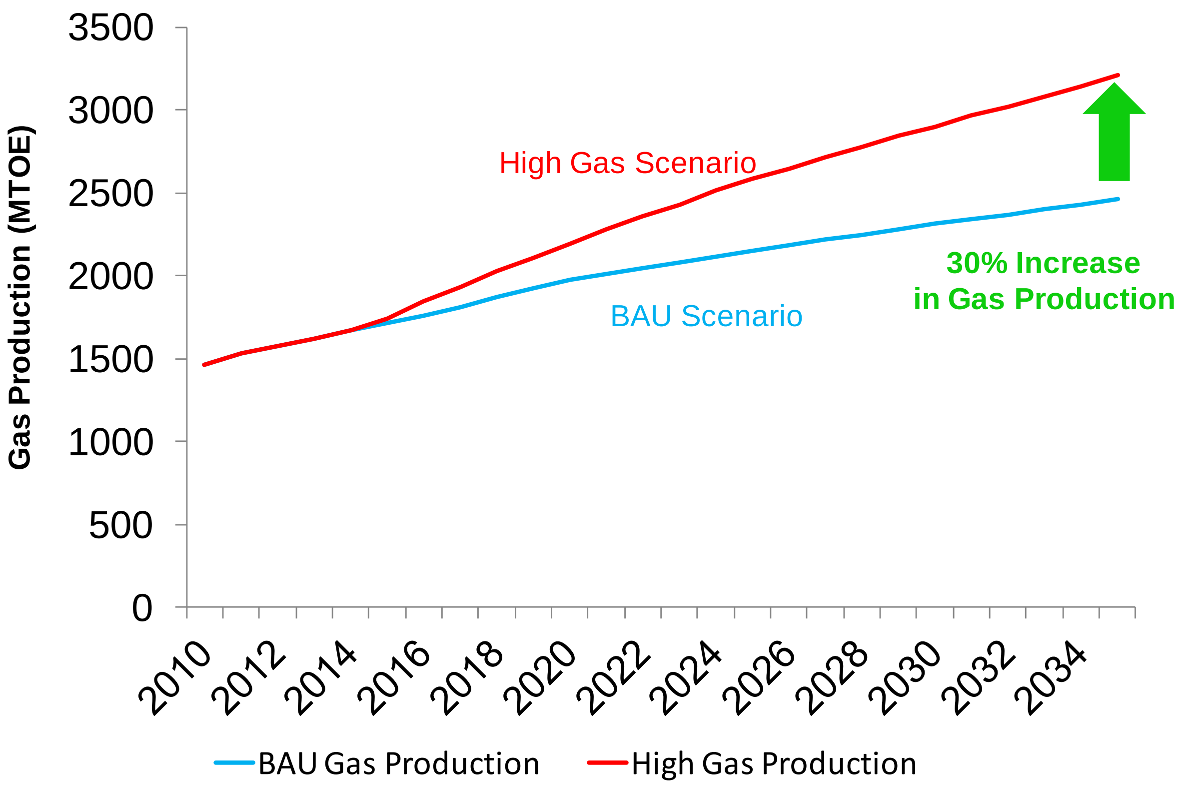
Items 1 and 2 are existing APEC initiatives where the implications for gas development might receive greater emphasis. Items 3 and 4 would be likewise consistent with APEC's mission of championing free and open trade and investment, promoting and accelerating regional economic integration, encouraging economic and technical cooperation, and facilitating a favourable and sustainable business environment (APEC, 2012).

With appropriate policies and regional cooperation, the APEC economies could use their gas resources to move toward a cleaner energy system, while promoting energy security and mutual prosperity. To illustrate some of the benefits that might accrue from removing the barriers to gas production and trade, APERC has developed an alternative 'High Gas Scenario'.

In the High Gas Scenario, APERC estimated the gas production that might be available without raising prices if existing constraints on gas production and trade were reduced. In most cases, the estimates are based on 'high gas' scenarios developed by economy governments. The results are conservative, since estimated shale gas production in some cases was low or not included. The assumptions and results for each APEC economy are discussed in the Economy Reviews in Volume 2.

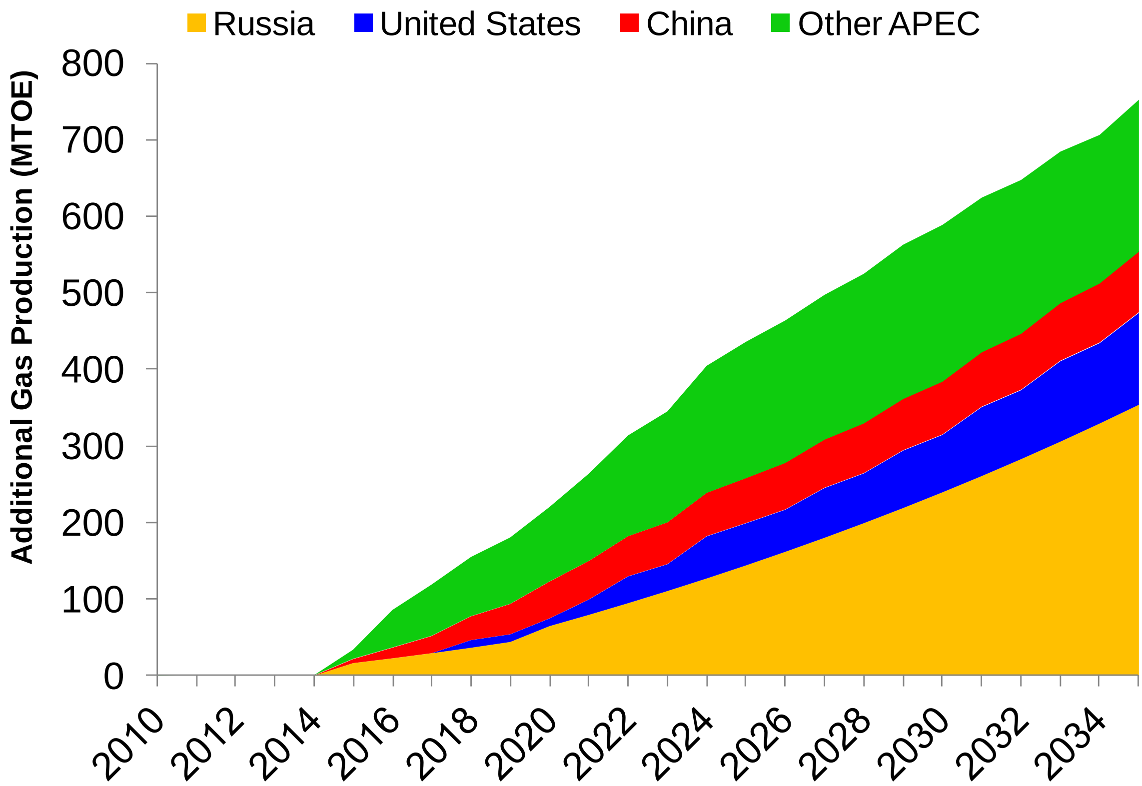
As shown in Figure 12.5, on an APEC-wide basis, gas production by 2035 was about 30% higher in the High Gas Scenario compared to BAU. As shown in Figure 12.6, Russia is the largest source of the additional gas, with the US and China also making large contributions. This should come as no surprise, given the immense estimated gas resources of those three economies.

Figure 12.5: High Gas Scenario – Increase in Gas Production



Source: APERC Analysis (2012)

Figure 12.6: High Gas Scenario – Sources of Additional Gas Production



Source: APERC Analysis (2012)

There are many ways the additional gas could be used in the APEC region, almost all of them positive in terms of economics, energy security, and/or the environment. Using gas to replace coal in electricity generation is an especially good option from a CO_2 emissions perspective due to the combined effect of two factors. First, because of its lower-carbon chemical composition, gas produces considerably less CO_2 emissions per unit of heat than coal—typically around 40% less, depending upon the type of coal (Ecofys, 2010, p. 21). Second, gas-fired generation is generally significantly more efficient than coal-fired generation in converting heat to electricity (see the sidebar 'Improving the Efficiency of Coal-Fired Electricity Generation' in Chapter 13). The combined effect of these two factors means that gas-fired generation typically has less than half the CO_2 emissions of coal-fired generation per unit of electricity produced.

Using gas in electricity generation would have other environmental benefits. When efficiently used:

- gas produces much less local air pollution than coal
- gas production is typically less damaging to land and water resources than coal production
- gas electricity generation can typically be more easily cycled on or off than coal, which allows it to better complement wind and solar generation.

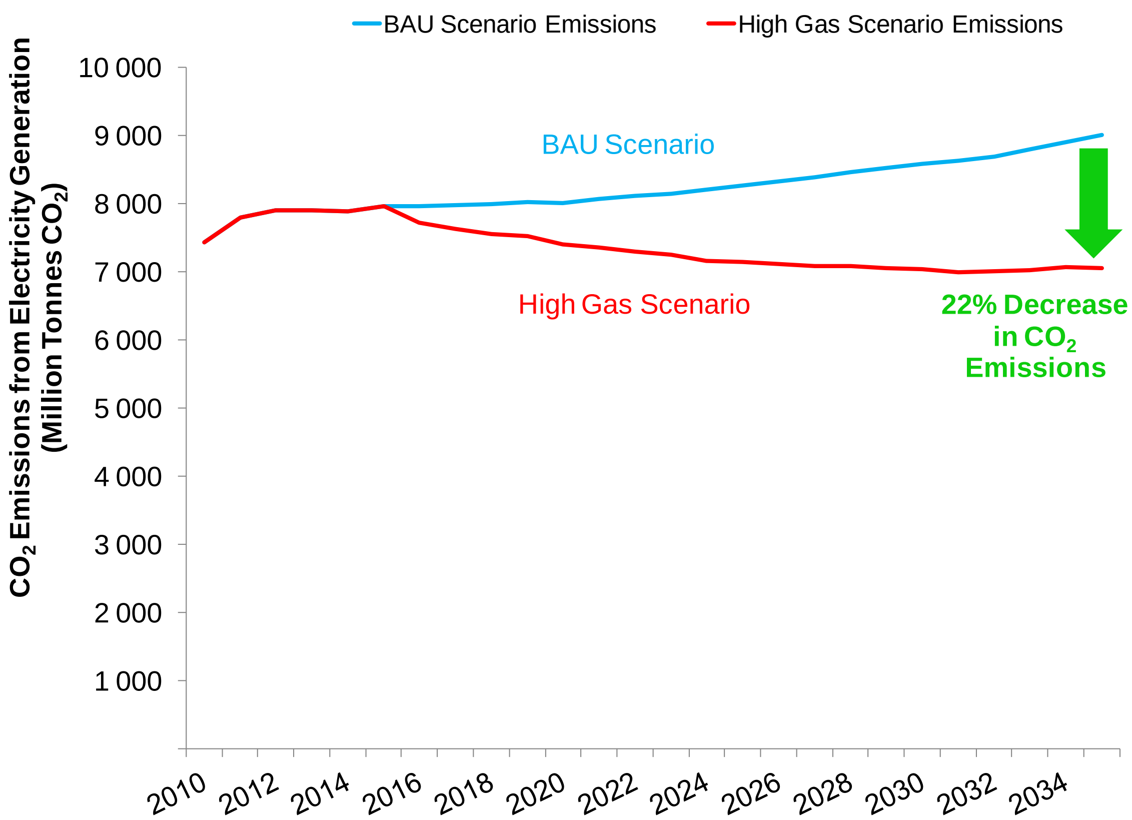
APERC therefore assumed that the additional gas in the High Gas Scenario would be used to replace coal in electricity generation.

As shown in Figure 12.7, the additional gas in the High Gas Scenario could reduce CO_2 emissions from electricity generation in 2035 by about 22% compared to BAU. This implies an overall reduction in energy CO_2 emissions of about 8% compared to BAU.

Alternatively, some of this added gas could be used to replace oil. In this case, there would be additional benefits from reduced oil imports in the form of greater energy security and economic stability. And regardless of how the gas is used, there would be large economic benefits to both producer and consumer economies.

It is worth re-emphasizing that given the immense gas resources of the APEC region, this High Gas Scenario is a conservative example of what could be accomplished if the potential constraints on gas production and trade could be reduced. It is also important to recognize that, in some APEC economies, there is growing public concern over the environmental risks of unconventional gas development. These will need to be addressed through better regulation if gas development is to win the public confidence it will need to deliver benefits like those illustrated in this scenario.

Figure 12.7: High Gas Scenario – Reduction in CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

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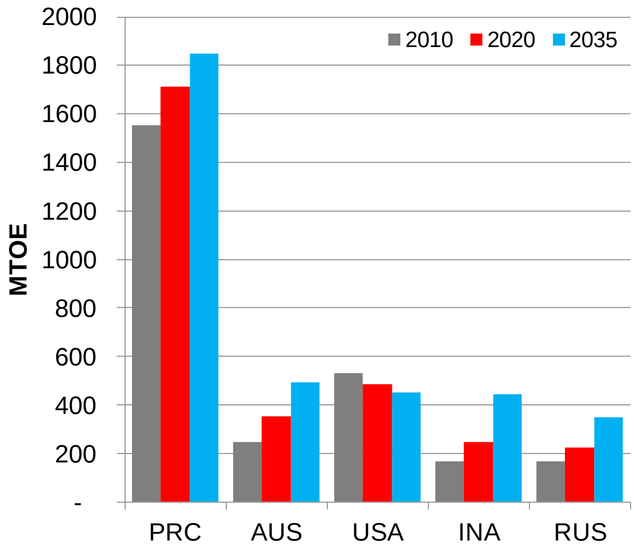
13 COAL SUPPLY

COAL PRODUCTION

Under business-as-usual (BAU) assumptions, coal production in the APEC region will continue to grow by 0.9% per year during the outlook period. It will amount to 3703 million tonnes of oil equivalent (Mtoe) in 2035 or about 37% more than in 2009. All 15 existing coal producing economies will continue to produce coal, while Papua New Guinea may start some minor production.

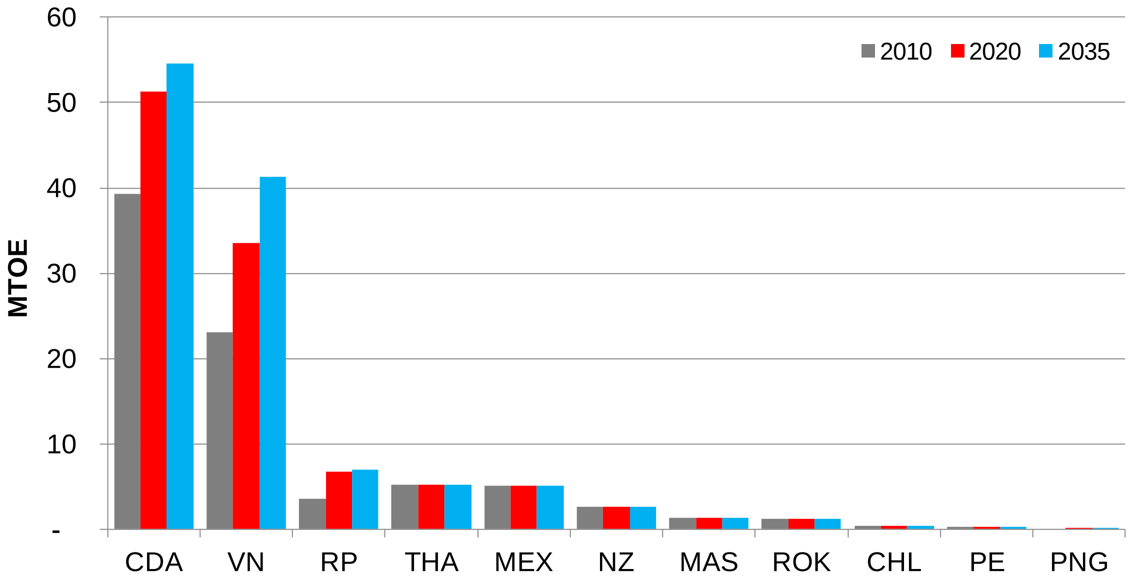
The five major coal producing economies (China, Australia, United States, Indonesia and Russia) are projected to maintain their 97% share of APEC's coal production throughout the forecast period. China will continue to be the major coal producing economy not just among the APEC economies, but worldwide. Production in China will be 1849 Mtoe in 2035, or about 50% of the APEC region's production; it was 57% in 2009.

Figure 13.1: Projected Coal Production in Mtoe, Major Coal Producing Economies



Source: APERC Analysis (2012)

Figure 13.2: Projected Coal Production in Mtoe, Other Economies



Source: APERC Analysis (2012)

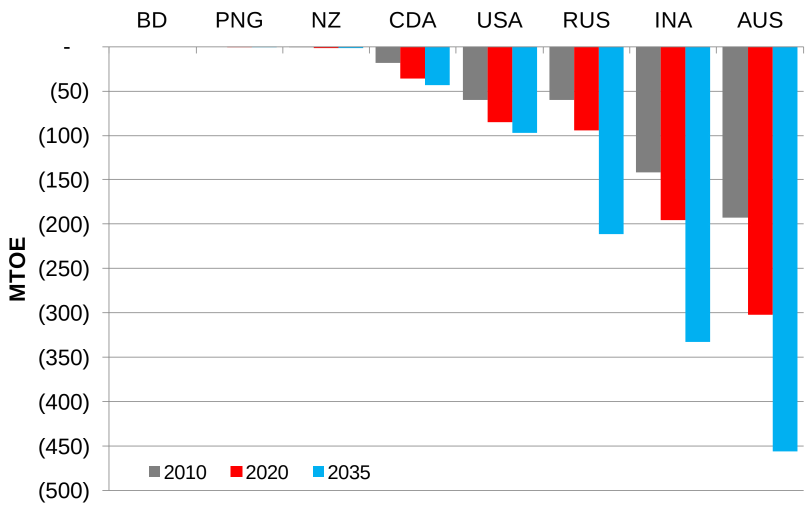
COAL IMPORTS AND EXPORTS

The APEC region is likely to be a net coal exporting region. Australia, Indonesia, Russia, United States and Canada will be able to supply 1046 Mtoe of coal to the international market in 2035. Papua New Guinea and New Zealand may start some minor export.

Figures 13.3 and 13.4 show that by 2035 there will be seven net coal exporting economies in APEC, and 13 more APEC economies that are net importers of coal. Brunei Darussalam is projected to have no production, consumption, imports, or exports of coal during the outlook period.

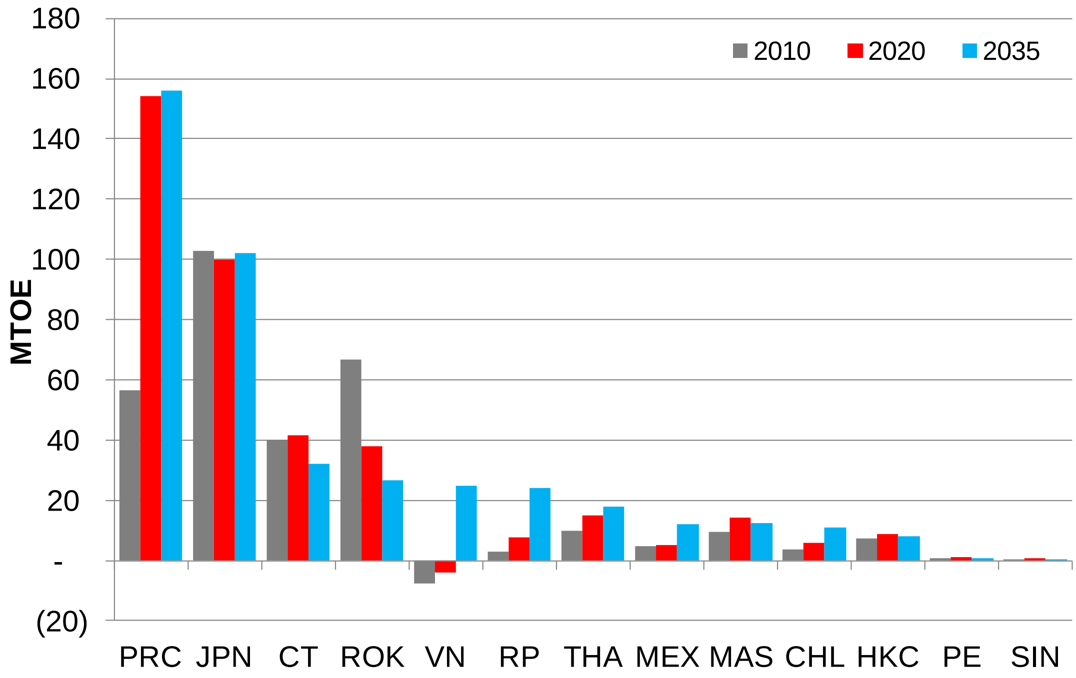
The largest coal importing economies are China, Japan, Chinese Taipei and Korea. Coal imports by Japan are projected to decline in the 2020–2035 period. China will be a large and growing net importer of coal, but imports will supply only about 5% of its demand in 2035. Viet Nam will become a net coal importer after 2020.

Figure 13.3: Projected Net Export (-) of Coal, APEC Coal Exporting Economies, in Mtoe



Source: APERC Analysis (2012)

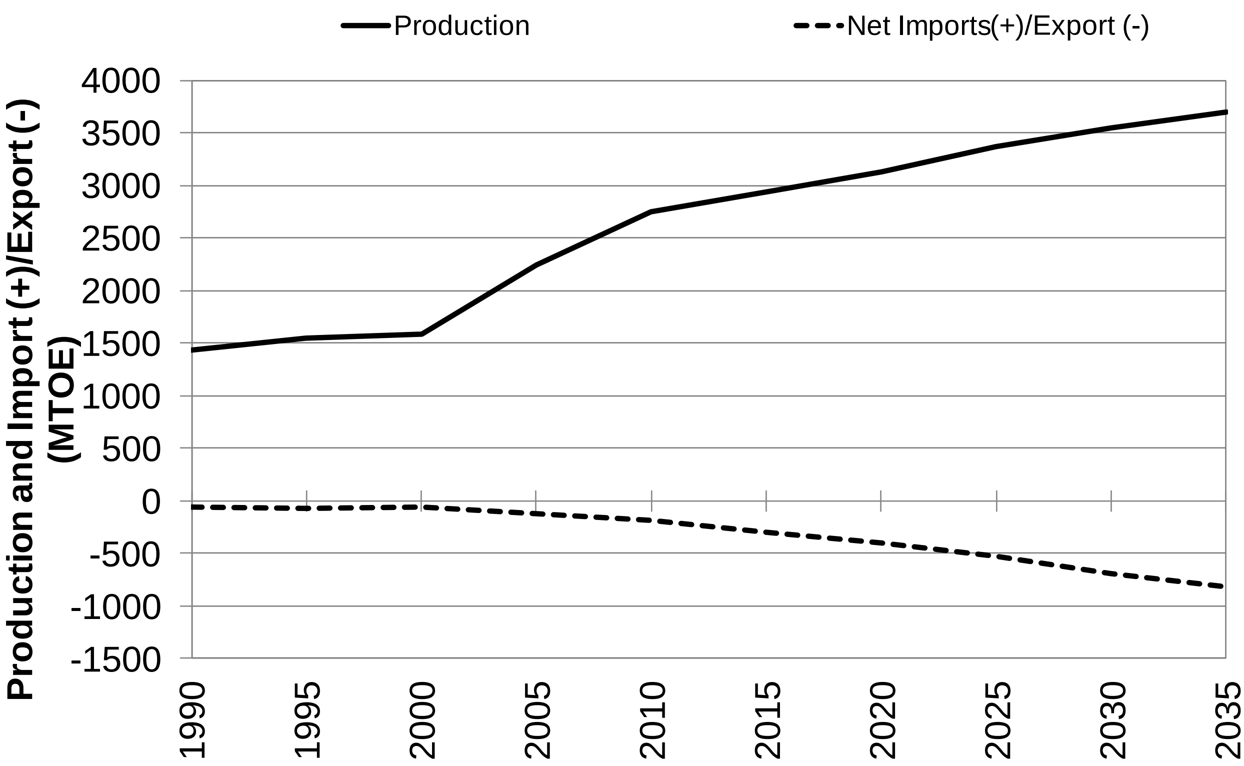
Figure 13.4: Projected Net Import of Coal, APEC Coal Importing Economies, in Mtoe



Source: APERC Analysis (2012)

As shown in Figure 13.5, net coal exports of the APEC economies are projected to increase from 122 Mtoe in 2009 to 715 Mtoe in 2035 under BAU assumptions. Note that negative net imports are exports.

Figure 13.5: Projected Production and Net Imports of Coal, all APEC Economies, in Mtoe

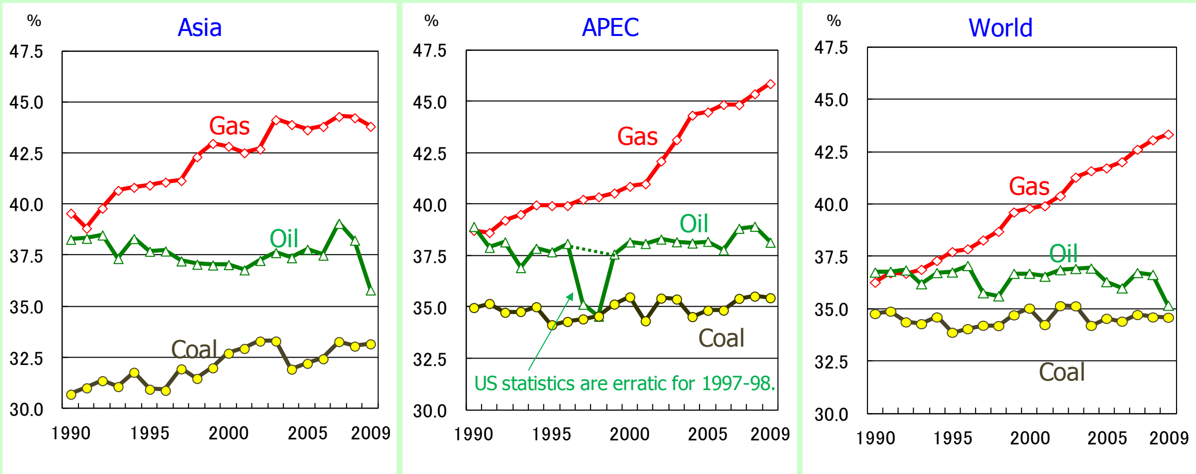


Source: APERC Analysis (2012)

IMPROVING THE EFFICIENCY OF COAL-FIRED ELECTRICITY GENERATION

In 2009, fossil fuels for electricity generation amounted to 38% of the world's total primary energy supply (TPES)—coal was dominant among them with a share of 47%. Thus, the efficiency of coal generation is a key for reducing greenhouse gas emissions. However, world coal generation efficiency has been hovering at around 35% for decades, while natural gas generation efficiency has improved remarkably as a result of combined cycle gas turbine (CCGT) technology. Due to the high cost of oil, oil generating plants are generally being phased out, with little new construction or replacement of plants being done.

Figure 13.6: Efficiency of Electricity Generation Technologies



Source: *World Energy Statistics* 2011 © OECD/IEA 2011

The lower efficiency of coal generation is because the energy density of coal is lower than that of oil and gas and, as coal is a solid, its combustion control is complicated. It is more so when low quality coals with high ash contents or high moisture contents are used.

At traditional coal generating plants, efficiencies may be assessed in three areas: coal combustion at the boiler, driving the steam turbines, and running supplementary systems (such as moving and pulverizing coal before burning, exhaust gas treatment to remove particulates, SOx and NOx, and ash disposal). Needless to say, coal preparation is an important process before combustion. Ramping rates and the optimum operation of the power plant are also important factors.

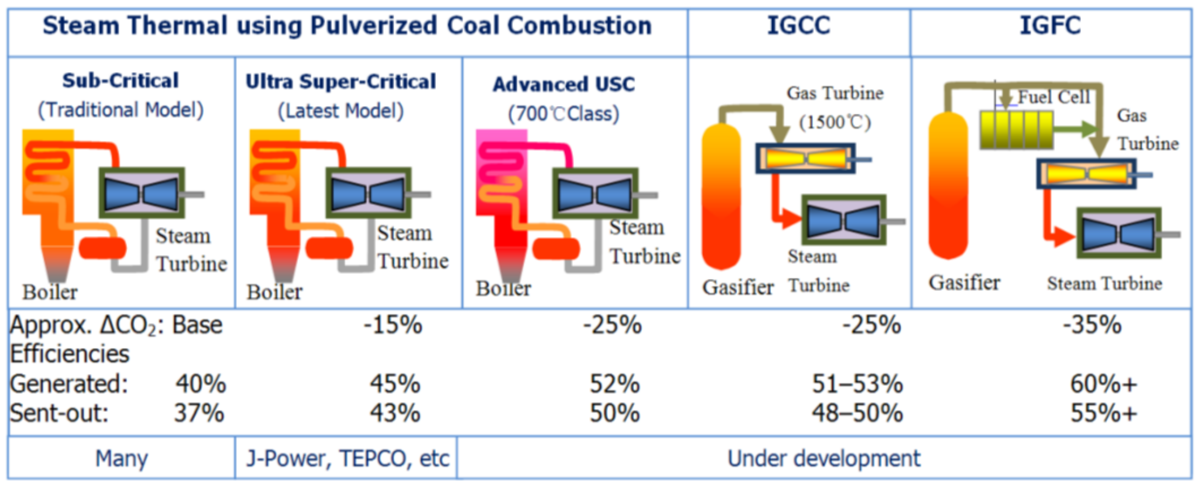
Regarding coal combustion, various technologies were tested in the 1960s and 1970s, and pulverized coal burning has become the standard technology. Recent efficiency improvements are mainly achieved through improvements in driving the steam turbines. In general, higher temperature and higher pressure steam drives turbines more efficiently. Turbine driving technology has evolved from the 'sub-critical' system to the 'super-critical' (SC) system. The latter uses steam above the critical temperature and pressure where distinct liquid and vapour phases cease to exist. The SC technology was adopted in Japan around 1980. It was further upgraded to the 'ultra-super critical' (USC) system in the late 1990s, with steam temperatures around 600 degrees C. The typical design efficiency (based on sent-out electricity and lower heating values of the coal) is:

- below 38–40% for sub-critical plants (250 MW class, typically at 16.6 megapascals (MPa), 566(main steam)/538(recovery steam) degrees C)
- 40–42% for super-critical plants (500-1000 MW class, typically at 24.1 MPa, 538/538 degrees C)
- 41–43% for ultra-super critical plants (600–1000 MW class, typically at 25 MPa, 600/610 degrees C).

The best USC plants in Japan have achieved 45% efficiency (25 MPa, 600/620 degrees C). Currently, a 700 degrees C, 35 MPa turbine system is under development as an 'advanced USC' (A-USC) aiming at a generating efficiency of 52% or a sent-out efficiency of 50% (J-Power, 2011).

Water becomes highly corrosive under super-critical conditions. The manufacture of USC systems requires high quality materials to cope with the high temperatures, pressures and corrosiveness. Sub-critical plants are still used in many economies as they are less expensive. Some may not even have exhaust gas treatment systems to remove particulates, SOx and NOx, resulting in heavily polluted air. Such situations need to be improved as soon as possible.

Figure 13.7: Improving Coal Thermal Plant Efficiencies



Sources: J-Power (2011), Energia (2010), METI (2009) and IEEJ (2012)

In addition to research and development on A-USCs, higher efficiency technologies are being developed to burn a synthetic gas produced from coal (coal gasification). This technology would bring the efficiency of natural gas CCGT generation to coal generation. Known as IGCC (integrated coal gasification combined cycle), such a hybrid system would burn the gas in a gas turbine then use recovered heat to produce steam to drive a steam turbine. An IGCC plant with a 1500 degree C gas turbine is expected to achieve 51–53% net energy efficiency. Although this is lower than the efficiency of natural gas CCGT generation (CCGT has already achieved 60% efficiency with 1600 degree C gas turbines at the #4 system of Tokyo Electric's Futtsu Power Station), IGCC will improve coal generation efficiency by almost 20% to 51–53%, from 43–45% for the best existing USCs. A further technological development would be an IGFC (integrated coal gasification fuel cell) system, using fuel cells on top of IGCC. IGFC aims at further efficiency improvements to above 60%. These technologies are now being intensely researched. They are expected to reduce greenhouse gas emissions substantially, especially when used in combination with carbon capture and storage.

In Japan, a verification test of IGCC with 1200 degree C gas turbines is being conducted on a commercial scale plant at the Nakoso Power Station by the Clean Coal Power R&D Co., Ltd. (a joint venture of Japanese power companies). At present, many developing economies are introducing SC and USC technology; the latter will dominate as the main technology for the near future. With the existing best USC systems, global coal thermal efficiency can be improved from 35% to 45%.

Although USC is an effective technology, its benefits would be limited where low-quality coal is the main fuel source, as the high moisture and ash contents prohibit efficient burning. Coal gasification can overcome this limitation by extracting pure gaseous fuel from the coal before burning. According to a recent study by the Institute of Energy Economics, Japan (IEEJ) on a renovation plan for a power plant in an Asian economy burning lignite, generation efficiency by the existing sub-critical system (16.1 MPa, 538/538) is 36.2% and that for a USC system (24.5 MPa, 600/600) will be 38.4%. Compared with this, an IGCC system (10 MPa, 550/550) is expected to achieve a 43.4% net generation efficiency (IEEJ, 2012). Thus, IGCC will bring significantly improving efficiencies to generating plants burning low quality coal, which are common all over the world.

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14 NUCLEAR SUPPLY

OUTLOOK FOR NUCLEAR ENERGY IN THE APEC REGION

Even after the serious accident at the Fukushima Daiichi Nuclear Power Plant in Japan in March 2011, considerable growth of nuclear energy utilization in the APEC region is projected over the outlook period. This growth reflects not only the economic and environmental advantages of nuclear energy, but also the focus on ensuring nuclear safety that has intensified since the accident. The economic advantages of nuclear energy include its low fuel cost and lower risk of fuel price fluctuations compared to fossil fuels. The environmental advantages include the technology's relatively low greenhouse gas emissions throughout its supply chain.

The main impediment to nuclear expansion is low public acceptance due to safety issues. The Fukushima accident has, of course, lead to increased concerns about safety. Since the accident was triggered by a huge natural disaster, the resilience of nuclear facilities in the face of natural disasters has gathered much attention. At the same time, there are concerns that similar serious accidents could be caused by malicious human attacks.

Therefore, an enormous effort will need to be made worldwide by the scientific, business and governmental communities to address these concerns and recover public confidence in the safety of nuclear power. In this regard, initiatives to develop advanced nuclear technologies, upgrade nuclear safety standards for construction and operation, and tighten nuclear security are being undertaken in many economies, and should be continued in the future.

The growth of nuclear energy utilization in the APEC region is expected to be predominantly centred in China, Russia, and Korea, whose policies promote large-scale development of nuclear power. Viet Nam also plans to add nuclear to its energy mix sometime after 2020. Other South–East Asian economies, like Thailand, continue preliminary studies and planning for construction of nuclear plants, but without a firm commitment to proceed as yet. On the other hand, the future of nuclear energy in Japan and Chinese Taipei, which have historically been major nuclear power users in the APEC region, is very uncertain at the time of writing.

On the other side of the Pacific Ocean, the United States currently has the largest nuclear capacity in the APEC region. However, the US nuclear fleet is aging. Before 2012, no construction of new reactors had been approved since 1978. Two new reactors in Georgia were given approval for construction in February 2012 and two more in South Carolina were approved in March 2012 (Wall Street Journal, 2012).

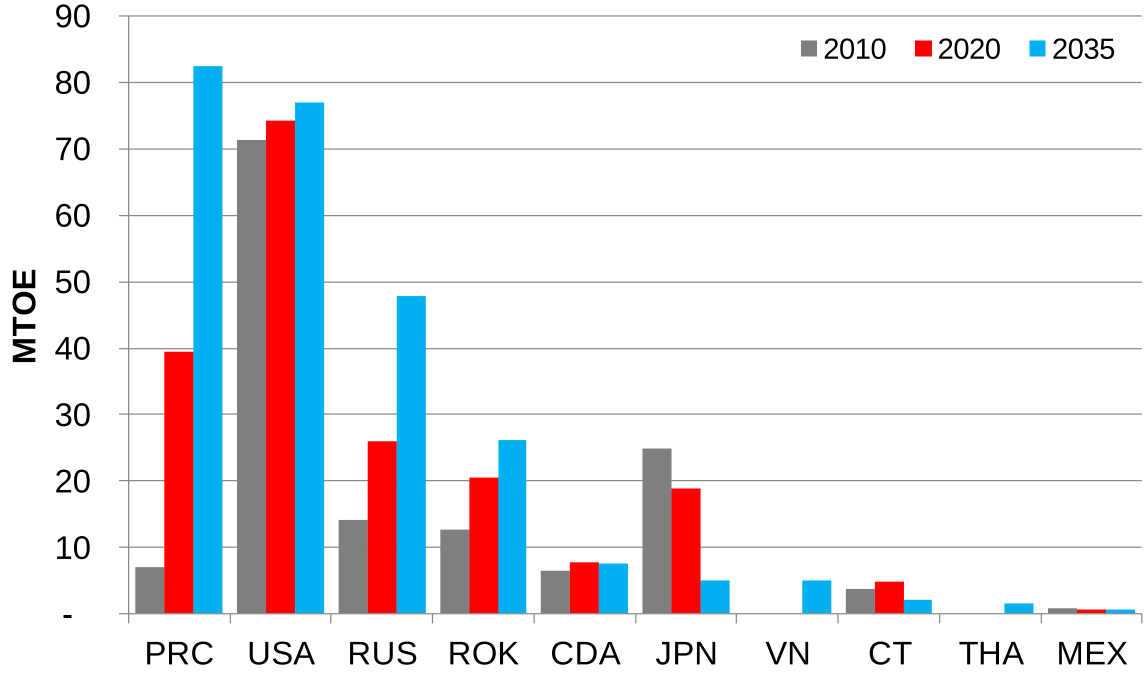
However, beyond these four reactors, plus one in Tennessee approved in the 1970s but only now being completed, further construction of new reactors in the US is likely to come slowly if at all (USEIA, 2012, pp. 50–51; Scientific American, 2012). Even before the Fukushima accident, high initial construction costs, regulatory uncertainties, safety concerns, the unresolved issue of waste disposal, and competition from low-cost natural gas were major obstacles to new US reactor construction. Nuclear energy in Canada and Mexico (which has only one commercial nuclear plant) faces similar obstacles.

Figure 14.1 shows projected electricity generation from nuclear energy by economy in Mtoe. By 2035, the amount of electricity generation by nuclear is expected to reach 292 Mtoe, compared to 141 Mtoe in 2009.

Overall, nuclear energy supply is projected to grow at a rate of 2.2% from 426 Mtoe in 2009 to 753 Mtoe in 2035. The share of nuclear energy in total primary energy is also projected to increase from 6% in 2009 to 7% in 2035.

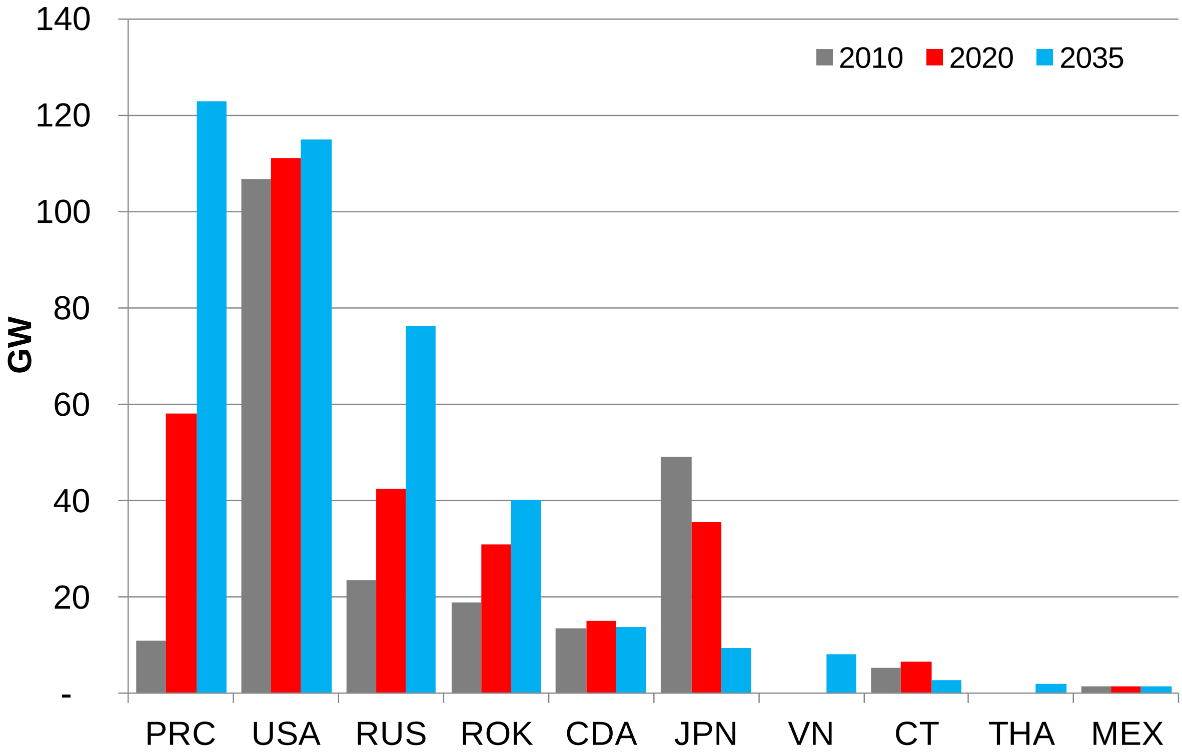
Figure 14.2 shows projected nuclear capacity by economy. In the APEC region, China is expected to be the clear leader in growth in nuclear power capacity, adding about 114 GW of capacity by 2035 to their 2009 capacity of about 9 GW. Russia will add 53 GW of new capacity, while Korea is expected to add about 21 GW of new capacity by 2035.

Figure 14.1: Projected Electricity Generation from Nuclear Energy



Source: APERC Analysis (2012)

Figure 14.2: Projected Nuclear Power Generation Capacity



Source: APERC Analysis (2012)

THE IMPACT OF THE FUKUSHIMA NUCLEAR ACCIDENT

When Japan revised its Strategic Energy Plan in 2010, aiming at doubling the rate of energy self-sufficiency (18% in 2010) and that of the zero-emission power sources (38% in 2010) by 2030, the key resource for achieving these targets was nuclear power. The share of nuclear generation in Japan's electricity generation mix was expected to be about 50% in 2030. That would require 14 or more nuclear power reactors.

However, the accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company (TEPCO), triggered by the Great East Japan Earthquake on 11 March 2011, has substantially changed not only the Strategic Energy Plan of Japan but also the outlook for nuclear development around the world.

The most dramatic impact was seen in Europe. In May 2011, Germany reconfirmed its earlier policy of phasing out nuclear energy by the early 2020s, beginning with the immediate shutdown of eight older plants, reversing a more recent policy of granting life extensions (BBC, 2011a). Switzerland dropped plans for new nuclear plants and decided to phase out its existing plants, although not until 2034 (New York Times, 2011). In Italy, which had abandoned nuclear energy in the 1980s, voter response to a referendum in June 2011 was 94% in favour of cancelling their government's plans for new reactors (BBC, 2011b).

Compared with Europe, the impact of the Fukushima accident in the APEC region has been more limited. Though all economies have reviewed their plans, and especially their safety regulations, no economy has so far decided to abandon nuclear energy. Except for two economies, the outlook for nuclear appears to be little changed.

The two exceptions are Japan and Chinese Taipei. In Japan, nuclear energy has become highly controversial, and there exists a great deal of uncertainty regarding its future. At the time of writing, only two of Japan's 50 remaining nuclear power units are in operation (four others at Fukushima Daiichi were decommissioned). The current nuclear situation in Japan is discussed in the Japan Economy Review in Volume 2. It will be up to the new Japanese government as elected in December 2012 to sort out Japan's nuclear policy going forward. In this Outlook, APERC has assumed nuclear generation will resume in Japan, but no new nuclear units will be built during the outlook period and existing units will be phased out at the end of their 40-year life.

In Chinese Taipei, the government has announced a policy of reducing dependence on nuclear generation, but has stopped short of a nuclear phase-out. Specifically, no life extension will be granted for the existing three nuclear power plants (six units), implying that the first unit will be decommissioned in 2018 and that all six existing units will be decommissioned by 2025. The one new plant currently under construction (two units) will, however, be completed and put into operation. See the Chinese Taipei Economy Review in Volume 2 for more discussion of the nuclear situation in that economy.

Recommendations of the Fukushima Nuclear Accident Independent Investigation Commission

As a basis for future nuclear policy, the National Diet of Japan established the Fukushima Nuclear Accident Independent Investigation Commission (NAIIC). The outcome of the NAIIC's investigation was seven recommendations. Although these recommendations were addressed to Japan, they provide important lessons for other economies involved in nuclear power development. In summary, the recommendations were (NAIIC, 2012):

1. **The National Diet should establish a permanent committee to supervise nuclear industry regulators** in order to secure the safety of the public.
2. **The crisis management system must be reformed**, including a consolidated chain of command and the power to deal with emergency situations. The boundaries dividing the responsibilities of national and local governments and operators must be made clear.
3. **The government must take responsibility for the public health and welfare consequences of the accident.** This includes continued monitoring of hotspots and spread of contamination, a detailed program of decontamination and relocation, and medical diagnosis and treatment of victims at state expense. Full information disclosure should be a priority.
4. **TEPCO should undergo a 'dramatic corporate reform',** including addressing issues of governance, risk management, and information disclosure with safety as the sole priority. The government should set rules and disclose information regarding its relationship with operators. Operators should set up a system of mutual peer review to maintain safety standards at the highest global level.

5. **A new regulatory body should be established which is independent, transparent, professional, consolidated, and proactive.**
6. **Laws related to nuclear energy should be reformed to meet global standards for safety, public health, and welfare.**
7. **Japan should establish a system of independent investigation commissions to deal with unresolved issues** including the reactor decommissioning process, spent fuel disposal, and post-accident decontamination.

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15 RENEWABLE ENERGY SUPPLY

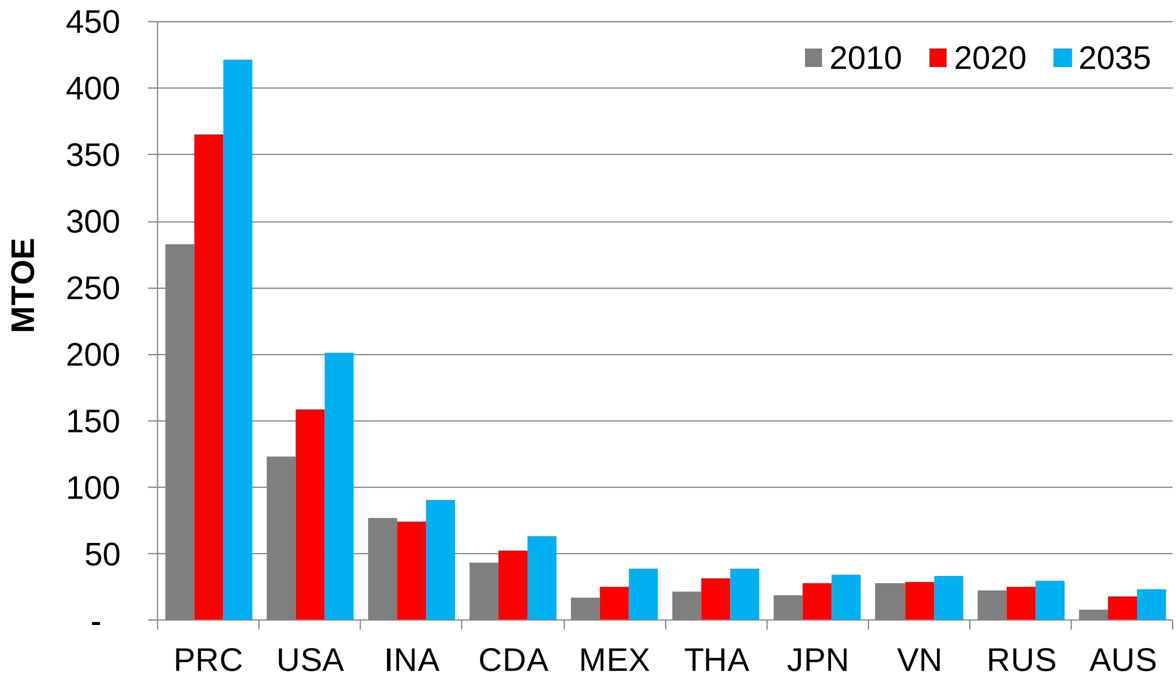
Renewable energy resources offer significant benefits for APEC economies. They are potentially secure, sustainable, and low in greenhouse gas (GHG) emissions. The quantity of resource potentially available is enormous.

Technological advancements have made it possible for APEC economies to harness more renewable energy resources, especially in the power generation sector. Spurred by these technological advances, coupled with existing supportive government policies, the contribution of renewable energy to the APEC region's energy supply is projected to grow over the outlook period under business-as-usual (BAU) assumptions—at an average annual rate of 1.8%, increasing from 684 Mtoe in 2010 to 1050 Mtoe by 2035.

China and the United States are expected to be the major contributors, making up over 50% of the total APEC primary renewable energy supply by 2035. At the same time, all APEC economies are expected to have some form of renewable energy contribution by 2035.

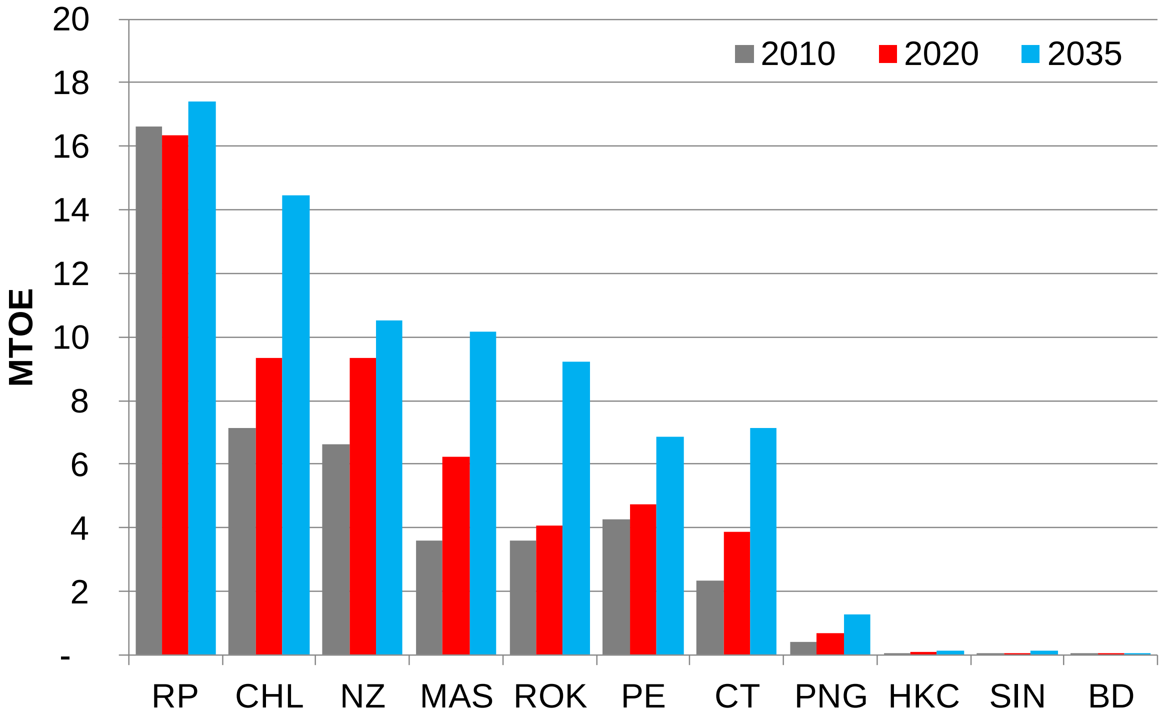
Figures 15.1 and 15.2 show the projected renewable energy supply for each APEC economy in the years 2010, 2020 and 2035. Note the difference in the scales of the vertical axis in the two figures.

Figure 15.1: Projected Renewable Energy Supply, Larger Supplying Economies



Source: APERC Analysis (2012)

Figure 15.2: Projected Renewable Energy Supply, Smaller Supplying Economies

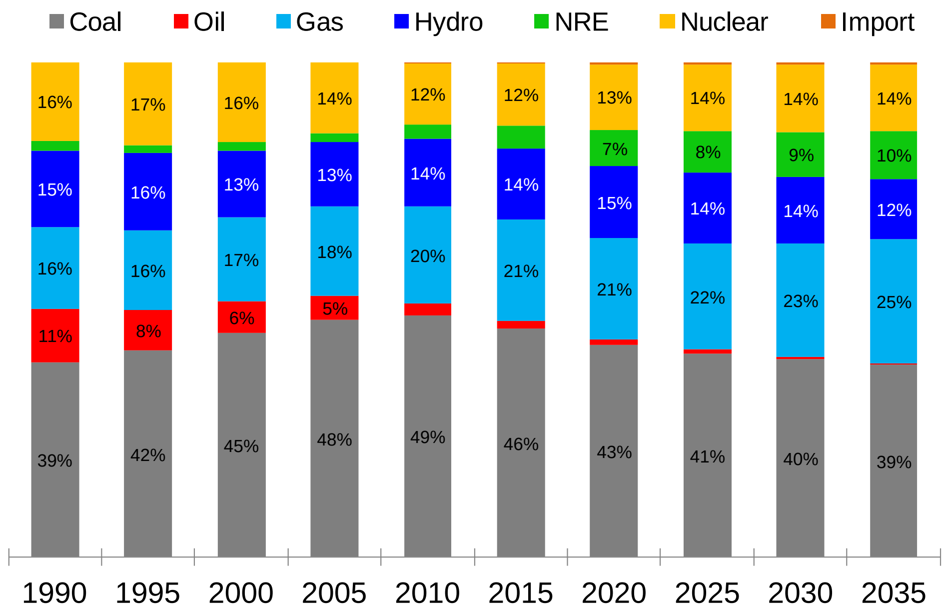


Source: APERC Analysis (2012)

RENEWABLE ENERGY IN THE ELECTRICITY GENERATION SECTOR

As APEC economies strive to minimize greenhouse gas emissions and air pollution, more renewable energy power generation capacity is being developed to counter the harmful effects of fossil fuel combustion. Figure 15.3 shows the renewable energy share (including hydro and new renewable energy) in the power generation mix will increase over the outlook period from 17% in 2010 to 22% by 2035. In APERC's terminology, new renewable energy (NRE) is understood to mean all renewable energy other than hydro.

Figure 15.3: APEC Region Electricity Generation Mix (1990–2035)



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The Role of Hydro in Electricity Generation

Use of renewable energy resources is not new in the APEC region. New Zealand, Canada and Peru used hydropower—mostly large-scale hydro—to generate more than half of their total electricity needs in 2010. Large-scale hydropower is a mature technology with generally favourable economic viability.

Further development options for large-scale hydro are limited in many APEC economies, as the best sites have already been developed. In addition, large-scale hydro has substantial social and environmental effects, such as dislocation of large numbers of people, loss of considerable amounts of productive land, and downstream impacts including diversion of water and trapping of silt. Hydro reservoirs may also emit methane, a potent greenhouse gas. However, the Intergovernmental Panel on Climate Change (IPCC) notes that for most hydro projects, lifecycle assessments have shown low overall net greenhouse gas emissions (IPCC, 2007, p. 274).

Total hydropower capacity in the APEC region is projected to increase from 532 GW in 2010 to 732 GW in 2035 under BAU assumptions. Accordingly, hydropower generation will increase at an annual average rate of 1.5% from 1840 TWh in 2010 to 2690 TWh in 2035. As shown in Figure 15.3, the share of hydro in the electricity generation mix will fluctuate between 12-15% over the outlook period. Since electricity production is growing faster than the primary energy supply growth, the share of the total primary energy supply coming from hydropower generation will increase from 2.1% in 2010 to 2.3% in 2035.

The Role of Non-Hydro Renewable Energy in Electricity Generation

NRE generation capacity is projected to grow rapidly in the APEC region over the outlook period, at an average annual rate of 7.3%. The growth in NRE capacity will be driven by existing supportive policies, as well as by rapidly declining costs. Wind energy is expected to be the technology with the greatest increase in capacity.

The long-term future of NRE, however, is likely to be based on solar energy. Solar is a rapidly advancing technology, which is easily scalable and distributable. Solar manufacturing costs, particularly for solar photovoltaic (PV) systems that directly convert sunlight into electricity, have declined rapidly as a result of advances in technology and from manufacturing economies of scale. Like computer chips, solar PV is a semiconductor technology that is amenable to the application of advanced science and engineering. It is expected that solar PV costs will continue to decline more quickly than those for mechanical and thermal technologies. Historically, solar PV has competed with concentrated solar power (CSP), which concentrates sunlight to produce heat. However, owing to its versatility in both small and large-scale applications, as well as its more rapidly declining costs, solar PV can be expected to lead the long-term growth in solar generation installations in the APEC region.

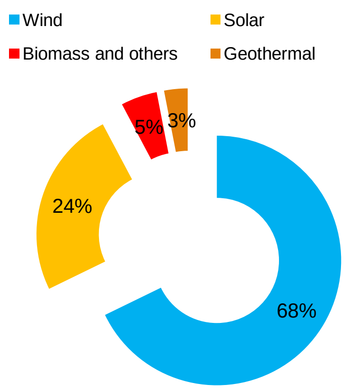
Module production costs for solar PV have declined sharply in recent years (IHS Consulting, 2012). Silicon module costs have declined from USD 4.50 per watt in the year 2000 to below USD 1.00 per watt in late 2011 (LBNL, 2011; IHS Consulting, 2012). Early estimates for module costs at the end of 2012 suggest they may be as low as USD 0.50 per watt. These cost estimates are for low-efficiency modules, but they serve as a good indication of the rapidly improving economics of PV solar. In the future, an increasing focus will be on reducing costs for the balance of the PV system other than the modules themselves, such as costs associated with installation and grid connection. Because of the decline in module costs, the balance of the PV system now typically accounts for two-thirds of total PV installation costs (LBNL, 2011).

Unsubsidized solar PV costs are expected to become competitive with the retail price of electricity in many regions as early as 2020—this is known as 'grid parity' (IEA, 2010). The economics of solar PV is especially attractive in places where electricity demand peaks on hot days when sunshine is likely to be most intense, which describes many APEC economies. Once the economics of solar are firmly established and cost competitive with conventional generation technology, growth in NRE should accelerate.

The NRE growth projections in this Outlook are founded on the plans of the individual APEC economies. It is likely that these projections do not consider the rapidly declining costs of NRE, particularly for solar PV. Therefore the NRE growth projections across APEC are conservative in nature.

From 2010 to 2035, it is projected that a total of 677 GW of NRE generation capacity will be installed in the APEC region under BAU assumptions. The likely breakdown (by energy source) of NRE generation capacity added from 2010 to 2035 is shown in Figure 15.4. It is expected that wind will dominate, followed by solar, biomass and others, and geothermal. In APERC terminology, 'biomass and others' means combustible renewable sources, which comprise solid biomass, liquid biomass, biogas, industrial waste and municipal waste.

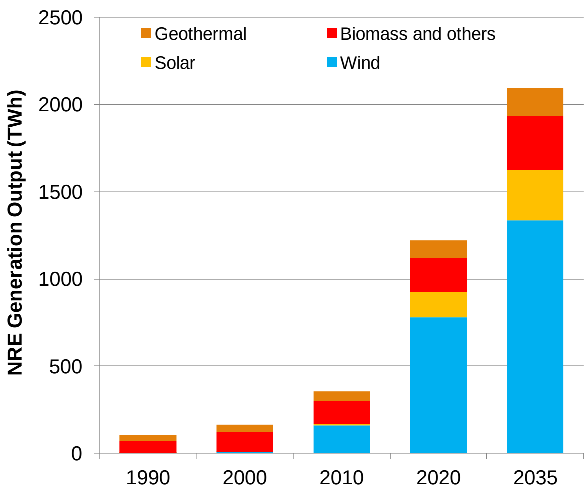
Figure 15.4: NRE Capacity Additions in APEC by Energy Source (Total for 2010–2035)



Source: APERC Analysis (2012)

Electricity generation output from NRE sources will increase dramatically from 355 TWh in 2010 to 2095 TWh in 2035. Figure 15.5 shows the growth in NRE electricity generation output by energy source. As with capacity additions, wind dominates, contributing 64% of the NRE generation mix. 'Biomass and others' is the second largest contributor at 15%, followed by solar (14%) and geothermal (8%).

Figure 15.5: NRE Electricity Generation in APEC by Energy Source (1990–2035)

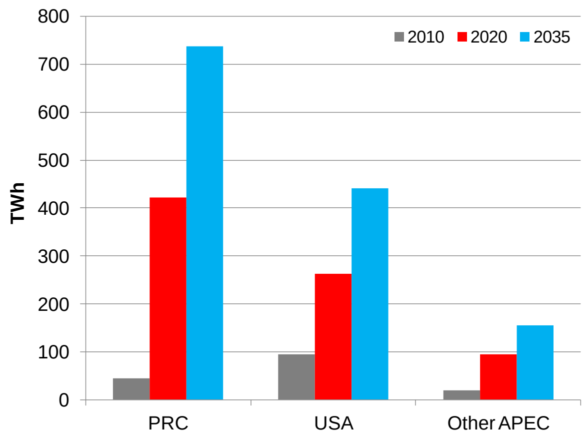


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Wind Power Generation

Figure 15.6 shows the breakdown of wind generation by economy. By 2035, China leads in the output of electricity generated from wind energy, reaching around 738 TWh. This is followed by the US on about 440 TWh. Together China and the US account for around 88% of wind-based generation output across the APEC region.

Figure 15.6: Wind-based Generation Growth, Top Two and Other APEC Economies (2005–2035)



Source: APERC Analysis (2012)

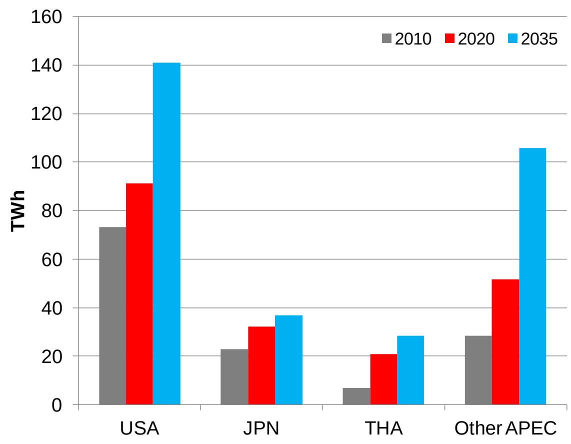
Biomass Power Generation

Biomass feedstock fuels used for electricity generation include forest wood and residuals, industrial waste, municipal waste and landfill gases. The most scalable biomass fuel source is from forests, where much of the projected growth in biomass generation in the APEC region will be sourced. Biomass has an increasing role as a feedstock for direct use in electricity production but also as a feedstock that is blended with coal to reduce GHG emissions.

Biomass is also expected to play an increasing role in improving energy security, as well as reducing emissions throughout APEC economies. The APEC-wide average annual growth rate in biomass generation is 3.5% over the outlook period.

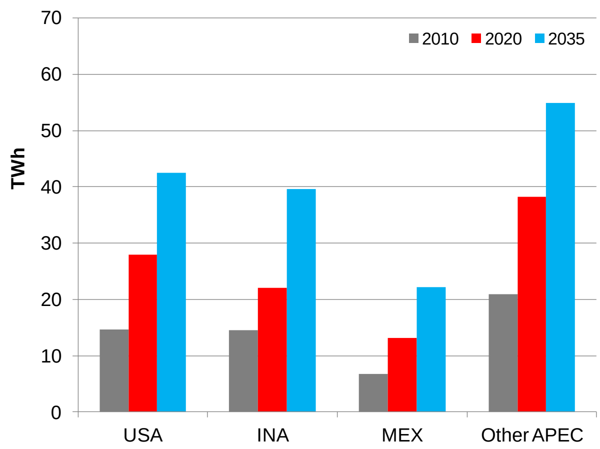
For the US, biomass use is vital to meeting many of the State Renewable Portfolio Standards for emission reductions (US EPA, 2012). Over the outlook period, the US will see rapid growth in biomass-based generation, with an average annual growth of 2.7%.

Figure 15.7: Biomass-based Generation Growth, Top Three and Other APEC Economies (2005–2035)



Source: APERC Analysis (2012)

Figure 15.8: Geothermal-based Generation Growth, Top Three and Other APEC Economies (2005–2035)



Source: APERC Analysis (2012)

Geothermal Power Generation

In some APEC economies, geothermal is one of the most economically attractive NRE sources. A major advantage of geothermal energy is that it can provide dependable base-load power generation. However, the potential for geothermal development in APEC is limited by its resource potential. Only around half of all APEC economies will have a geothermal capacity exceeding 300 MW by 2035 under BAU assumptions.

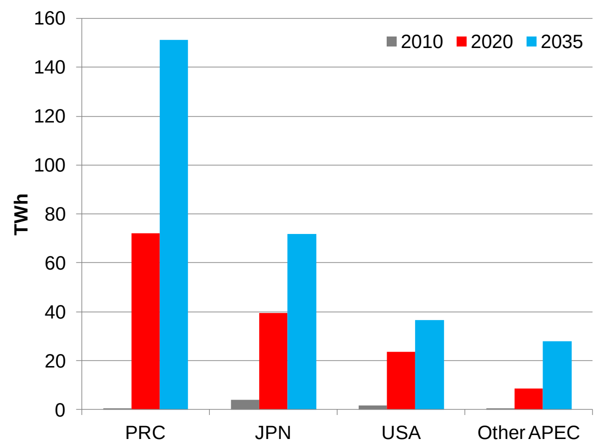
In the APEC region geothermal power generation is expected to grow at around 4.2% per year over the outlook period. The United States will lead the growth in geothermal-based generation, reaching 43 TWh in 2035, followed by Indonesia and Mexico. Australia, Chile and Japan are also likely to see modest growth in geothermal power generation.

Owing to its small electricity demand and attractive geothermal resources, the share of geothermal generation in New Zealand will reach 19% of its total generation in 2035—the highest in the APEC region.

Solar Power Generation

As discussed earlier, solar technology is advancing rapidly. From a base of near zero in 2010, solar-based electricity output (lead by China, Japan and the US) will reach over 288 TWh in 2035. This is an average annual growth rate of 16%.

Figure 15.9: Solar-based Generation Growth, Top Three and Other APEC Economies (2005–2035)

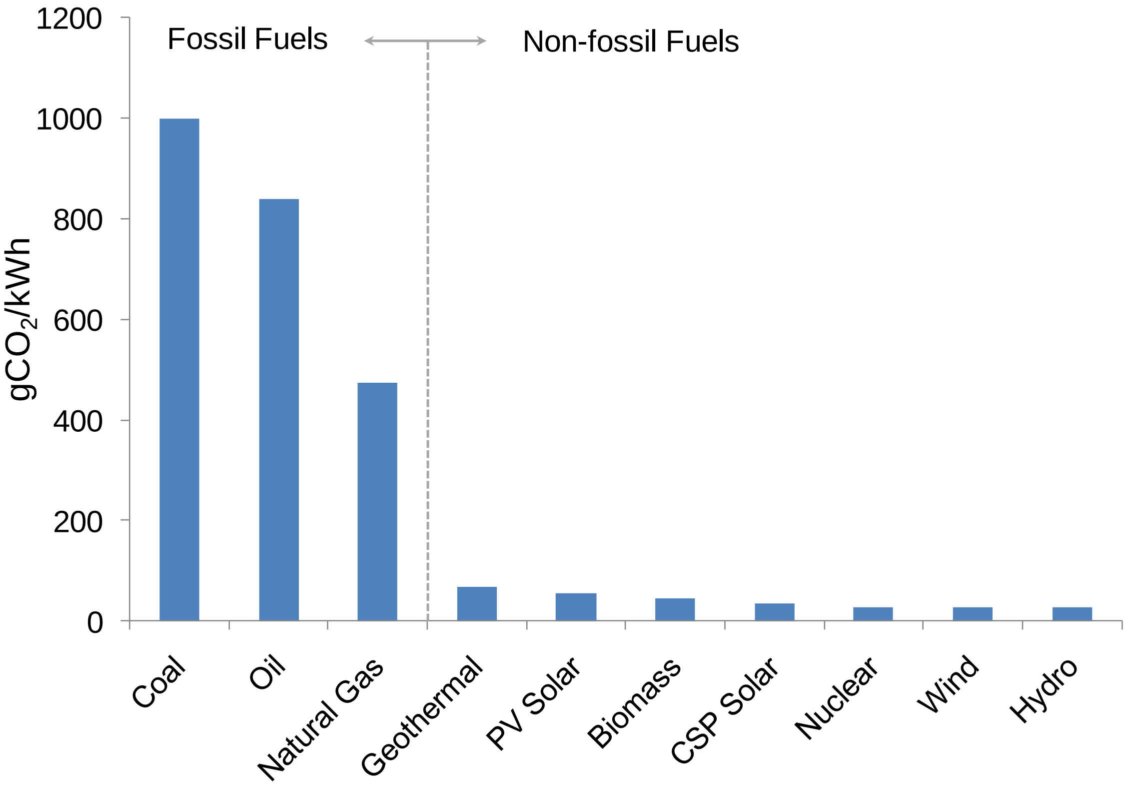


Source: APERC Analysis (2012)

Lifecycle Emissions of Renewable and Non-Fossil Electricity Generation

While the energy security benefits of electricity generation from renewable and non-fossil energy sources are readily apparent, there are often misunderstandings as to whether it offers significant reductions in greenhouse gas emissions on a lifecycle basis. Obviously, renewable and non-fossil generation, as the names suggest, use non-fossil energy sources. However, since the technology to extract this energy often involves an extensive upfront investment in manufacturing and construction, net emissions benefits must consider all stages of development and all production inputs. The World Nuclear Association (WNA) and Intergovernmental Panel on Climate Change (IPCC) have each summarized the findings from a comprehensive number of different research analyses. Based on these two sources, the median lifecycle emissions for each generation technology were estimated and are shown in Figure 15.10.

Figure 15.10: Median Lifecycle Emissions Estimates, by Electricity Generation Technology



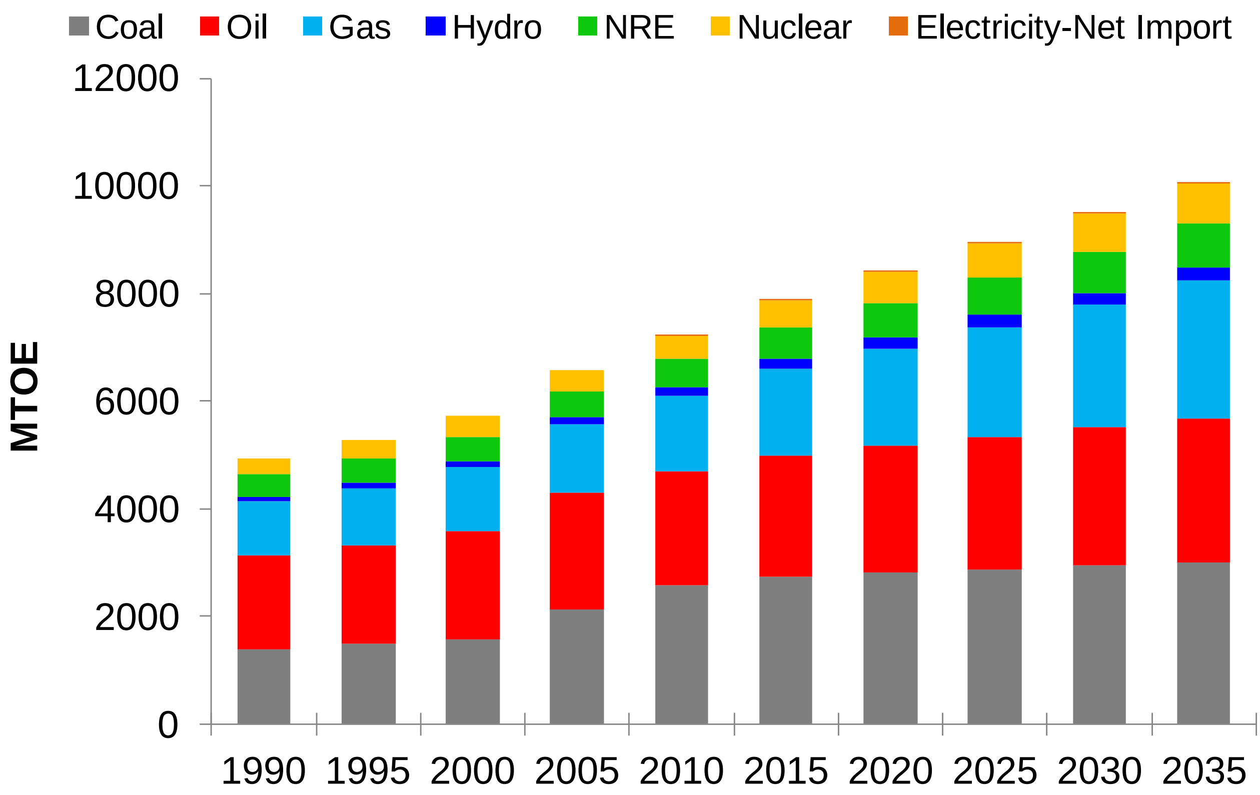
Sources: Adapted from WNA (2011) and IPCC (2011, p. 732)

Figure 15.10 illustrates the clear divide in lifecycle CO_2 emissions between fossil and non-fossil generation. Among fossil fuels, natural gas generation has the lowest lifecycle emissions, while geothermal and PV solar have the highest lifecycle emissions of the non-fossil fuels. (In earlier years, PV lifecycle emissions were noticeably higher than shown in Figure 15.10. However, advances in manufacturing and technology have now reduced PV solar lifecycle emissions estimates to levels comparable with other renewable energy technologies.) Overall, CO_2 emissions on a lifecycle basis for both geothermal and PV solar are less than natural gas by more than a factor of 6.

DIRECT USE OF NRE

The NRE share of the total APEC primary energy supply was 7.3% (530 Mtoe) in 2010. Of this, about 80% was used directly, rather than converted to electricity. In 2035, the NRE share is projected to have increased to 8.1% (818 Mtoe), of which about 41% is expected to be used directly. NRE resources are currently dominated by biomass, and this is expected to remain the case in 2035.

Figure 15.11: APEC Region Total Primary Energy Supply Mix (1990–2035)



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

NRE Use in the Residential Sector

NRE utilization in the APEC region varies depending on the resources and technology available. Biomass resources such as wood, animal dung and agricultural residues have been used for many centuries for residential cooking, space heating and lighting. These fuels are still widely used by the poor in some less developed areas of the APEC region, where commercial fuels are too expensive or unavailable. The use of residential biomass may have negative impacts, especially in terms of severe indoor air pollution, which causes diseases and respiratory problems. Gathering of biomass may reduce the fertility of the land. In addition, residential biomass use may also lock people, especially women and children, into poverty, since time spent gathering fuel means reduced time for education and income-generating activities (APERC, 2009, p. 45).

In the APEC region, rising incomes, improved availability of commercial fuels and urbanization will likely work against the use of residential biomass. However, there are many uncertainties about residential biomass, starting with a lack of basic data: since most residential biomass is never traded commercially, it is not possible to survey producers or marketers.

It is likely that residential biomass will continue to be popular in the APEC region throughout the outlook period, given its affordability and availability, and the cultural preferences for wood fires and wood cooking. This need not be a cause for concern, as modern technology allows biomass to be produced in an environmentally sustainable fashion and to be burned cleanly and efficiently. It is important that government policies ensure that this modern technology gets applied, and that those who use residential biomass do so by choice, and not by poverty-driven necessity.

NRE Use in the Commercial and Industrial Sectors

More sophisticated methods are also being developed to extract energy cleanly and more efficiently from solar and geothermal resources, as well as from biomass, for non-power applications in the commercial and industrial sectors. These include:

- *Biomass energy.* The pulp and paper, forest products, food, and chemical industries are examples of industries that utilize biomass energy directly in their industrial processes by burning their own waste products. Biomass feedstock can now be transformed into more convenient solid, liquid or gaseous forms to generate heat for industrial processes and combined heat and power (CHP) systems (IPCC, 2011, p. 217).
- *Solar energy.* New buildings are being designed to effectively manipulate solar energy for heating, cooling and natural lighting. This method is called 'passive solar technology', whereas 'active solar technology' uses collectors with chemical, mechanical or electrical elements to collect, circulate and store heat from solar energy more effectively. A popular use for solar energy in Asian countries is the domestic solar water heater, which is a cost-effective system to generate hot water for bathing and washing.
- *Geothermal energy.* Direct applications of geothermal energy include space heating, bathing and balneology (therapeutic use of baths), horticulture (greenhouses and soil heating), industrial process heat and agricultural drying, aquaculture (fish farming) and snow melting (IPCC, 2011, p. 416).

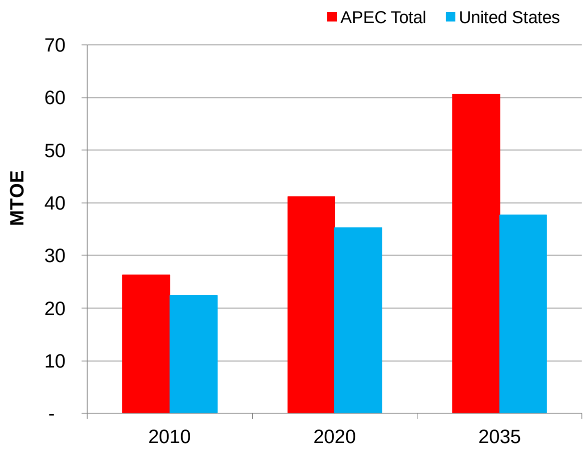
NRE Use in the Transport Sector

Biomass feedstock can be converted into liquid biofuels such as ethanol and biodiesel for use in road transportation. Ethanol today is made primarily from corn and sugar cane, while biodiesel can be produced from virgin plant oils, waste vegetable oil, animal fats, fish oil and algae (REN21, 2011, p. 31). These are categorized as first-generation biofuels.

While first-generation biofuels provide net energy benefits, when all associated emissions are accounted for, biofuels may produce more greenhouse gas emissions than they avoid. There are also added negative externalities in the form of rising food costs and damage to local ecosystems (APERC, 2009, p. 78).

Second-generation technology is expected to solve some of the problems of today's commercial biofuels. 'Cellulosic' biofuel can be made from almost any plant, as well as from forestry and agricultural residues and from city waste. It has even been reported that this advanced biofuel could help cut transport emissions by 80% (Renewable Energy World, 2011). However, due to the significant production and technological challenges, as of 2012 there is still no large-scale commercial production of second-generation biofuels. Many organizations are working, some with government support, to commercialize various pathways for producing cellulosic biofuels. Until these second-generation technologies are deployed, the increased energy security offered by biofuels comes at a high cost.

Figure 15.12: Biofuel Use in Transport Sector in APEC Economies



Source: APERC Analysis (2012)

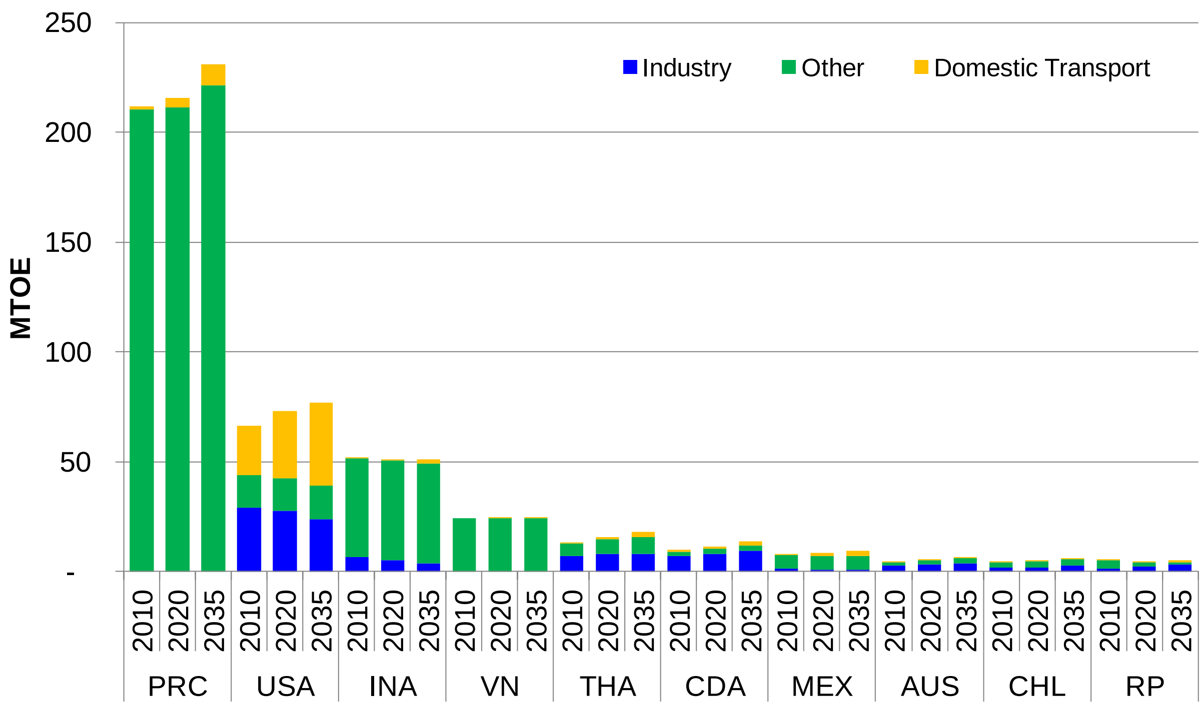
From Figure 15.12, it can be seen that the United States is the leading biofuel consumer in the APEC region, consuming up to 85% of the total 26 Mtoe biofuel demand in 2010. As other economies begin to adopt the technology, the United States share is expected to decline, reaching about 62% by 2035, with China taking up 15.5%, Thailand 4.5%, and Mexico 3.8%.

Projections for Direct Use of NRE in the APEC Region by Economy

Projections of direct use of NRE in APEC economies by sector are shown in Figures 15.13 and 15.14. As noted earlier, data on direct use of renewable energy is limited, so available data may not represent a complete picture of NRE utilization.

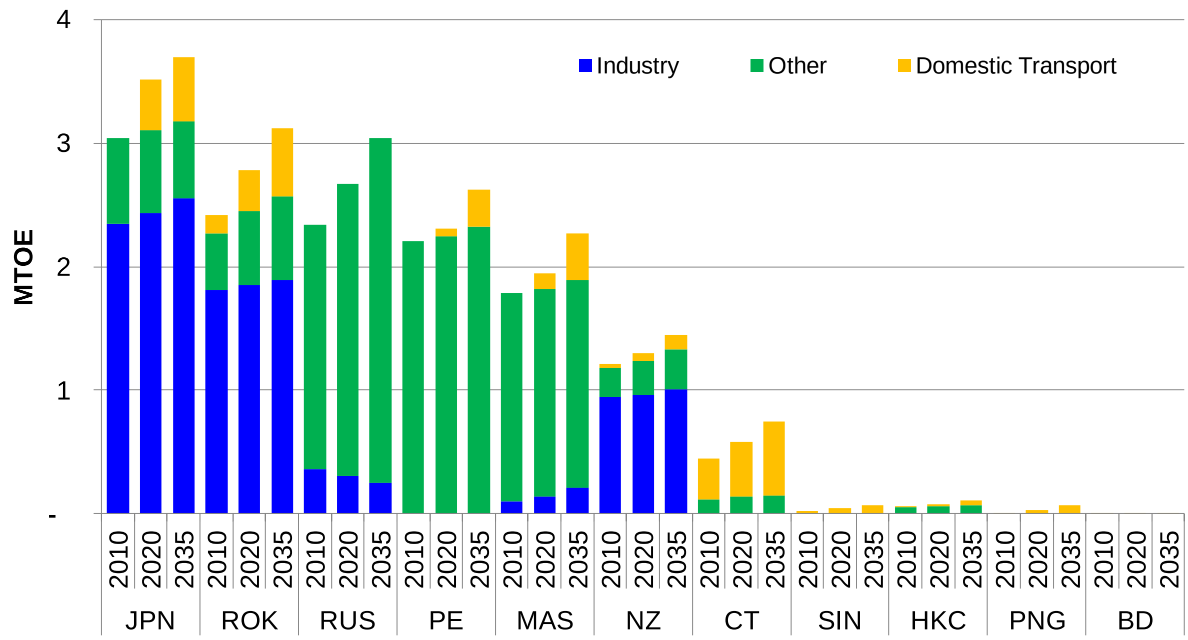
Overall, direct use of NRE will show an increase across all economies. Developing economies like China and Indonesia tend to use more NRE sources in the 'other' sector, while developed economies like United States, Japan and Korea use more NRE in industry. NRE use in the 'other' sector in developing economies would mostly be for residential biomass—with better access to commercial energy, biomass use in the residential sector would decline. However, this reducing trend in residential biomass use would likely be offset by the growth of modern NRE direct use technologies in the industry and transport sectors. By 2035, China will account for about half of NRE direct use in the APEC region, followed by South-East Asian economies (24%) and North American economies (19%).

Figure 15.13: Direct Use of NRE by Sector, Larger Supplying Economies



Source: APERC Analysis (2012)

Figure 15.14: Direct Use of NRE by Sector, Smaller Supplying Economies



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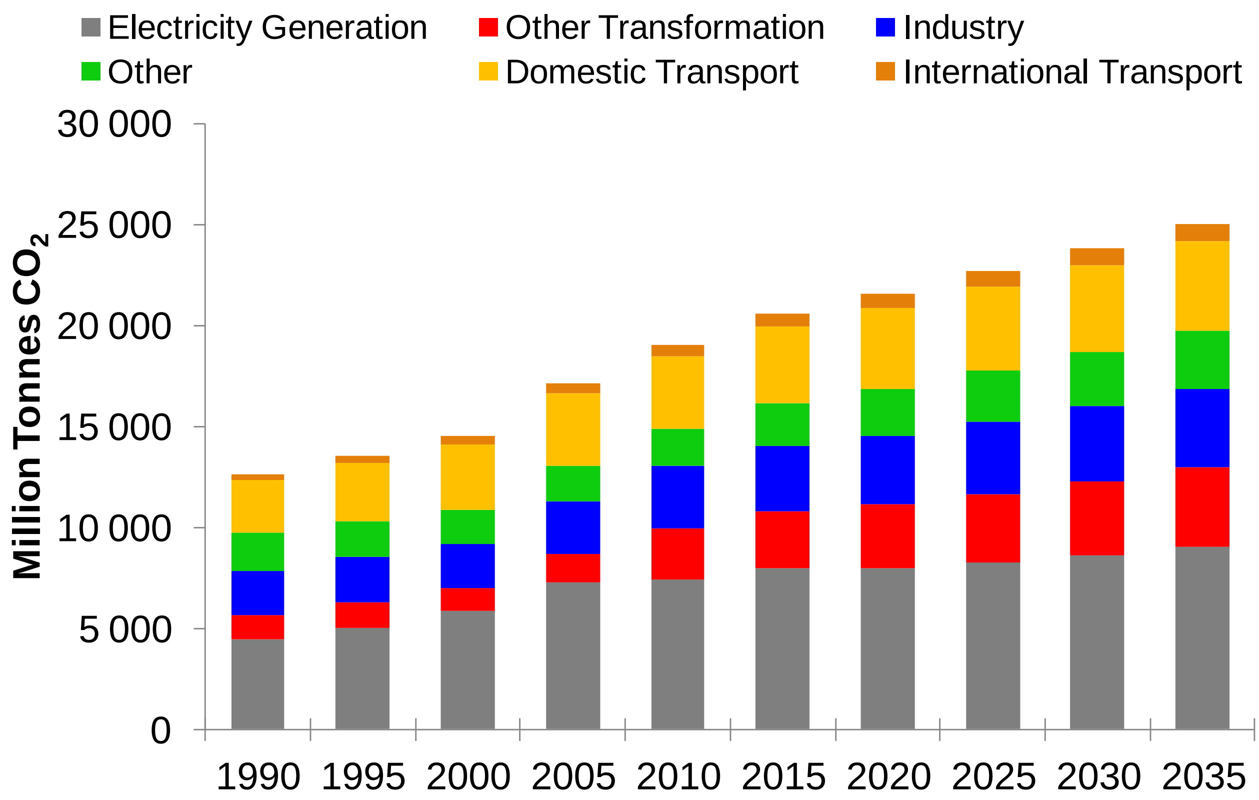
16 CARBON DIOXIDE EMISSIONS

The APEC region's CO_2 emissions from fuel combustion are projected to rise by about 32% between 2010 and 2035 (see Figure 16.1). These emissions pose a threat to humanity, to the environment, and to the economies of the APEC region and the world. This chapter discusses the details of these emission projections and their implications for policymakers.

APERC has modelled only the emissions of carbon dioxide (CO_2) from fuel combustion. As noted in Chapter 1, in 2009 CO_2 emissions from fuel combustion accounted for 89% of energy-related greenhouse gas emissions worldwide on a CO_2-equivalent basis, and these energy-related emissions in turn accounted for about two-thirds of total greenhouse gas emissions on a CO_2-equivalent basis (IEA, 2011, p. III.45). Non-CO_2 energy emissions are difficult to model because they depend not just on the quantity of fuel burned, but also on details of the conditions under which the fuel was burned or escaped into the environment (IPCC, 2006).

Figure 16.1: APEC Projected Business-as-usual CO_2 Emissions from Fuel Combustion

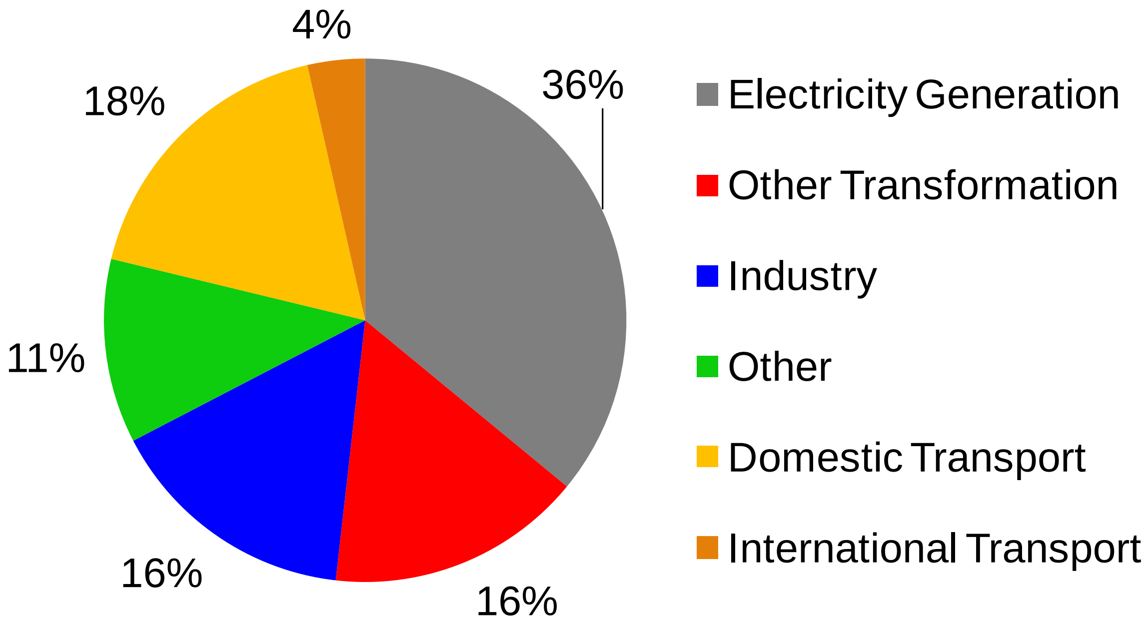


Source: APERC Analysis (2012)

CO_2 EMISSION RESULTS

CO_2 emissions from APEC economies are projected to increase under our business-as-usual (BAU) assumptions from 19.0 billion tonnes in 2010 to 25.1 billion tonnes in 2035. Electricity generation alone (Figure 16.2) will account for 9.0 billion tonnes, or about 36% of these emissions in 2035. Domestic transport at 4.4 billion tonnes or about 18% is in second place. 'Other Transformation' (which includes refineries and other energy sector own use, heat generation, and hydrogen generation) at just under 4.0 billion tonnes or 16% is almost tied for third place with Industry at a bit more than 3.9 billion tonnes (16%).

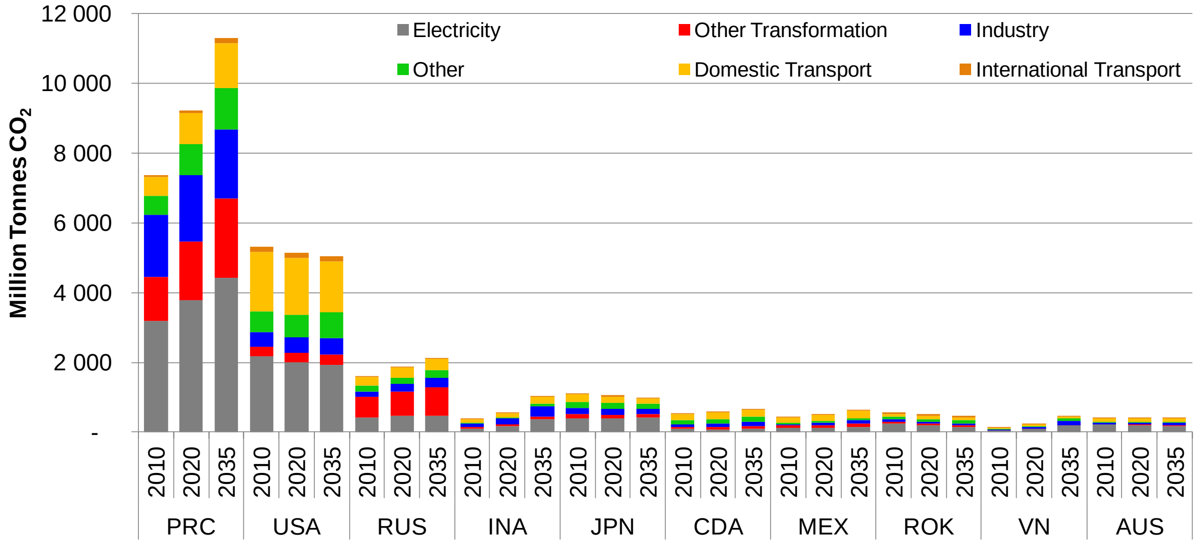
Figure 16.2: APEC Projected Shares of CO_2 Emissions from Fuel Combustion by Sector in 2035



Source: APERC Analysis (2012)

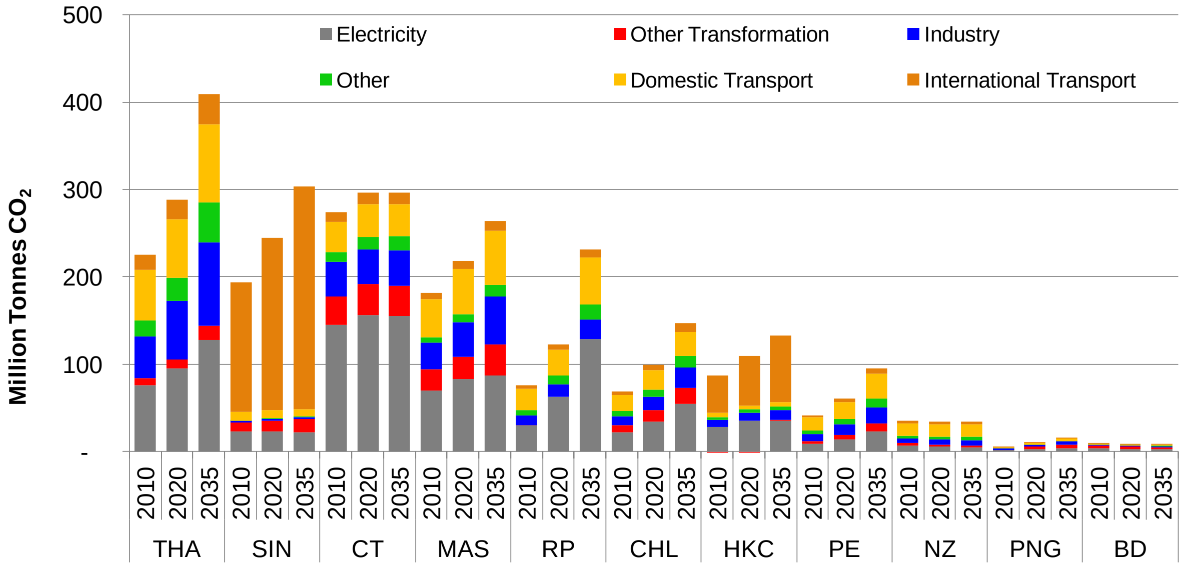
As shown in Figure 16.3 and Figure 16.4 (note the difference in scales between the figures), the importance of each sector in contributing to emissions varies considerably by economy. However, in 13 of the 21 APEC economies, electricity will be the leading source of CO_2 emissions in 2035.

Figure 16.3: CO_2 Emissions from Fuel Combustion by Sector, Higher Emitting Economies



Source: APERC Analysis (2012)

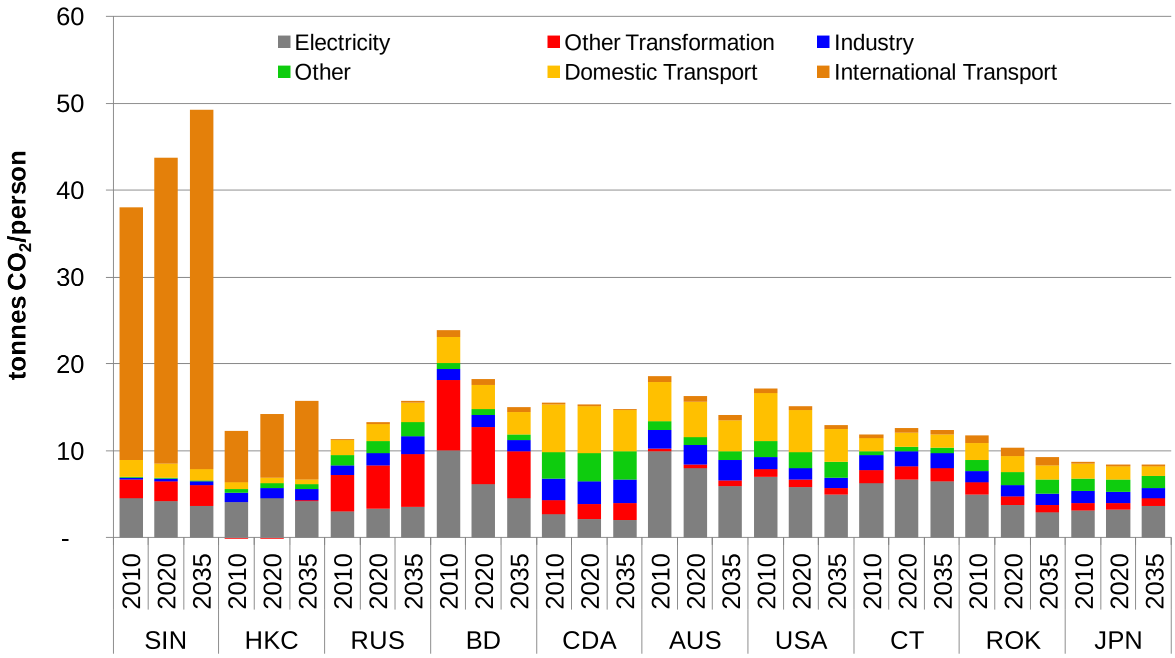
Figure 16.4: CO_2 Emissions from Fuel Combustion by Sector, Lower Emitting Economies



Source: APERC Analysis (2012)

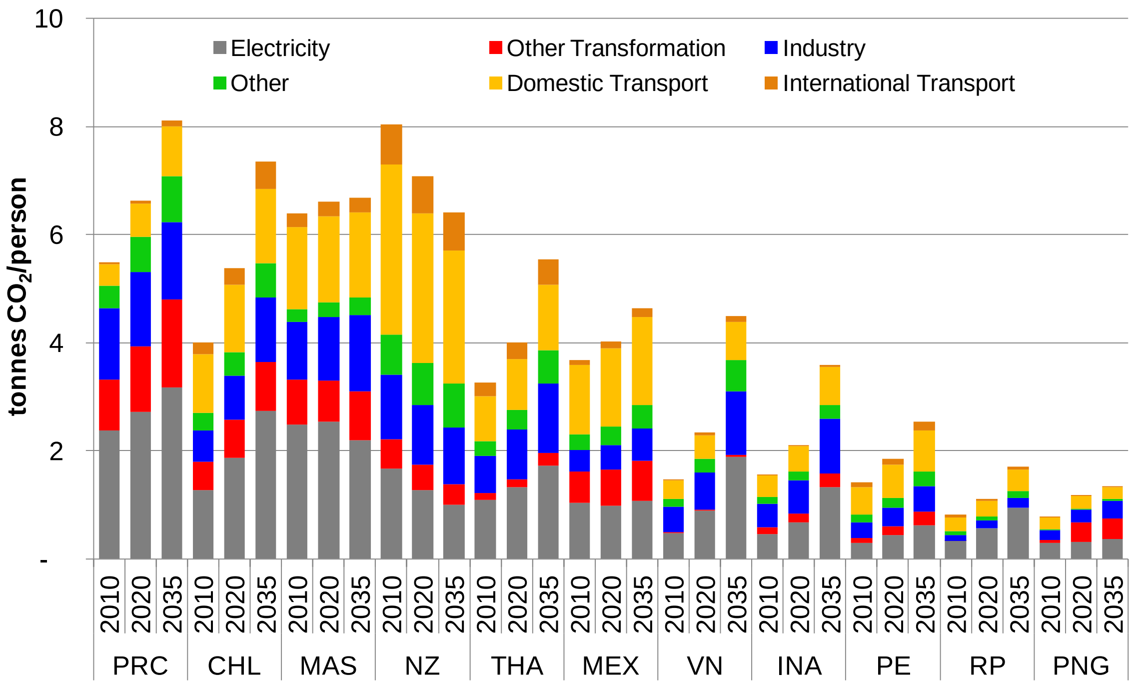
Considering emissions on a per capita basis paints a somewhat different picture of who is responsible for these emissions. As shown in Figure 16.5 and Figure 16.6, it is the APEC's more developed economies that have the highest per capita emissions, although emissions per capita in the developing economies are also rising rapidly. Singapore and Hong Kong have high emissions from international transport due to their role as major shipping and air transport hubs.

Figure 16.5: CO_2 Emissions per Capita from Fuel Combustion by Sector, Higher Per Capita Emission Economies



Source: APERC Analysis (2012)

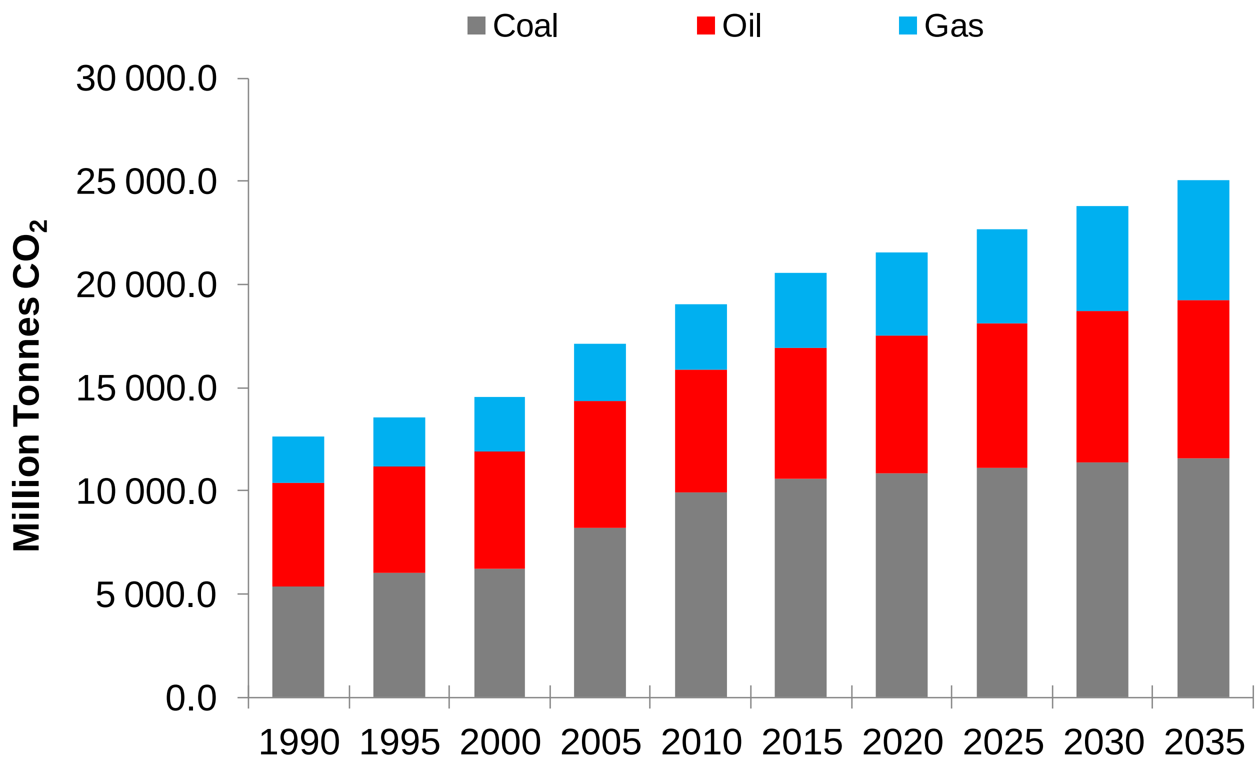
Figure 16.6: CO_2 Emissions per Capita from Fuel Combustion by Sector, Lower Per Capita Emission Economies



Source: APERC Analysis (2012)

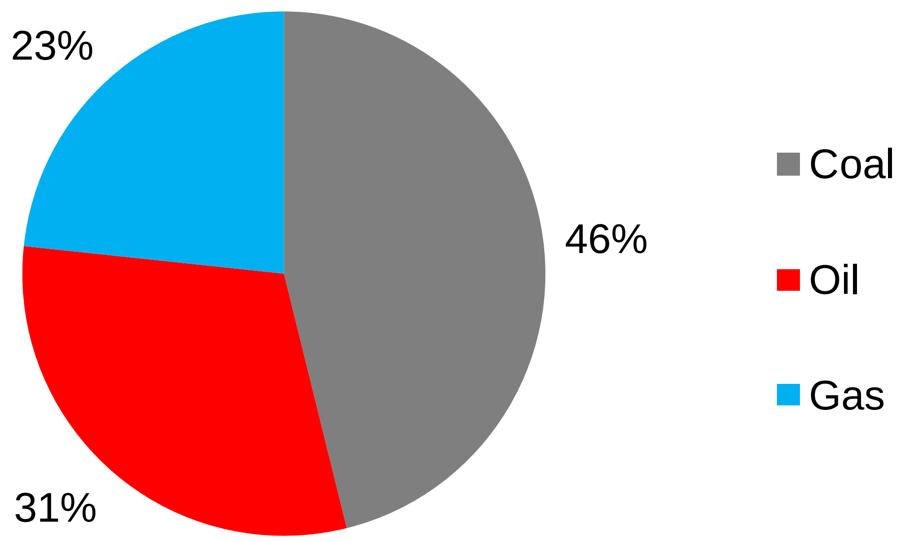
Among the fossil fuels, coal is projected to provide the largest contribution to APEC's primary energy supply by 2035. As it is also the most carbon intensive of the fossil fuels, coal not surprisingly contributes the most to CO_2 emissions. Coal contributes 46% of greenhouse gas emissions in 2035, whereas oil and gas contribute 31% and 23%, respectively (Figures 16.7 and 16.8).

Figure 16.7: APEC Projected BAU CO_2 Emissions from Fuel Combustion, by Fuel



Source: APERC Analysis (2012)

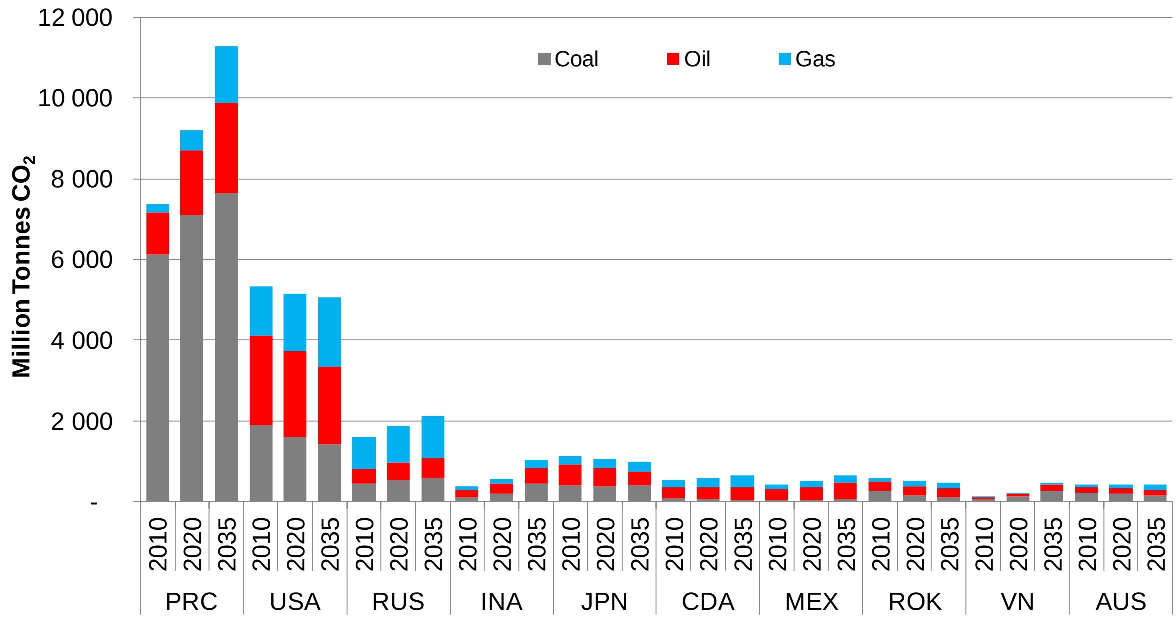
Figure 16.8: APEC Projected Shares of CO_2 Emissions from Fuel Combustion by Fuel in 2035



Source: APERC Analysis (2012)

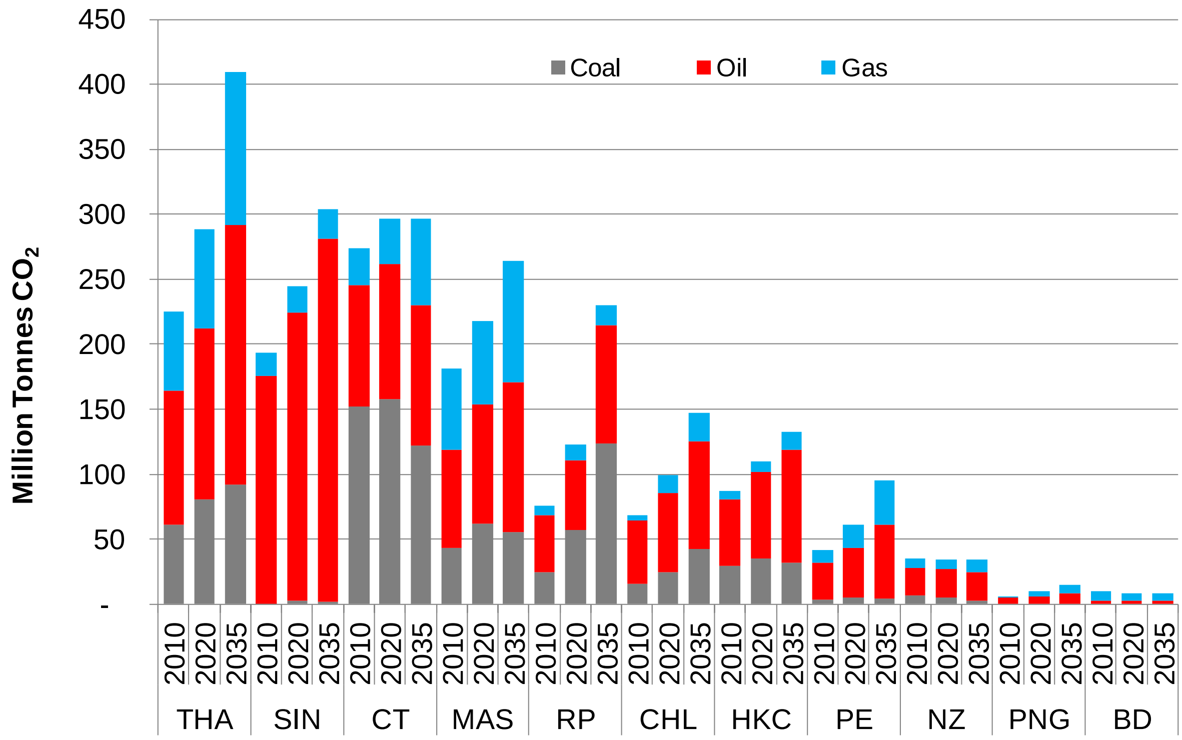
However, as shown in Figure 16.9 and Figure 16.10, the share of the three fuels in CO_2 emissions varies dramatically among the economies.

Figure 16.9: CO_2 Emissions from Fuel Combustion by Fuel, Higher Emitting Economies



Source: APERC Analysis (2012)

Figure 16.10: CO_2 Emissions from Fuel Combustion by Fuel, Lower Emitting Economies



Source: APERC Analysis (2012)

In 2009, the APEC economies accounted for about 60% of world CO_2 emissions from the combustion of fossil fuels (calculated from IEA, 2011, pp. III.45–49). It is, therefore, no exaggeration to say what happens in APEC will largely determine what happens in the world. As discussed in Chapter 1, the best science is saying that the world needs to make dramatic reductions in greenhouse gas emissions to avoid potentially disastrous climate change consequences. This need for reductions stands in stark contrast with the 32% increase in CO_2 emissions from fossil fuel consumption between 2010 and 2035 under our BAU scenario. Clearly, the BAU projection is incompatible with APEC's commitment to "…prevent dangerous human interference with the climate system" (APEC, 2007).

THE WAY FORWARD

Finding ways to make large reductions in greenhouse gas emissions in fast-growing economies, such as those of the APEC region, is a challenge that ranks among the greatest of our times. CO_2 is an inherent product of fossil fuel consumption; unlike toxic air pollutants, it cannot be eliminated with improved combustion technology. There are fundamentally only three ways to reduce CO_2 emissions: use less energy, switch to less-emission-intensive energy sources, or find a way to capture and permanently store the CO_2. Given that under our BAU projections the APEC region will depend upon fossil fuels for over 80% of its primary energy supply in 2035, each of these alternatives will involve huge changes.

While this study has not attempted a detailed analysis of alternatives, there are some general recommendations that emerge from the analysis presented here.

1. *Educate*. Dealing with a challenge the size of the climate change problem will require a serious commitment from a lot of people. Policymakers will need support and cooperation from their stakeholders and constituents if effective policies are to be agreed upon and adopted. This kind of support and cooperation will only come if those stakeholders and constituents understand the magnitude of the challenge and the consequences of an inadequate response. Since climate change is a challenge that will have to be dealt with over a time span of decades, it makes sense to insure that young people are appropriately educated on climate change science, technology, and institutions in schools of all levels. And no opportunity should be lost to educate their elders as well.
2. *Promote energy efficiency*. As discussed in Chapter 4, there are a variety of market barriers preventing the most efficient use of energy resources. Removing these barriers, or adopting policies to offset them, can often simultaneously reduce emissions, reduce costs, and promote energy security. Improved energy efficiency is likely to be the quickest and least-cost first line of attack on the climate change problem.
3. *Promote energy research*. As discussed in Chapter 15 and others, there are a variety of promising low-emission energy supply technologies, including various types of renewable energy, carbon capture and storage, and advanced nuclear. Technology can also improve energy efficiency using advanced vehicles, smart grids, better communication as an alternative to transportation, and in many other ways. The cheaper and more convenient that emissions-reducing technology can be made, the easier it will be to deal with the challenges of climate change. Technology will be especially important over the longer term, since once the economic emission reductions from the technology available today have been achieved, further reductions will require new technology.
4. *Put a price on emissions*. As noted in Chapter 4, a major market failure results from the fact those who emit greenhouse gases pay no cost for the damage they are doing. Some kind of scheme for putting a price on emissions, such as an emissions cap and trade program, or a carbon tax, would address this market failure. Some low-emission technologies, such as carbon capture and storage, can probably never be cheaper than conventional technology, while others may take a long time to get there. A price on emissions will pave the way for low-emissions technology to move from research to commercialization.

   An economy could avoid a loss of competitiveness to their industry by levying the emissions price on the emissions embedded in what is consumed, rather than on the emissions from production. Such an approach might make a price on emissions more politically acceptable (see the sidebar 'Did the Kyoto Protocol Get It Backwards?' in this chapter).

5. *Cooperate*. Climate change is a global challenge. No one economy can deal with it alone. Trade is a key example of where cooperation will be required, but there are a number of others, including infrastructure development, financial mechanisms, regulatory frameworks, research and development, information sharing, and education and capacity building (APERC, 2008). APEC could play an important role in many of these areas.

MODELLING CO_2 EMISSIONS

Projecting CO_2 emissions from combustion is, in principle, simple if we know the amount of each fuel to be combusted: just multiply the quantity of each fuel combusted by the emission factor (CO_2/unit of fuel) for that fuel. The emission factor for each fuel is a fixed chemical property of the fuel.

In practice, data limitations make these calculations more uncertain. There are many types of coal, many types of oil and oil products, and even natural gas may vary slightly in chemical composition. However, because of limitations on data and model complexity, APERC projects the demand for only three generic fossil fuels: coal, oil, and gas. So what to do?

One approach would be to use the worldwide average emission factor for each of these three generic fossil fuels. These may be calculated by dividing worldwide CO_2 emissions from that generic fuel by worldwide demand. Such a calculation (using data from IEA, 2011, pp. II.7–16) yields the following generic emission factors for the year 2009:

- Coal—3.8293 million tonnes CO_2/Mtoe
- Oil—3.0179 million tonnes CO_2/Mtoe
- Gas—2.3972 million tonnes CO_2/Mtoe.

These emission factors are broadly consistent with the default emission factors for combustion given in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006, Table 1.4). (The IPCC's figures are given in TJ/Mtoe; given there are 41 868 TJ/Mtoe (IEA, 2012), the emission factors above would imply average CO_2 emissions of about 91 500 kg/TJ for coal, 72 081 kg/TJ for oil, and 57 300 kg/TJ for gas.)

These emission factors could be multiplied by the projected demand for each of the three generic fuels to project CO_2 emissions. This approach, however, fails to capture the differences in the mix of specific fuels used in each economy.

APERC, therefore, goes one step further, calculating a specific emission factor for each generic fuel for each APEC economy for the base year 2009. This is accomplished by dividing the economy's CO_2 emissions from each generic fuel (again from IEA, 2011, pp. II.7–II.16) by demand for that generic fuel. These emission factors thus take into account the specific mix of fuels in each economy. For the year 2009, modelled emissions are guaranteed to match actual emissions, since the emission factors were calculated from actual emissions. For future years, the mix of fuels in the economy could change somewhat over time, but this method should be a good approximation and probably about the best possible given the limitations of the demand models.

DID THE KYOTO PROTOCOL GET IT BACKWARDS?

Under the Kyoto Protocol, 37 developed economies and the European Union agreed to limit their greenhouse gas emissions over the five-year period 2008–2012 (UNFCCC, 2012). However, a post-2012 successor agreement with binding limits has attracted only meagre participation thus far (Washington Post, 2012). In many economies, there has been strong opposition to such binding emissions limits, and especially to the carbon pricing (carbon taxes or emission trading) that will probably be needed to enforce them.

The basic dilemma here is that any disparity in the regulation of emissions between economies, and especially in the price of carbon, will put the economy with the stricter regulations at a competitive disadvantage. And unless every economy in the world agrees to a common carbon pricing scheme—an unlikely outcome given the 'free-rider' advantages accruing to any economy that stays out of the agreement—there will always be disparities.

Energy-intensive industries, and their workers, tend to be politically powerful, and will demand that carbon pricing be abandoned, or at least that export-competitive industry be exempted or compensated, which significantly weakens the emission reduction impact. Governments are effectively forced to make a trade-off: climate protection vs. economic growth and jobs. When the policy question is posed in these terms, it is inevitable that climate protection will lose. No-one likes new taxes, but when they look like a tariff on your economy's own products that is not faced by foreign competitors, the difficulties can become overwhelming for even the most environmentally committed political leaders. Indeed, a 'race to the bottom' for weaker emission regulation would seem to be the natural outcome, and it largely has been.

What is happening here can be viewed as a classic market failure. Economic principles tell us markets work when consumers pay the full cost (including environmental costs) of the products they consume, and any departure from this principle produces 'market failures' that give people an incentive to behave in ways that are not in society's best interests. Yet under the Kyoto Protocol, with its limits on the emissions produced by each economy, the consumer can avoid paying the full environmental costs they are imposing on society by purchasing products from economies with weak emission regulation. The result is a classic market failure, which explains much of the difficulty in reaching and in implementing an agreement.

The alternative that avoids market failure is for each participating economy to pledge to limit the emissions embedded in what they *consume*, not what they *produce*. As with the Kyoto Protocol, the limits could be enforced in each participating economy through measures of their own choosing. Some kind of carbon pricing scheme, such as a carbon tax or emissions trading, but applicable only to domestic consumption, would be the obvious choice. The carbon price would, however, need to cover *all* domestic consumption, whether the product was produced domestically or imported. So it would need to be charged on imported products, and refunded on exported products.

With consumption-based emission limits, there would be no competitive benefit to the industries in an economy that does not participate in the agreement. The products of non-participating economies would have to bear the same carbon price when they are sold to participating economies as domestic products in those economies. This means, even if an economy chooses not to participate in the agreement, their industries would still face strong economic incentives to minimize the carbon embedded in their products if they wish to remain competitive in participating economies. Thus, the incentives facing each economy and their industries would be completely different from those under Kyoto-style production-based limits.

Such a proposal raises two obvious questions. The first is whether such a scheme would be legal under international trade agreements. The basic requirement of international trade agreements is non-discrimination. The border adjustments proposed here would meet this requirement, since imported products in each economy would be charged for carbon emissions in the same manner as domestically produced products (Horn and Mavroidis, 2011 and Khrebtukova, 2010). Today's value-added taxes, which are charged on imports and refunded on exports by many countries, have set a precedent for this (Lockwood and Whalley, 2008). Of course, the most logical way to avoid the risk of trade disputes over border adjustments for carbon pricing would be to explicitly incorporate the rules for them into international trade agreements (Barrett, 2011; Whalley, 2011).

The second question is whether the carbon accounting required by border adjustments could be implemented in the real world fairly and at reasonable cost. Clearly, there are accounting challenges in implementing such consumption-based emission limits, specifically in determining what the carbon content of a particular product is. These accounting challenges should be manageable, although full implementation would take time. Efforts already underway in this area include the Greenhouse Gas Protocol of the World Resources Institute and World Business Council for Sustainable Development (WRI/WBCSD, 2012) and ISO Standard 14067 (PCF World Forum, 2012).

This section is a short summary of Samuelson (2012), which should be consulted for a more detailed discussion of consumption-based emission limits.

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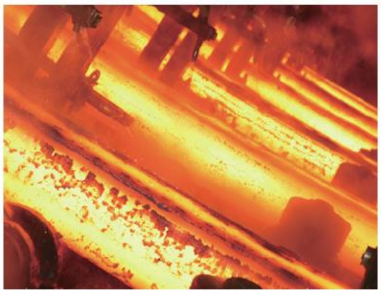

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