APERC Workshop
The 48th APEC Energy Working Group and Associated Meetings
Port Moresby, Papua New Guinea, 17 November, 2014

2-3. Electricity Supply Model

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Asia-Pacific
Economic Cooperation

I. Overview of the electricity supply model

II. Preliminary results (BAU scenario)

III. Conclusion/Future work

APERC's model structure

APERC is developing four sectoral models. Electricity demand is projected in other three sectoral models and input into electricity supply model.

| Input (Microsoft Excel) | Electricity Supply Model (GAMS software) | Output (Microsoft Excel) |

Input (Microsoft Excel)

- Demand, load duration curve
- Supply facility data
  - ✓ Installed capacity
  - ✓ Capital / O&M costs
- Energy / Carbon prices
- Policy constraints / trends (**Nuclear, Renewables,...**)
- Historical trends   etc.

Electricity Supply Model (GAMS software)

"Least Cost" Approach
Capacity addition and generation volume are determined based on costs (capital costs, O&M costs, fuel costs, etc.) under various constraints.

Output (Microsoft Excel)

- Electricity generation mix
- Capacity addition required
- Investment associated with new generation assets
- Fuel consumption
- CO_2 emissions
- Electricity generation costs

etc.

Objective Function (Currently LP Model)

Min. Total system cost (summation of 2011~2040) = Capital cost + Fuel cost + O&M cost + Carbon cost

Constraints

(e.g.) Electricity supply demand balance

Electricity supply and demand are balanced using a load duration curve.
Demand is represented in 10 segments.

$$\sum_i xp_{i,y,t} = Load_{y,t}$$

$xp_{i,y,t}$: Output of i-th power plant in time segment t, year y [MW]
$Load_{y,t}$: Electricity load in time segment t, year y [MW]

Load Duration Curve:
larger load in the left
and smaller one in the right

Legend: Oil_ST, Gas_Turbine, Gas_CCGT, Coal_Conv., Coal_Adv., Biomass etc, Solar, Wind, Hydro, Geothermal, Nuclear, Electricity Load
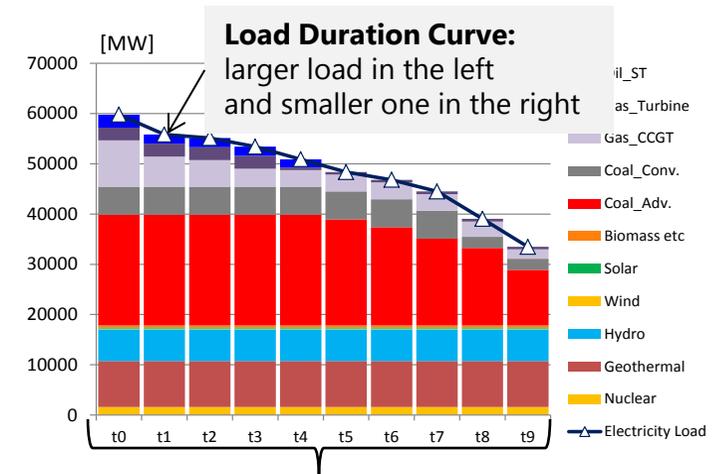
One year is divided into 10 segments ("t0~t9")
→→ 876 hours/segment

Other constraints

Reserve margin constraint, Maximum availability constraint, Actual availability constraint,
Minimum output constraint, Power plant capacity additions constraint, etc.

Power Plant Type in the Model

Type	Definition
Nuclear	Nuclear
Coal_Conventional	Coal (Sub-Critical, Super Critical)
Coal_Advanced	Coal (Ultra Super Critical, Advanced USC) IGCC (Integrated Gasification Combined Cycle)
Gas_Turbine	Gas steam turbine, Gas turbine
Gas_CCGT	Gas combined cycle
Oil	Oil steam turbine, Diesel engines
Hydro	Hydro (large and small-scale)
Wind	Wind (offshore and on-shore)
Solar	Solar PV, Solar thermal
Biomass etc	Biomass, biogas, municipal solid waste etc.
Geothermal	Geothermal

I.   Overview of the electricity supply model

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Legend:
- China
- East Asia (except China)
- SE Asia
- North/Central America
- South America
- Oceania

CAGR (2011-2040)

2040 values: 3.0%, 0.8%, 4.4%, 0.8%, 3.9%, 1.6%
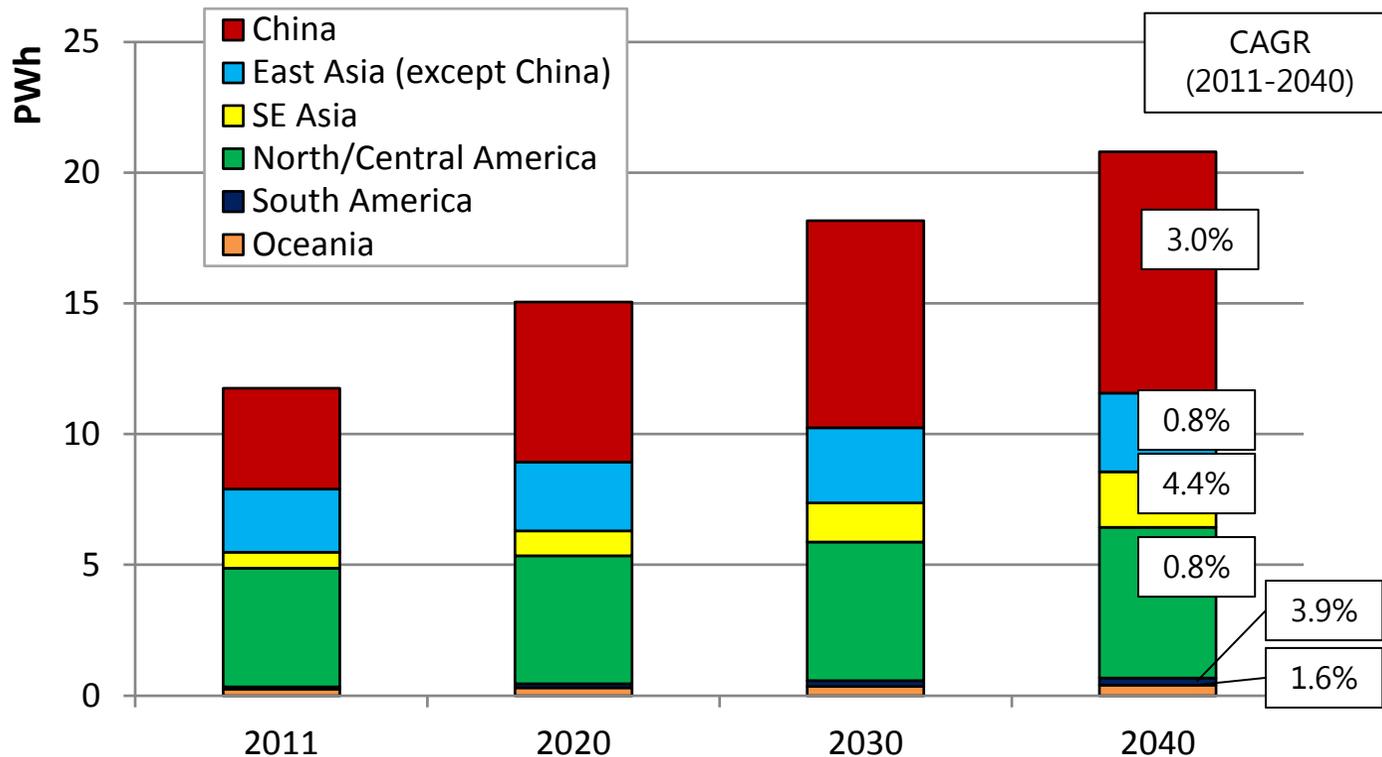
APEC Total
2011 12 PWh
↓
2040 20 PWh

China
2011 4 PWh
↓
2040 9 PWh

- According to APERC's projection, electricity demand is expected to grow by 2.0% per year on average (1.8 times in 2040 compared to 2011).
- China maintains the largest share at 33% in 2010 and 44% in 2040.

Assumptions: Costs and Energy Prices

Cost / Energy price

- Capital cost [$/kW] is based on each economy studies, IEA World Energy Outlook, and APERC's assumptions.

- Yearly O&M cost is considered in proportion to capital cost (e.g 3% of capital cost for coal power plants)

- Energy prices are estimated based on IEA WEO 2013 (CPS) and APERC's assumptions.

		2012	2020	2025	2030	2035	2040
Crude Oil	$/bbl	109	120	127	136	145	154
	$/toe	778	857	907	971	1035	1100
Natural Gas U.S.	$/MMBtu	2.7	5.2	5.8	6.2	6.9	8
	$/toe	107	206	230	246	274	302
Japan	$/MMBtu	16.9	14.7	15.2	15.9	16.7	18
	$/toe	671	583	603	631	663	694
Coal	$/t	99	112	116	118	120	122
	$/toe	59	67	70	71	72	73

(Source) IEA WEO 2013, APERC

Electricity Generation
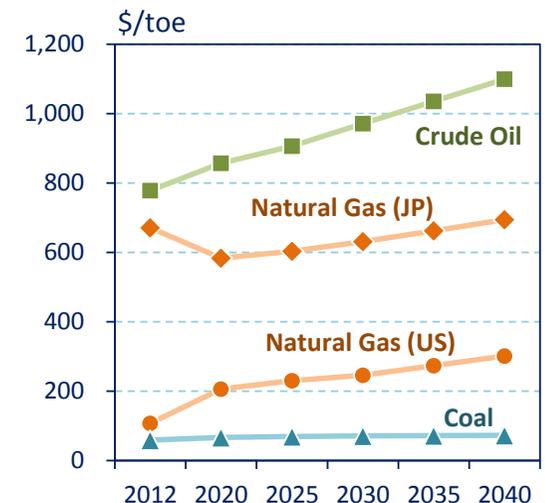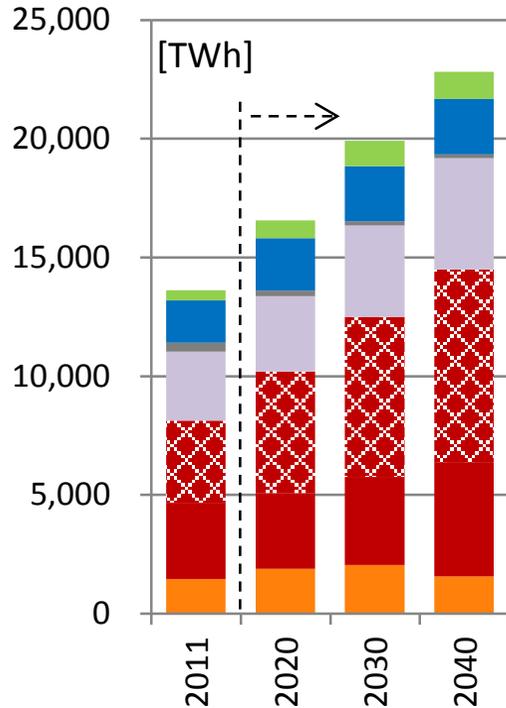
Generation (APEC)

Share [TWh%]
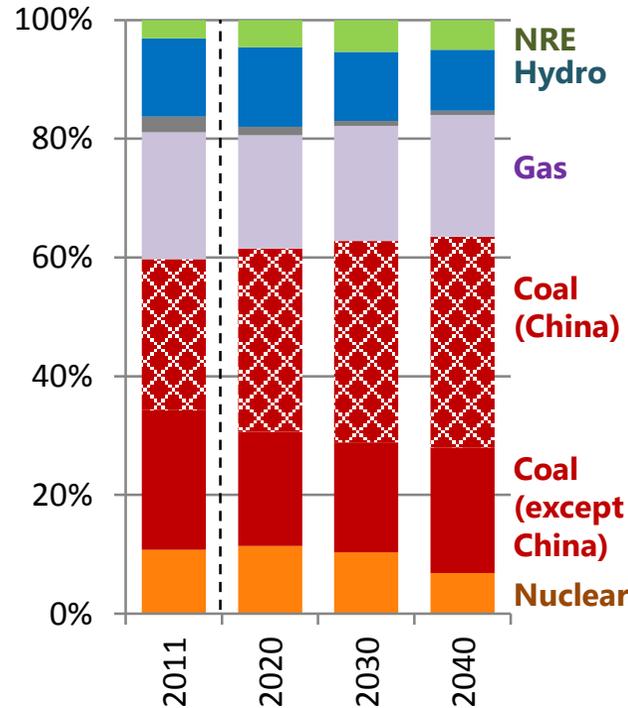
## Nuclear Capacity(BAU)
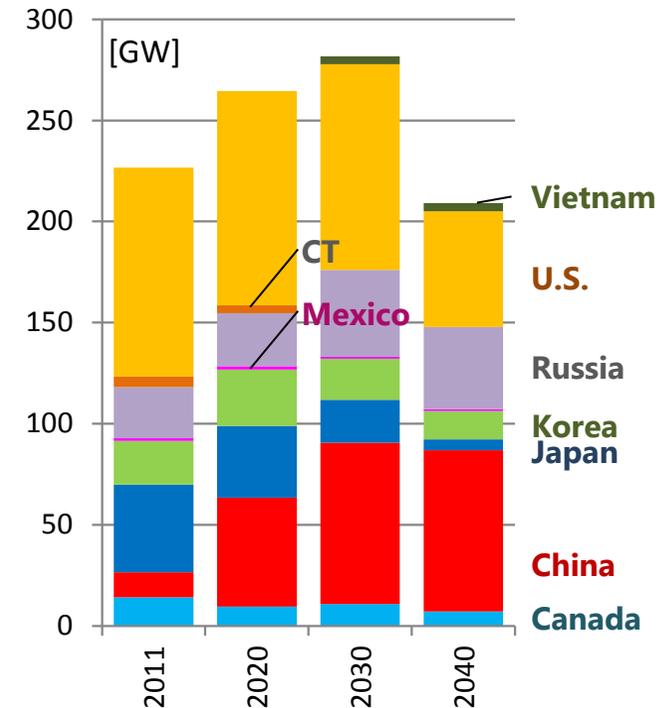
- Coal remains the dominant source in the region. However, about 60% of APEC coal generation is in China in 2040.

- As for nuclear, under our BAU assumptions (based on existing plan and lifetime), its capacity in the region shifts to declining trend after 2030.

*Please note that Projection of NRE is still under discussion inside APERC and the results are preliminary.

Generation in 2011 and 2040 [TWh]

China: Coal is dominant

EastAsia(except China)+Russia : Coal↑

North/Central America : Gas↑

SE Asia: Coal&Gas↑

Oceania: Gas↑

**South America: Coal&Gas↑**

Legend:
- NRE
- Hydro
- Oil
- Gas
- Coal
- Nuclear
- CO2 Emissions
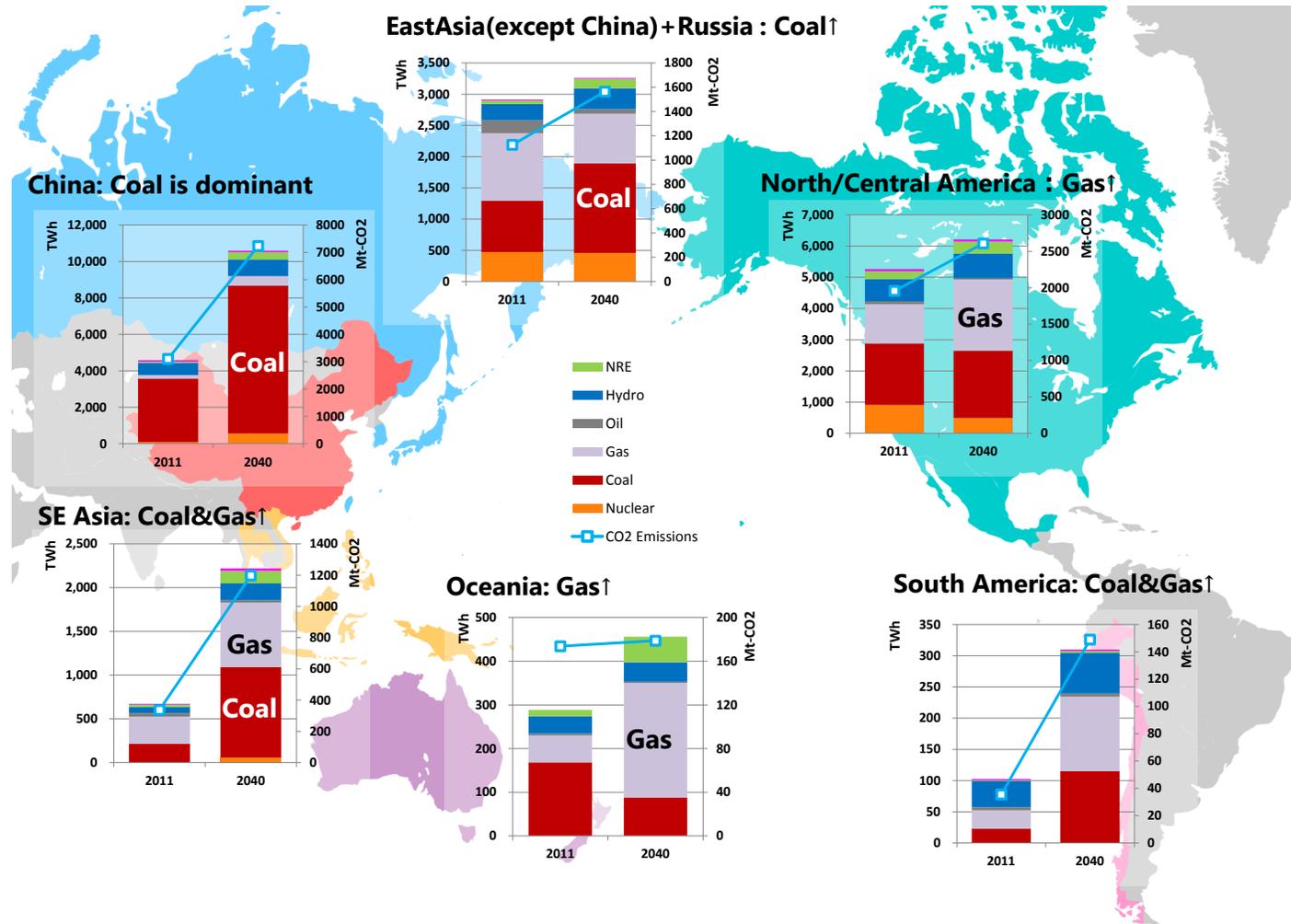
- Gas-fired plants expand in Oceania and North / Central America.

- Coal-fired plants play a major role in East Asia, and both coal and gas plants expand in SE Asia and South America.

CO2 Emissions from Power Generation
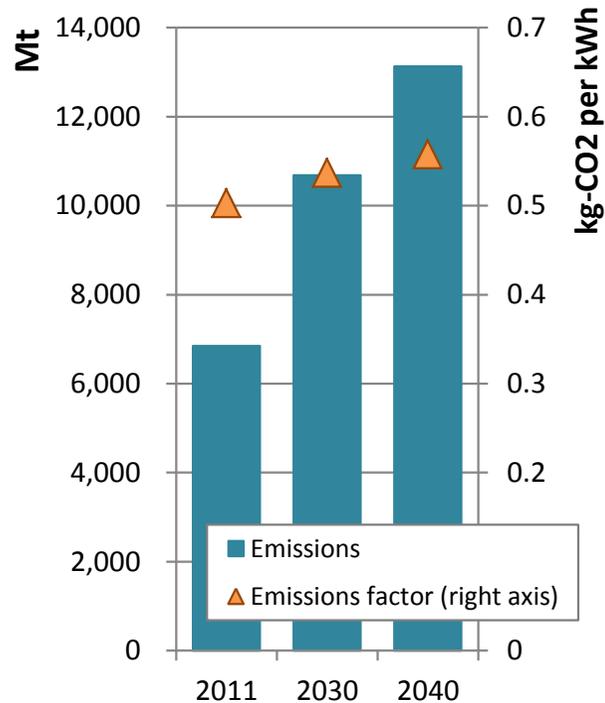
Emissions (APEC)

Emissions in 2010 and 2040 by region

[Gt-CO2/year]

East Asia
1.1Gt
↓
1.6Gt

N/C America
2.0Gt
↓
2.6Gt

China
3.1Gt
↓
7.2Gt

2011

2040

SE Asia
0.3Gt
↓
1.2Gt

Oceania
0.17Gt
↓
0.18Gt

South America
0.04Gt
↓
0.15Gt
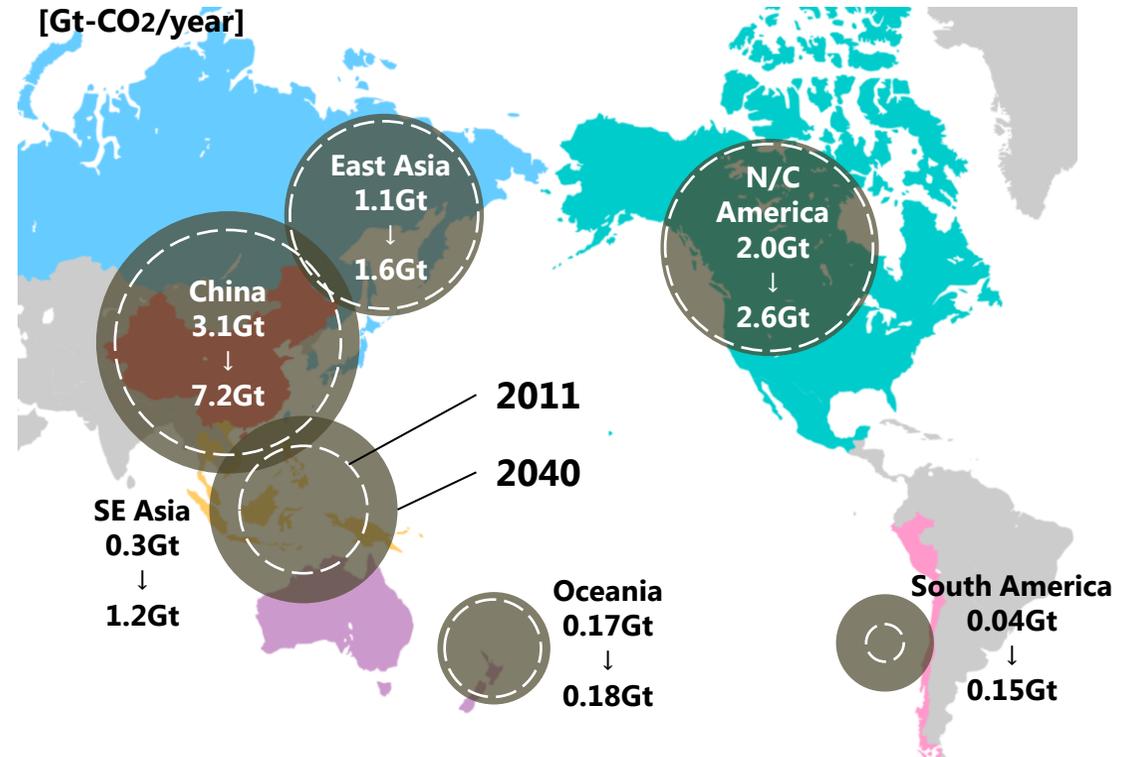
- CO_2 emissions increase by 75% in 2040 from 2011 (7Gt → 13Gt).
- Share of annual emissions in China grows from 46% (2011) to 56% (2040).

Cumulative investment required for power generating facilities

[Billion $]

1172
764
850
661
174
82

Legend:
- NRE (green)
- Hydro (blue)
- Oil (gray)
- Gas (light purple)
- Coal (red)
- Nuclear (orange)
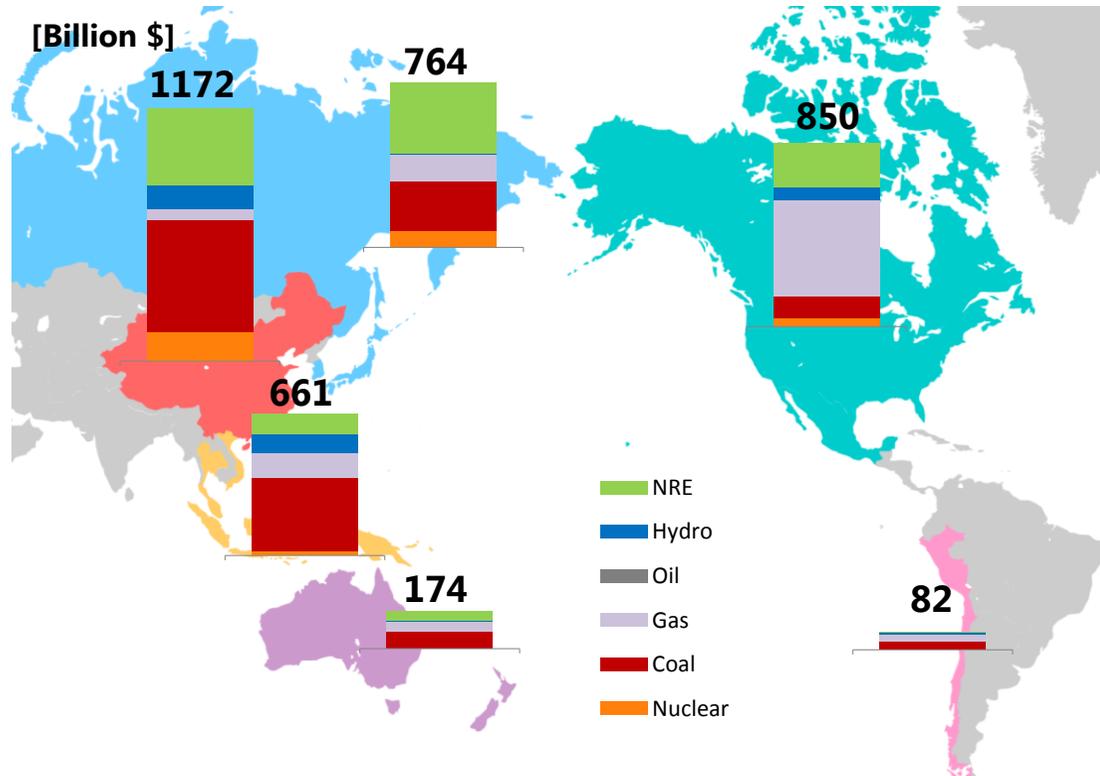
APEC Total
3,704 Billion $

China
1,172 Billion $
(32% of APEC total)

SE Asia
661 Billion $ (18%)

- SE-Asia+China require large investment in coal-fired power generating facilities (340B$+518B$, respectively), and North/Central America requires 440B$ for gas-fired plants.

- The share of renewables is relatively large in East Asia (43%) and China (30%).
  *Please note that Projection of NRE is still under discussion inside APERC and the results are preliminary.

Conclusion / Future work

Conclusion

- APERC has developed electricity supply model.

- The preliminary results show coal remains as a dominant fuel type in power generation. In some regions, gas-fired plants replace coal-fired due to coal phase-out policies or cheap gas prices.

- China's emissions levels may reach 56% of APEC total in 2040 under BAU scenario.

Ongoing/Future work

- Finalizing nuclear projection.

- Projecting renewable energy in APEC economies.

- Alternative case?
    - High renewable/nuclear case? : impacts on CO_2 emissions, costs, investments, etc.
    - Analyze the potential penetration level of renewables?

- Analyzing energy security implications (by considering fossil fuel import/export ratios).

Thank you for your attention