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# Future Perspective of Nuclear Power Development in the APEC Region: A Modelling Study

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Asia Pacific Energy Research Centre

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  Nuclear power in the APEC region
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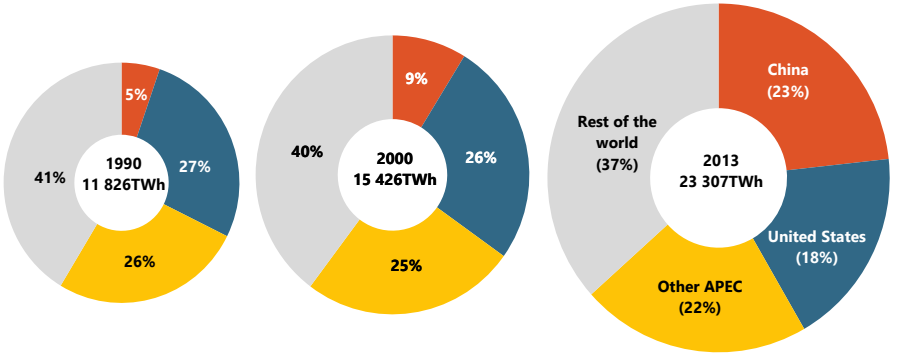
- **Conclusion**

# Asia-Pacific Economic Cooperation (APEC): 21 economies, accounting for 60% of global generation


**APEC Economies (total 21)**

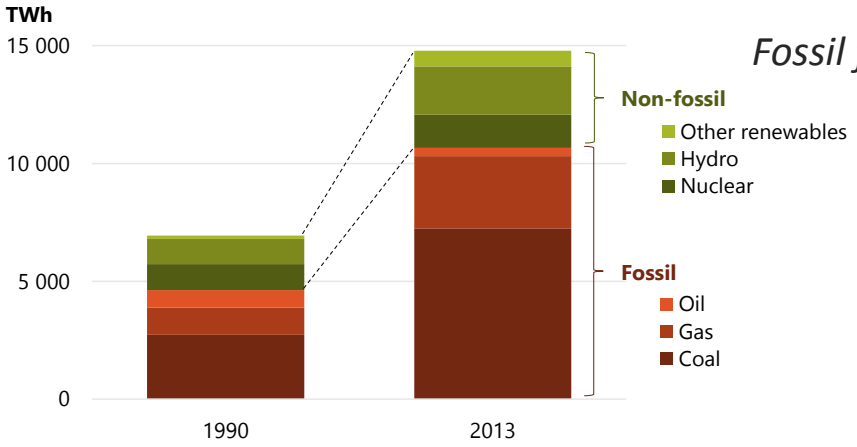
| | |
|---|---|
| Australia | Brunei Darussalam |
| Canada | Chile |
| China | Hong Kong, China |
| Indonesia | Japan |
| Republic of Korea | Malaysia |
| Mexico | New Zealand |
| Papua New Guinea | Peru |
| Philippines | Russia |
| Singapore | Chinese Taipei |
| Thailand | United States |
| Viet Nam | |

## Share of APEC in global generation




*63% in global generation in 2013*

## Fossil vs non-fossil in APEC

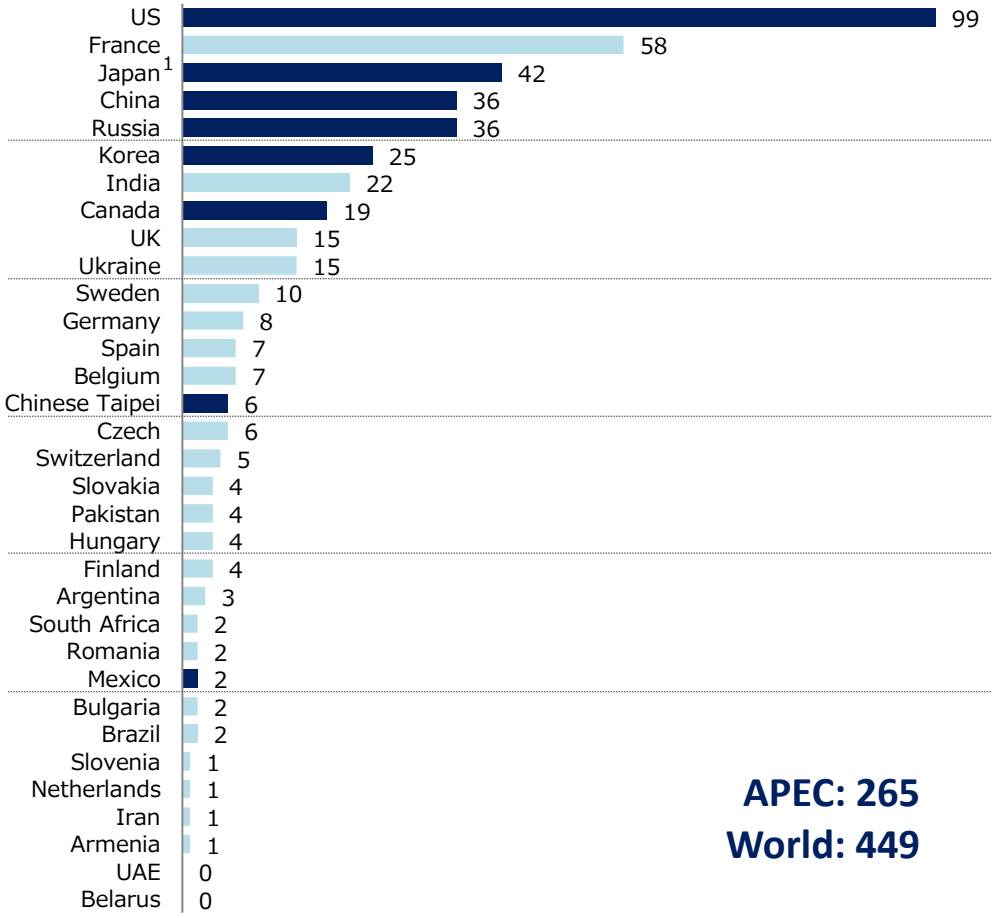



*Fossil fuels dominate the power mix*

Sources: IEA statistics, APEC Energy Working Group.

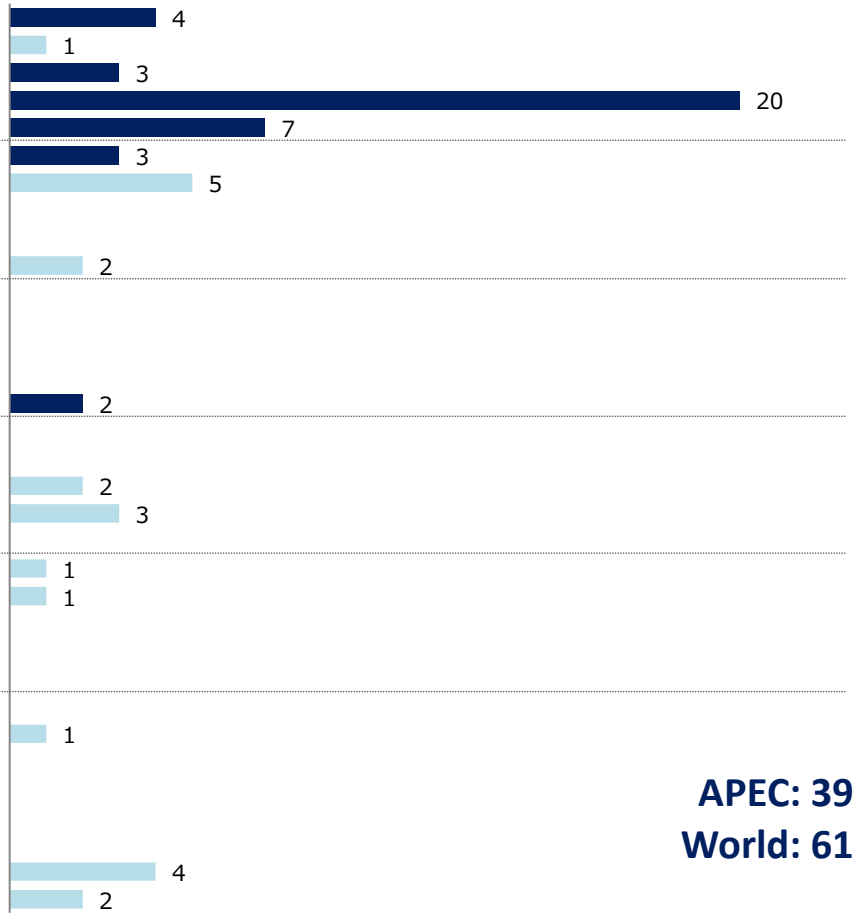
# Major nuclear utilizing/expanding economies are in APEC

## Number of reactors in operation (as of Nov 2016)




**APEC: 265**
**World: 449**

## Under construction (as of Nov 2016)




**APEC: 39**
**World: 61**

1. We refer to IAEA PRIS database. We adjusted data in several economies; for example, in Japan, Ikata unit 1 is excluded from the figure in operation, and the number of reactors under construction is revised from 2 to 3.

# However, future direction varies by economy and uncertainties exist

## Nuclear plans and targets, selected economies

| | |
|---|---|
| China | Target by 2020: 58GW in operation and 30GW under construction |
| Japan | Amended reactor regulation acts to limit lifetime of reactors, yet the government aims for a share of 20-22% in generation by FY2030. |
| Korea[1] | Addition of 4 reactors which are currently under construction (Shin-Kori 4&5, Shin-Wolseong 1&2) and retirement of 12 reactors by 2040, as outlined in the 8th Basic Plan for Long-Term Electricity Supply published by MOTIE. |
| Chinese Taipei | Nuclear phase out policy by 2025 |
| Russia | Rosatom plans to expand nuclear mainly in the west part of Russia |
| United States | NRC is preparing guidance for an 80-year lifetime (Subsequent License Renewal) |
| "Newcomers" | Thailand: PDP2015 plans to install 2GW by 2036. |
| | Viet Nam: Halt to Ninh Thuan project. |

1. This study was conducted in 2017 before the announcement of the 8th Basic Plan for Long-Term Electricity Supply.

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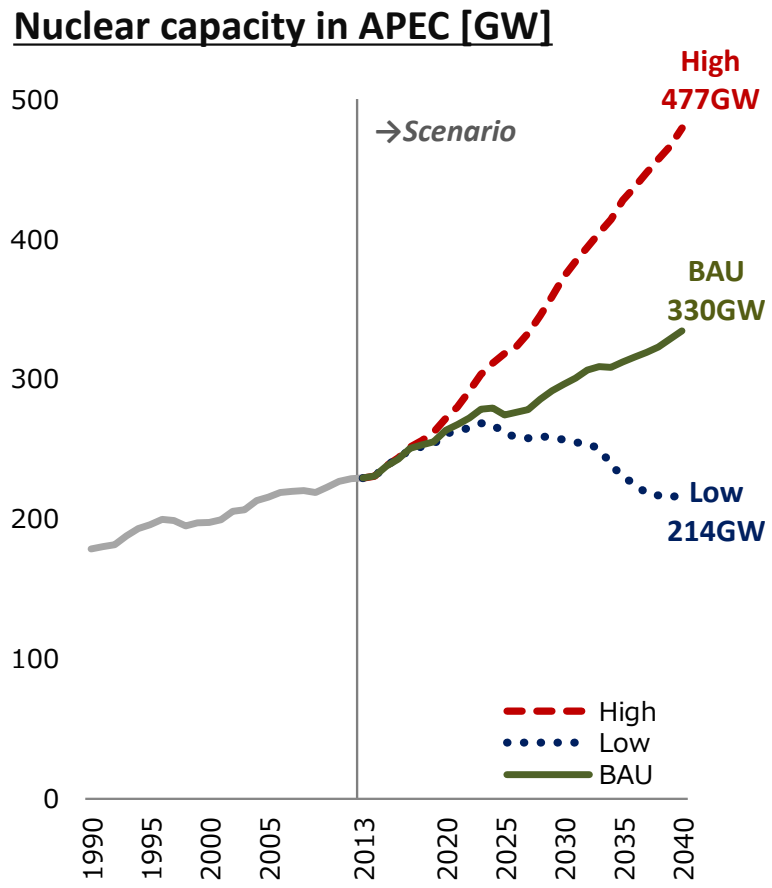
# Three scenarios to discuss the future of nuclear in Asia-Pacific

- **Business-As-Usual (BAU)**
  Current policy exists over the projection period (2013-2040).
  Recent nuclear construction/retirement trends considered.
  Proposed projects are not included in most of the economies.

- **High-nuclear (High)**
  Proposed projects are included in addition to BAU projects driven by energy security, environmental and economic reasons.
  License extensions applied to most of the existing reactors.

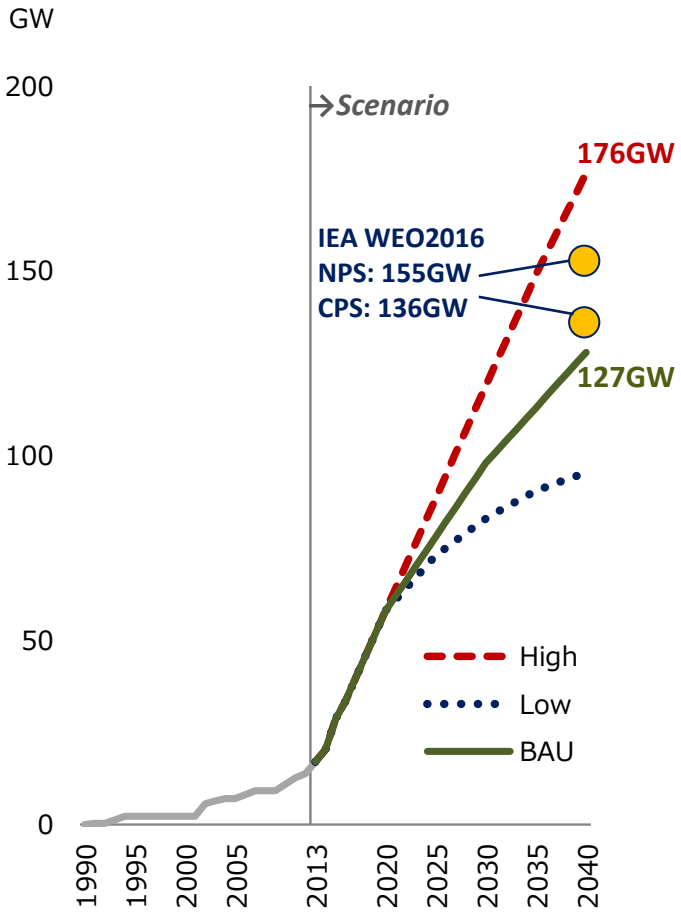
- **Low-nuclear (Low)**
  Slow down of nuclear developments and accelerated retirements of existing reactors due to various concerns, including safety and waste management.




Source: APERC

**Example of economy assumption**

# China – projected to be the largest nuclear economy in APEC




## Current status (as of 1st Nov 2016)

- 36 reactors in operation
- 20 reactors under construction
- Target: 58GW in operation and 30GW under construction by 2020 ("Energy Development Strategy Action Plan (2014-2020)" and The 13th Five-Year Plan)

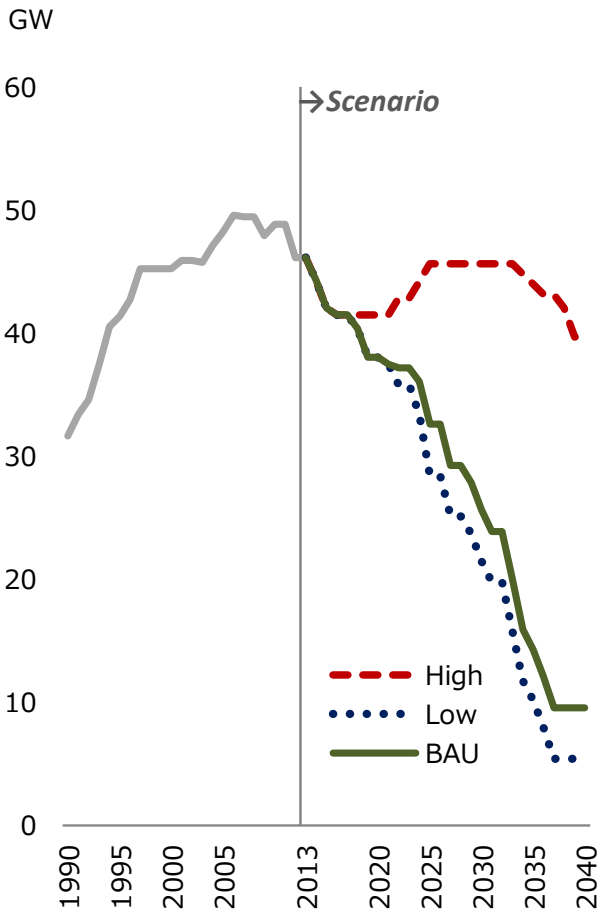
## Scenario assumptions

| | 2020 operation target (58GW) | New additions after 2020 |
|---|---|---|
| High | Achieved | 5-6 reactors/year (projected trend in the late 2010s continues) |
| **BAU** | **Achieved** | **3-4 reactors/year (The annual average number of reactors installed in 2012-2016 Sep.: 4 reactors/year)** |
| Low | Achieved | 1-3 reactors/year |

Sources: IAEA, State Council.

**Example of economy assumption**

# Japan – license expiration of existing reactors has significant impacts




## Current status (as of 1st Nov 2016)

- 42 reactors in operation
- 3 reactors under construction (Shimane-3, Oma-1, and Higashidori-1)
- Lifetime: 40 years, and an extension of maximum 20 years allowed under nuclear reactor regulation act
- Strategic Energy Plan (published in April 2014): *"Dependency on nuclear power generation will be lowered to the extent possible"*

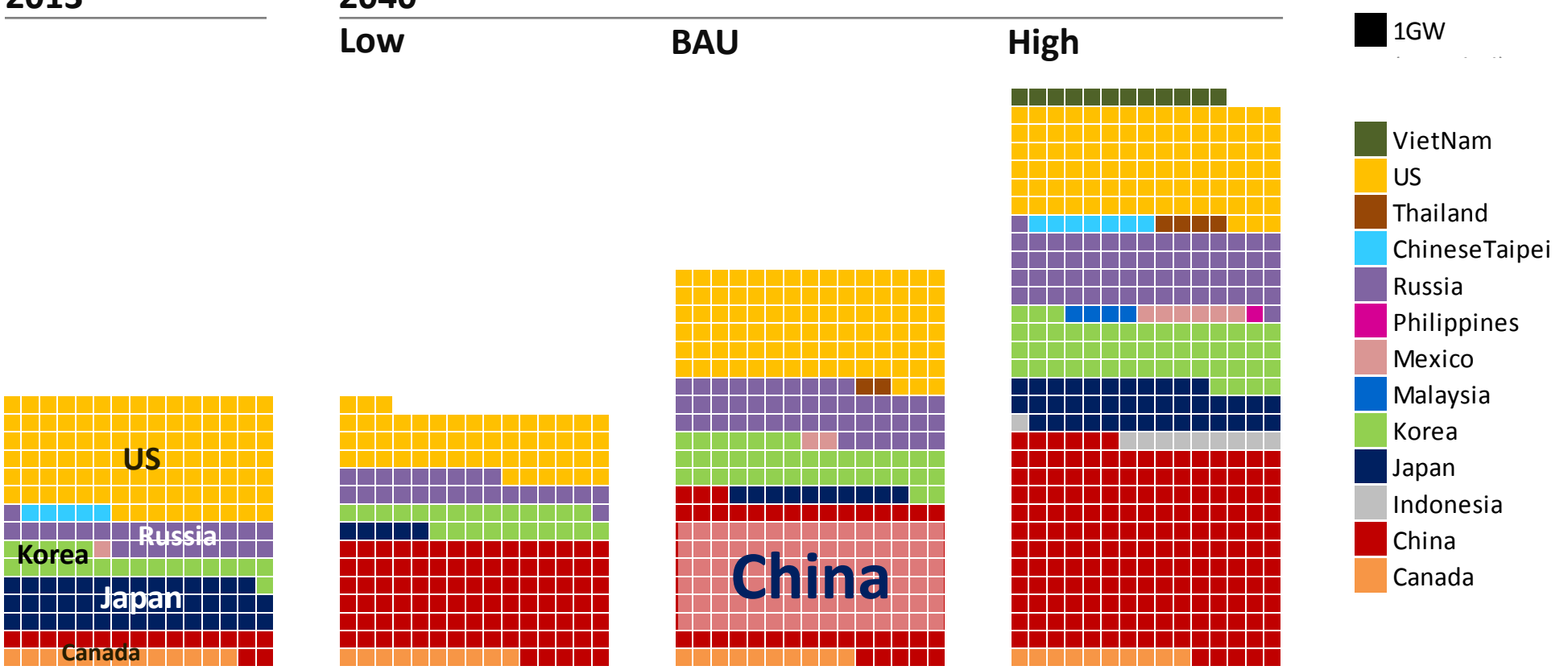
## Scenario assumptions

| | Lifetime of existing reactors | New reactor additions |
|---|---|---|
| High | 60 years | 3 units currently under construction |
| **BAU** | **40 years (except for the reactors approved/examined for extension)** | **3 units currently under construction** |
| Low | Same as BAU | No new reactors |

Sources: OCCTO and METI.

# China's increasing presence in APEC nuclear generation

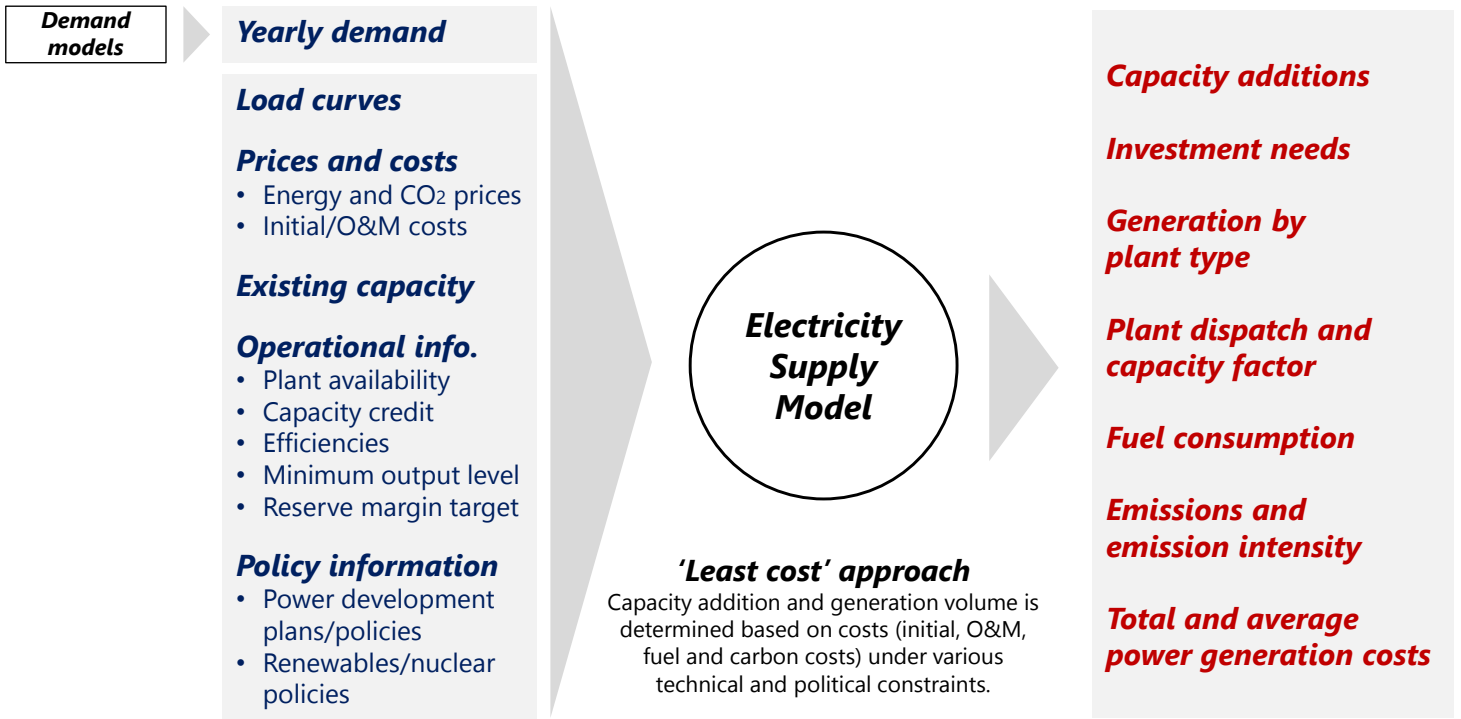
**APEC nuclear capacity [GW]**




Note: Nuclear capacity in each economy is rounded. The number of block does not necessarily means the exact installed capacity. Source: APERC.

# APERC uses a long-term power supply model based on cost-optimization

## Electricity supply model structure




## Modelled technologies

**Generation**

- Nuclear
- Coal-fired (sub-critical)
- Coal-fired (super / ultra-super critical)
- Gas turbine
- Gas combined cycle
- Oil-fired
- Solar PV & solar thermal
- Wind (onshore, offshore)
- Geothermal
- Biomass and others

**Storage**

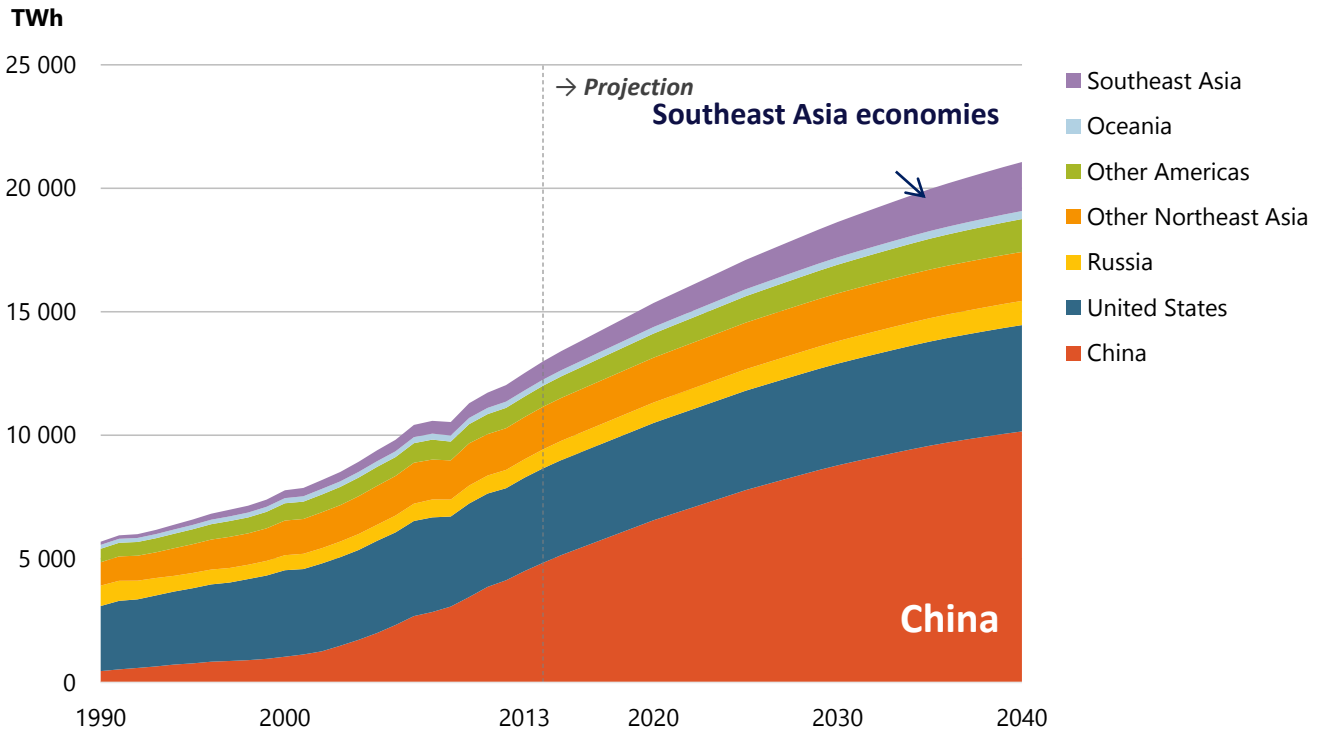
- Pumped hydro
- Battery

- Future nuclear capacity is assumed by the scenario (not based on optimization)
- The model determines fossil fuel-fired capacity and operation of all technologies, considering policy directions

Source: APERC.

# China and Southeast Asian economies drive demand growth

## Assumed electricity demand, regional grouping[1]




- Electricity demand in APEC grows by 70% over the outlook period
- China and Southeast Asian economies more than double their demand

[1] Source: APERC (2016) "APEC Energy Demand and Supply Outlook 6th Edition"

# Cost assumptions

## Fossil fuel prices[1]

| | 2013 | 2020 | 2030 | 2040 |
|---|---|---|---|---|
| Crude oil [USD/bbl] | 108 | 73 | 97 | 121 |
| Natural gas in Japan [USD/Mmbtu] | 15.9 | 10.4 | 12.4 | 13.7 |
| Natural gas in the US [USD/Mmbtu] | 3.6 | 4.4 | 5.4 | 6.6 |
| Steam coal [USD/tonne] | 110 | 86 | 103 | 128 |

## Capital costs of nuclear plant, selected region[2]

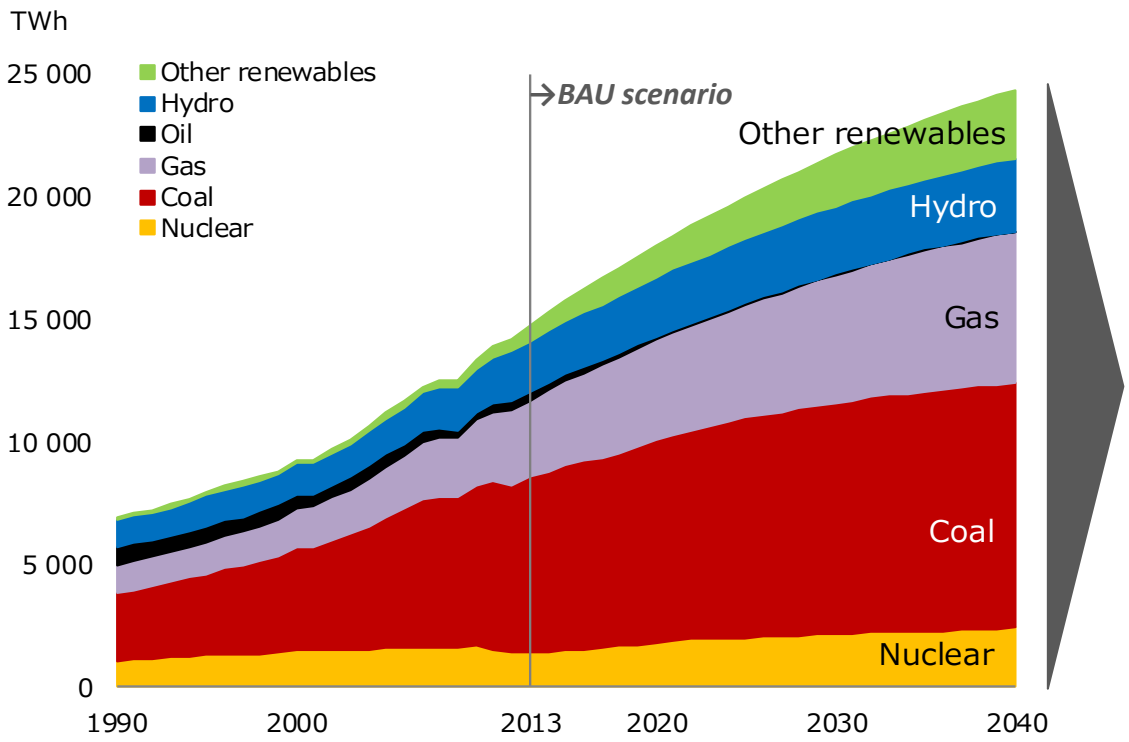
| Unit: USD/kW | 2013-2040 |
|---|---|
| China | 2000 |
| Japan | 3500 |
| Southeast Asia | 2000 |
| Russia | 3500 |
| US | 5400 |

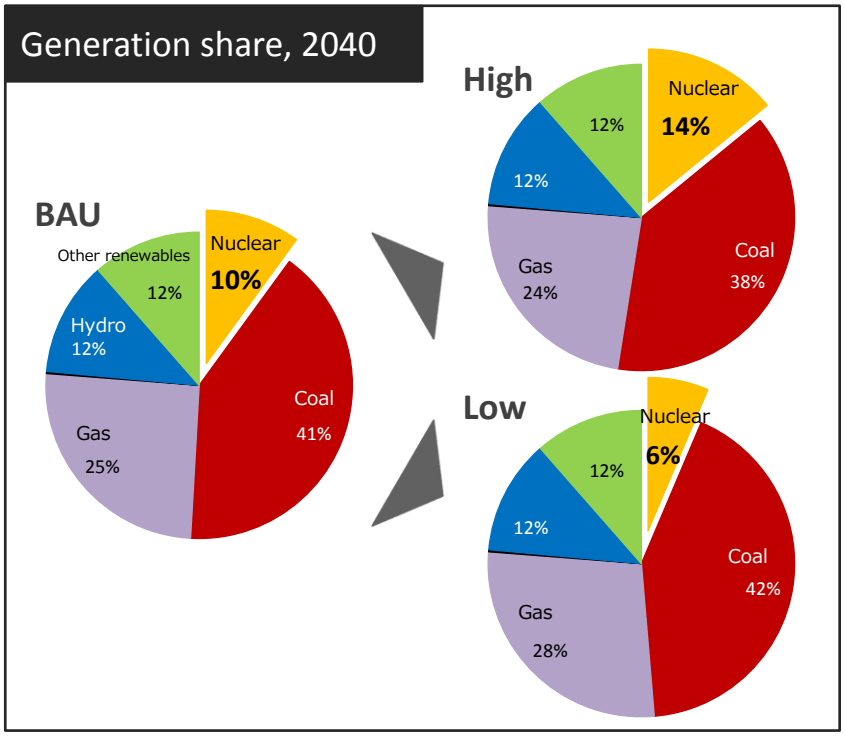
1 The Outlook energy price assumptions are based on IEEJ's 2015 AWEO reference case and converted to USD 2012 PPP using World Bank PPP conversion factors; bbl = barrels; and Mmbtu = million British thermal units.

2 Sources are as follows: EIA for US and IEA WEIO for other economies.

# Fossil fuels dominate in the BAU and even in High-nuclear, but …

## APEC electricity generation, BAU



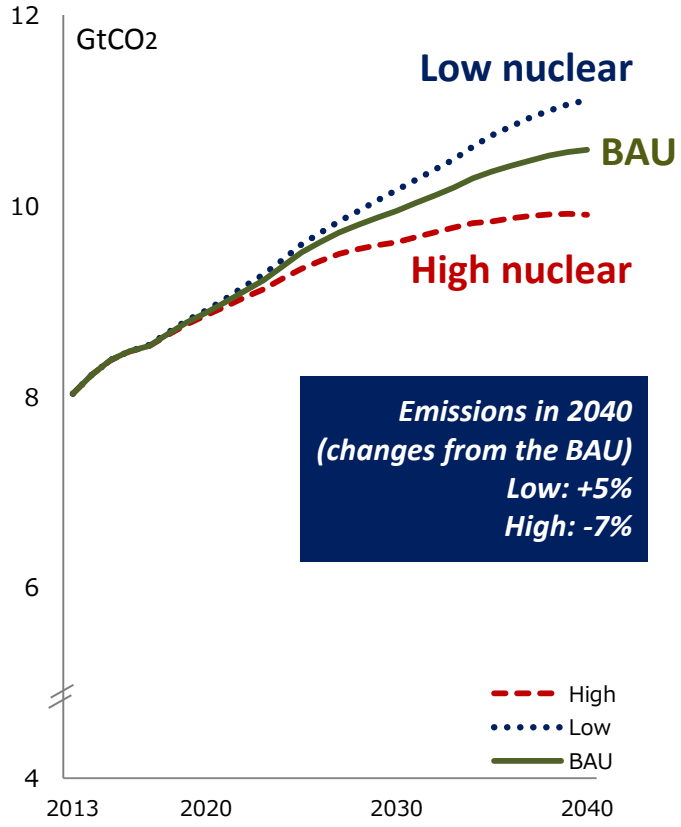




- Fossil fuels dominate in the BAU scenario, and even in the High nuclear scenario, although accelerated nuclear development contributes to reducing fossil fuel generation.

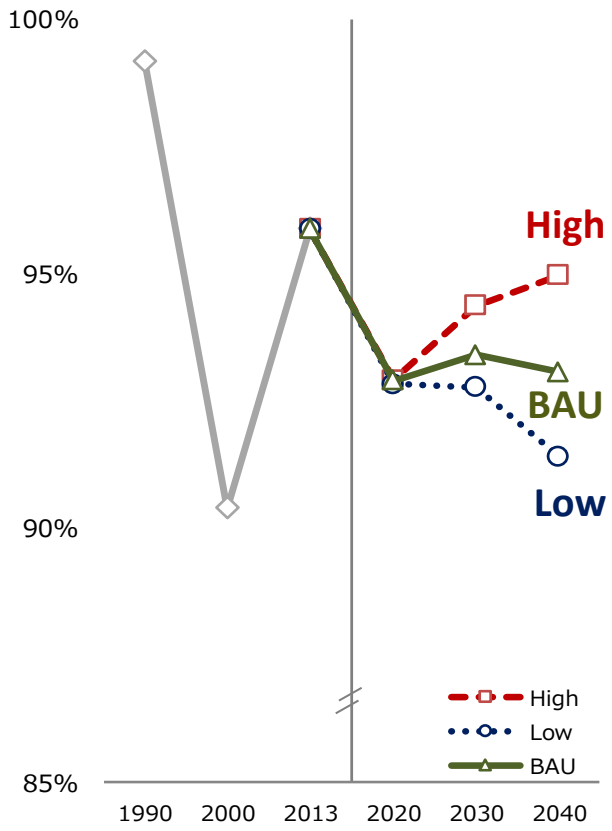
Source: APERC.

# … but, nuclear contributes to APEC from the "3E" perspective

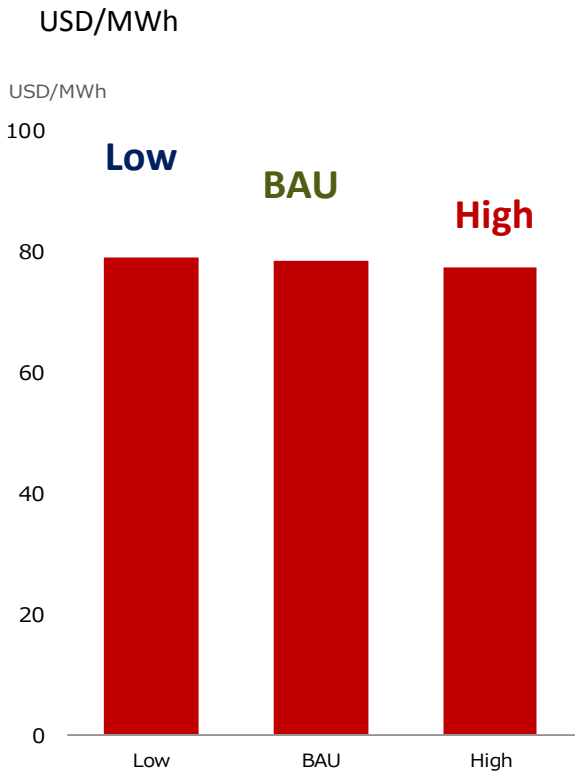
## APEC Annual emissions[1]




## APEC Energy self-sufficiency rate




## APEC Average cost, 2040

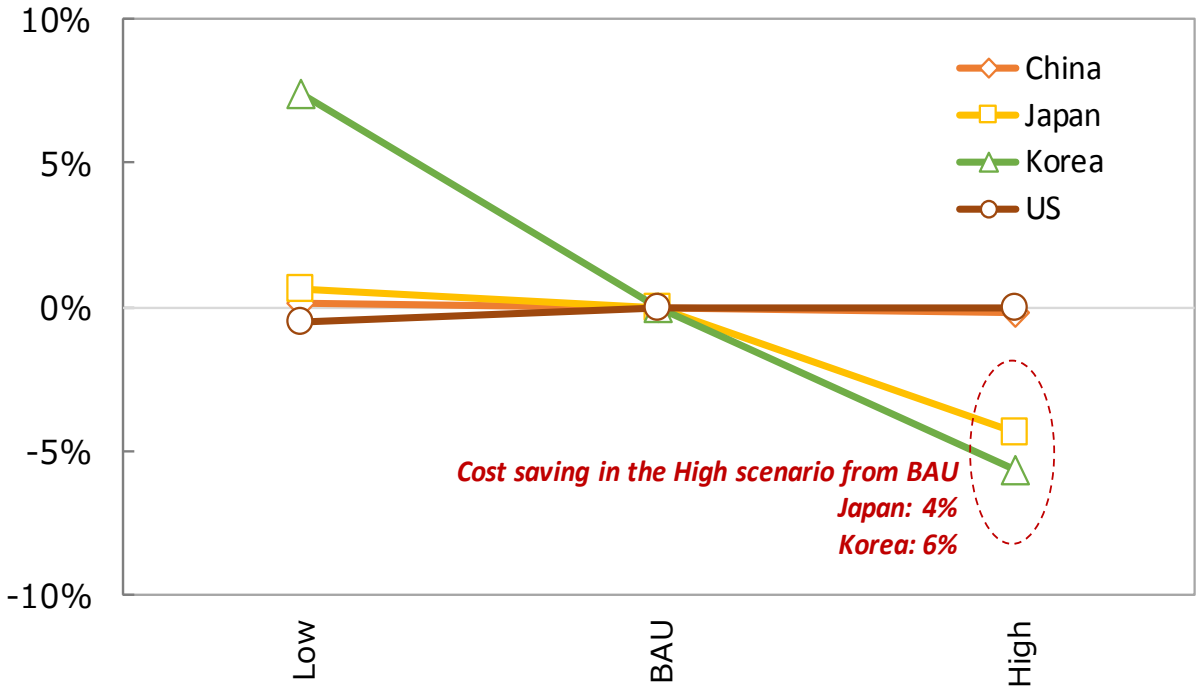



1 Emissions from electricity generation in APEC

Source: APERC.

# Economic impacts vary by economy, reflecting cost-competitiveness of the technology

## Generation cost changes relative to BAU, 2040, selected economies

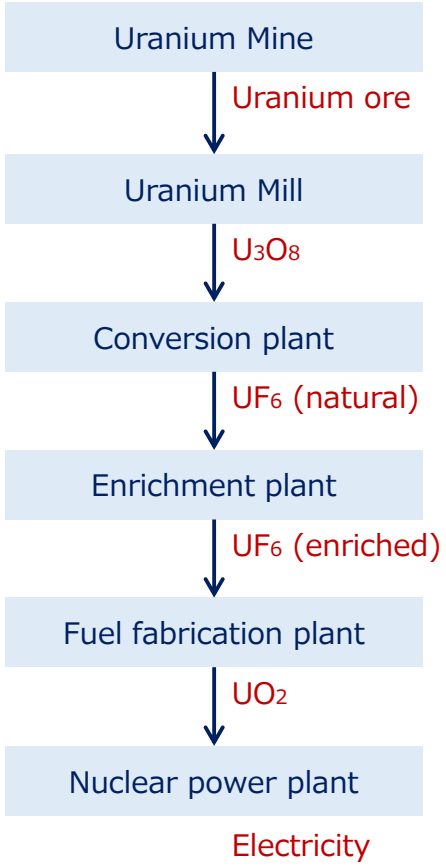



- In general, larger impacts on “energy importing” economies, such as Japan and Korea (-4% and -6% in High, respectively)
- Changes in China and US are relatively small

Source: APERC.

# A sub-model to estimate uranium consumption and spent fuel

## Front-end model (LWR[1] model as an example)



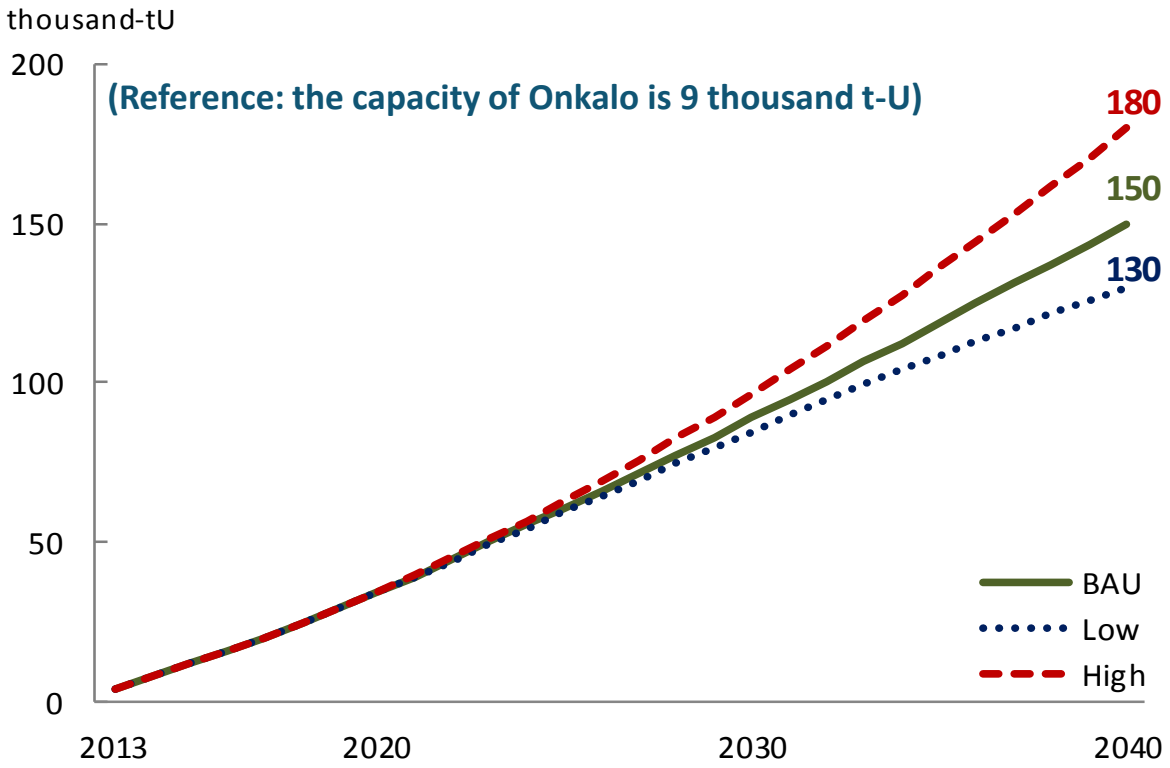

- Losses: 0.5%
- Product assay: **4**wt-% $U_{235}$ (BWR/PWR/ABWR/APWR), **2.4**% (LWGR)
- Tail assay: **0.3**wt-% $U_{235}$ (all LWR reactors)
- Losses: 1%
- Fuel burnup: **45**MWd/tU (BWR/PWR/ABWR/APWR), **15**MWd/tU (LWGR)
- Efficiency: **34.5**% (BWR/PWR/ABWR/APWR), **33.3**% (LWGR)

1 LWR=Light Water Reactors. APERC also developed another model for heavy water reactors.

Source: World Information Service on Energy and APERC,

# Waste management: headache for nuclear utilizing economies

## Spent fuel (cumulative from 2013, APEC)[1]




- Estimated amount of spent fuel reaches 130-179 thousand tons of Uranium; even Low-nuclear scenario reaches 70% of the level in High scenario
- Economies need to construct sufficient intermediate storage and final disposal facilities

1 This estimation assumes a once-through fuel cycle for all economies.

Source: APERC.

# Conclusion

- This study examined the impacts of three nuclear scenarios on APEC's generation mix
- Future nuclear development in the APEC region is driven mainly by China, increasing its presence in nuclear generation in Asia-Pacific
- Nuclear power contributes to the APEC region from the "3E" perspective, especially in terms of Environment
- Despite the capacity growth in the BAU, the share of nuclear remains around the current level due to increasing demand; further accelerated installation and license extension are important to increase the share
- A large amount of spent fuel is estimated even in the Low Scenario. Economies need to implement policies to construct sufficient facilities for storage and/or disposal

# Thank you for your kind attention!

Website link to the full report: http://aperc.ieej.or.jp/file/2017/8/30/APERC_Nuclear_Power_AsiaPacific_Final.pdf

http://aperc.ieej.or.jp/

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