Nuclear Power in the Asia-Pacific Region: Current Status and Future Perspective

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This paper presents the current status and future perspective of nuclear power in the APEC region. We design three scenarios, including Low-nuclear Scenario, Business-as-Usual Scenario (BAU) as well as High-nuclear Scenario, in order to quantitatively evaluate contribution of nuclear power to the low-carbon energy system. Preliminary results from the modeling are presented in the paper, and the drivers and challenges for nuclear power development in the APEC region are discussed.

Keywords: Nuclear Power, Asia-Pacific Region, Electricity, Low-carbon Energy

1. Introduction

The Asia-Pacific Energy Cooperation (APEC) region accounts for more than half of the world real GDP and about 60% of the world's energy demand. In terms of nuclear power, APEC is also the most active region. Among the 21 APEC member economies, 13 economies either use nuclear-based generation or have plans to develop it in the future [1]. As shown in Table.1, by the end of 2015, a total number of 262 nuclear reactors are in commercial operation, accounting for 60% of the world share, 44 reactor units are under construction in APEC, accounting for 69% of the world share [2]. It is believed that the APEC region has the biggest potential for the future nuclear power development.

In the APEC Energy Demand and Supply Outlook 6th Edition, different alternative power scenarios were introduced along with Business-as-Usual Scenario (BAU), including a high-nuclear case [1]. In order to further study the contribution of nuclear power and support analysis on a sustainable and low-carbon energy path for APEC, we conducted research on the future development of nuclear power in APEC, and made analysis on the major drivers and challenges for nuclear in this region.

2. Methodology

Based on the evaluation of all potential projects and development plan for nuclear power in each APEC economy, three nuclear power scenarios were designed, including Business-as-Usual Scenario (BAU), High-Nuclear Scenario (HN) and Low-nuclear Scenario (LN).

Operational nuclear reactor unit number	262
Operational nuclear capacity (GW)	236.85
Nuclear reactor under construction unit number	44
Nuclear capacity under construction (GW)	47.44
APEC total electricity generation in 2015	13 052
APEC total nuclear electricity generation in 2015 (TWh)	1 468
Nuclear share in APEC (2015)	10.46%
Nuclear share in the world (2015)	10.8%

Table 1: APEC nuclear power indicators by the end of 2015

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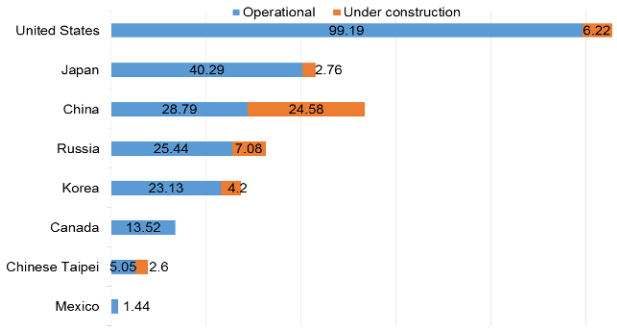

Figure 1: Nuclear capacity in APEC economies (GW), by the end of 2015

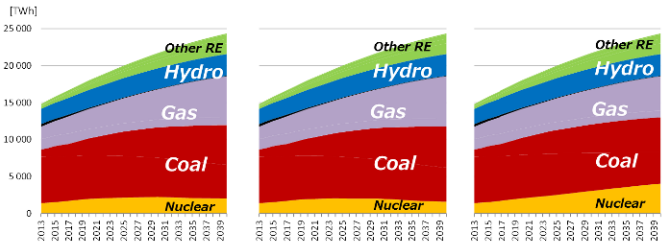

Figure 2: APEC power generation mix by 2040, from the left to the right: LN scenario, BAU and HN scenario

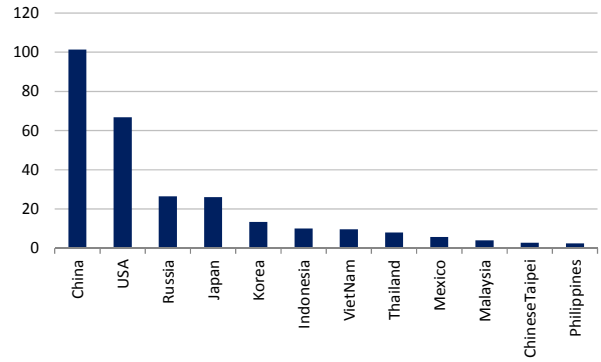

Figure 3: The contribution from economies to the nuclear capacity (GW) change from BAU to HN

Definition and assumptions of the three scenarios is as follows:

(1) BAU: It is based on current development plan in each economy, and 60 year operation life for current reactors is assumed. The BAU scenario is the same with our projection in the APEC Energy Supply and Demand Outlook 6th Edition, We project 283 GW nuclear capacity for APEC by 2040 [1].

(2) HN scenario: All the projects in the plan will be commisioned on time, and more capacity than planed will be commissioned on time (based on the evaluation of the new projects in the middle-term and long-term plan). 80 year operation life time for the current reactors is assumed. Based on these auumptions, we project 483 GW nuclear power capacity by 2040 for the HN case, more than double of the LN case. China will deploy 178 GW nuclear power, and South-East Asian economies including Viet Nam, Malaysia, the Philipnes, Indonesia and Thailand are assumed to deploy 23 GW nuclear power in total.

(3) LN scenario: Some new projects in South-East Asian economies will be cancelled or delayed; Most of the plans could not be met by 2040; 40 year operation life for current reactors is assumed. Baed on these assumptions, we project 219 GW nuclear power capacity by 2040. China will deploy 105.5 GW nuclear power, less than its 150 GW target for 2030. The South-East Asian economies will not deploy nuclaer power before 2040. The USA will decrese its nuclear capacity to 50.4 GW by 2040.

As shown in Figure 2, in APEC power mix, the share of nuclear power under BAU, HN and LN is 8%, 16.5% and 6.5% respectively. As shown in Figure 3, the biggest contribution for the capacity change from BAU to HN comes from China, USA, Russia and Japan, assuming that China will deploy more new projects and the other three economies will extend the life of current reactors and reduce the retiring reactor number by 2040. Figure 4 presents the capacity and power generation trend during the projection period between 2013 and 2040.

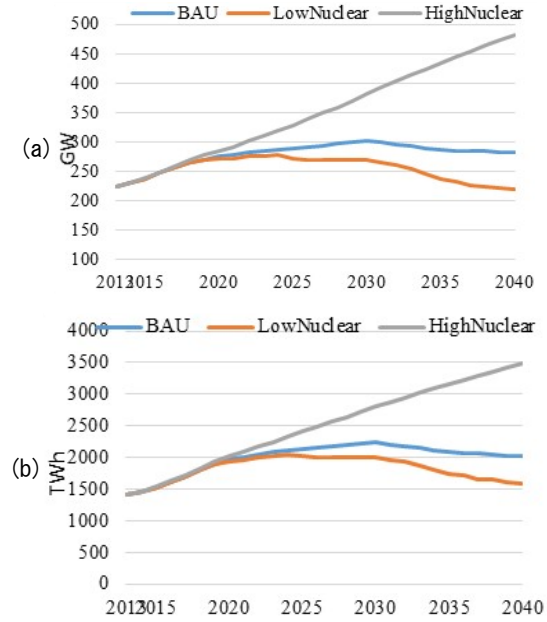

Figure 4: (a) Capacity projection under BAU, LN and HN scenario; (b) Power generation projection under BAU, LN and HN scenario

3. Preliminary results

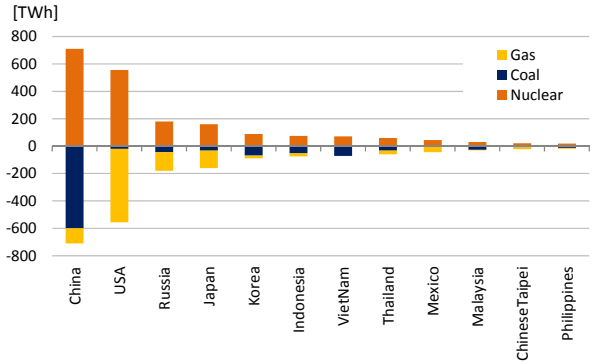

Figure 5: Generation changes from BAU to HN scenario 2040

The modelling is based on analysis of the 6th Edition APEC Energy Supply and Demand Outlook. We assumes the new nuclear capacity will replace the coal and gas in HN case (as shown in Figure 5). In China, we assume most of the new nuclear power capacity will replace coal power, as the coal share in China is more than 60 percent. While considering the power mix in the USA, most of the new nuclear power will replace gas. For the other economies such as Russia, Korea, South-East Asia economies, Chinese Taipei, we evaluate the current situation of energy supply to determine the suitable assumption for LN and HN scenarios.

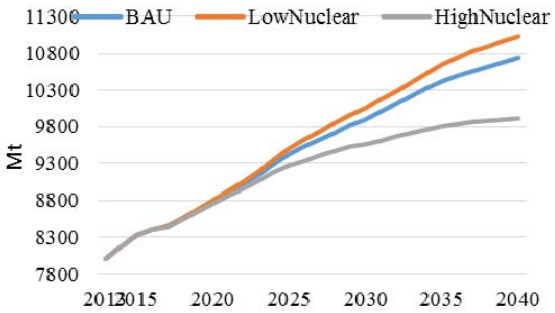

Figure 6: CO_2 emission projection from power sector

As shown in Figure 6, according to the modelling results by 2040 HN case would reduce 1130 Mt CO2 emission compared with LN case, as well as 829 Mt CO2 compared with BAU. The CO2 reduction from BAU to HN accounts about 9% of the total CO2 emission from the power sector.

4. Drivers for nuclear power development in APEC

4.1 The growth of energy demand in APEC

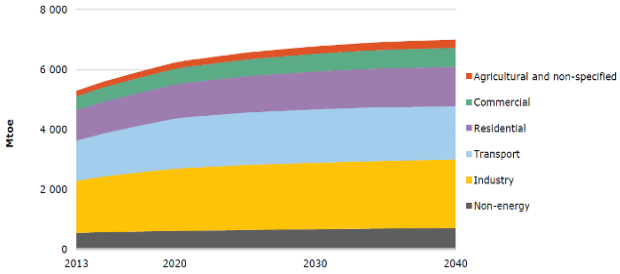

Figure 7: APEC final energy demand projection by sector [1)]

According to the 6th Edition APEC Energy Demand and Supply Outlook, energy demand in the APEC Region will keep growing in the next decades. As shown in Figure 7, total final energy demand in the APEC Region reaches 7 000 Mtoe in 2040, a 32% increase from the 2013 level of 5 293 Mtoe that represents an AAGR of 1%. China and South-East Asia will be the main drivers of this increase. With the advantage of high energy density, nuclear power can be a choice to meet the energy demand growth in the APEC Region.

4.2 The environment pressure and CO2 emission issues

Pollution becomes a critical issue to the emerging economies, especially China and the South-East Asian economies. As a clean energy without pollutant emission, nuclear power should play important role to address local environmental problems [3)]. In additional, addressing climate change becomes a hot topic recently. In total, 19 economies from the APEC region are participating in the United Nations Framework Convention on Climate Change (UNFCCC) process, all of which submitted Intended Nationally Determined Contributions (INDCs) for COP21 in December 2015. Based on an evaluation of all INDCs, we estimate the total emissions in 2030 to range from 19.6 Gt CO_2 to 21.7 Gt CO_2, representing an increase in energy related emissions of between 8% and 19% compared with the 2010 level of 18.5 Gt CO_2 [1)]. Nuclear power will play an important role in reducing CO_2 emission and achieve APEC economies' emission target.

4.3 To reduce fossil fuel and improve energy security

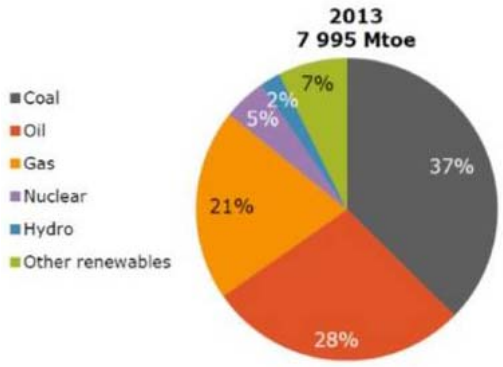

Figure 8: APEC total energy supply by fuel, 2013 [4)]

As shown in Figure 8, fossil fuels dominate the APEC energy mix. In 2013, 86% of total primary energy supply came from fossil fuels. Coal demand in APEC doubled from 1990 to 2013, reaching 3 000 Mtoe (IEA, 2013). In the emerging economies in APEC, especially China and South-East Asian economies, industry is the major driver in energy demand growth, which needs more stable base-load energy. Thus, nuclear power should be more suitable in fossil fuel reduction than intermittent renewables.

Energy security has been one of the highest priorities for APEC economies. As the definition of energy security is an on-going discussion, here we only focus on self-sufficiency. We analysis finds that nearly half of APEC members will have self-sufficiency levels below 60% by 2040 [1)]. The nuclear power will greatly contribute to the improvement of energy-sufficiency, especially in Japan and Korea, whose energy self-sufficiency rates are even lower than 25%.

5. Challenges

5.1 The concerns for nuclear safety

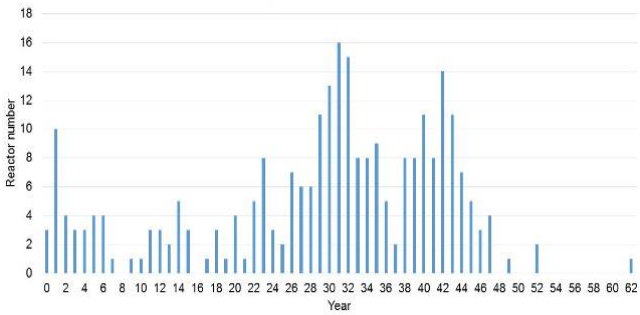

Figure 9: The age of nuclear power fleet in APEC

Nuclear safety is always a big concern in all economies. For the nuclear power economies in APEC, the ageing nuclear power fleet is one of the challenges. Among the operational reactors, 159 reactors are more than 30 years old, accounting for more than 60%. And 212 reactors are more than 20 years old, accounting for more than 80%. It is noteworthy that in the 1980s, 97 power reactors were commissioned in the APEC Region, including 47 in USA, 18 in Japan and 14 in Russia. All of them are the Second Generation (Gen II) reactors, and now need careful assessment of nuclear safety. For the new comer economies in APEC, nuclear safety is also the most important issue they need to carefully consider. A lot of work need to be done before they determine to deploy a nuclear power plant, including an effective regulation system, technology evaluation, radioactive material control, environment protection, emergency response capability, etc [5)].

On the other hand, with the development of novel nuclear technologies especially the Third Generation (Gen III) and the Fourth Generation (Gen IV) reactors in the past decade, nuclear safety has been greatly improved. The first AP1000 reactor will be commissioned early next year in China, which is regarded as the first real Gen III reactor in the world. Also, the Gen IV reactor as well as small modular reactor (SMR) is in the process to realise deployment in the near future.

5.2 Public acceptance

In the aftermath of the Fukushima Dai-ichi Accident numerous public opinion surveys were conducted, A multi-country comparison of surveys with similar questions about whether respondents support or oppose nuclear power or view nuclear power favourably or unfavourably was conducted by Ipsos in the end of 2011 (some results shown in Figure.10). We can find the public acceptance is still relatively low in some economies. The APEC economies which will continue or start nuclear power generation need to muster a sustained effort to provide the general public with open, honest and balanced information.

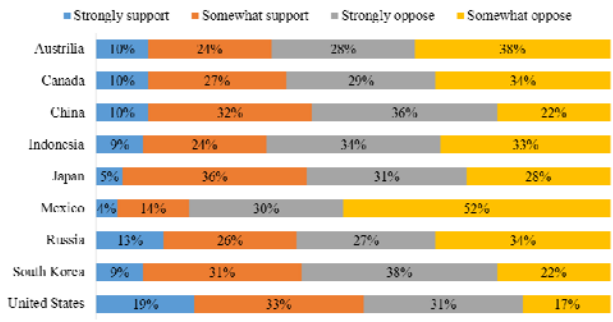

Figure 10: Survey results by Ipsos, the public attitute towards nuclear power

5.3 Investment and economic competitiveness

The economics of new nuclear power plants is always a controversial subject. New nuclear power plants typically (such as AP1000 and EPR) have high capital costs for building the first several plants, after which costs tend to fall for each additional plant built as the supply chains develop and the regulatory processes settle down. However, one of the advantages for nuclear power is that fuel costs only contribute a minor proportion of total generating costs, which is much smaller than thermal power plants.

According to our research, economic competitiveness becomes a challenge for nuclear power in USA and Canada, where can acquire plenty of low price shale-gas. In 2014, the US Energy Information Administration estimated the levelized cost of electricity (LCOE) from new nuclear power plants going online in 2019 to be $0.096 /kWh before government subsidies, comparable to the cost of electricity from a new coal-fired power plant without carbon capture, but higher than the cost from natural gas-fired plants. According to the study, in China and South-East Asian economies, it is not a big issue as the LCOE of nuclear power is still comparable with that of coal power and less than that of gas power since they do not have low-price shale-gas. In China, the nuclear power price follows a standard pricing formula approved by the central government. Most of the provinces in China use the price of 0.43 RMB/kWh (about $0.065 /kWh) for nuclear power.

5.4 Nuclear waste

There are currently no operating disposal facilities for high level radioactive waste in the APEC Region, and spent fuel inventories are therefore growing. All spent fuels are initially stored under water in storage pools at reactor facilities for between 9 months and several decades, depending on the storage capacities of the pools. After that, the used fuels may be reprocessed to recover fissile and fertile materials in order to provide fresh fuel for existing and future nuclear power plants. Currently in the APEC region, Russia, China and Japan have policies to reprocess used nuclear fuel. They will be transported to a reprocessing facility and stored there in buffer storage pools before being fed into the process.

The USA and Canada have currently opted for direct disposal. Dry cask storage, which is a new technology was used in the USA and Canada. It is more limited in heat dissipation capability than wet storage, but has the advantage of being modular, which spreads capital investments over time, and, in the longer term, the simpler passive cooling systems used in dry storage reduce operation and maintenance requirements and costs. In the USA, by the end of 2009, 13,856 metric tons of commercial spent fuel in dry casks. In Canada, some above-ground dry storage sites has been used and some are under construction.

For the economies who have deployed nuclear power plants for a relatively long time, such as USA, Russia, South Korea and Japan, nuclear waste disposal and storage becomes a serious problem to be addressed, as storage space grows tight at plant sites and more storage sites are needed. However, for the new comer economies, it is not so critical for the nuclear power development at the beginning. But they should pay attention and draft a long-term plan to this issue before nuclear power deployment.

6. Conclusion

According to our research, nuclear power can be a feasible choice for a sustainable and cleaner energy system in future, especially considering the climate change issues and energy security.

However, after Fukushima Accident, public attitude towards nuclear power has changed and the future is still uncertain. Nuclear safety, public acceptance

and nuclear waste disposal and storage are the challenges which should be addressed. Also the economic competitiveness still has uncertainty due to the unstable fuel prices. We will contemplate possible regional cooperation among APEC economies, in order to promote the development of nuclear power and find a sustainable path for cleaner energy future.

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