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The prospects of small modular reactors in Southeast Asia

Victor Nian

Energy Studies Institute, National University of Singapore, Singapore

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ABSTRACT

The size of a nuclear reactor has increased from below 300 MWe to more than 1000 MWe to achieve better economies of scale since the 1950s. Across the 1970s and 1980s, severe nuclear accidents, completion time overrun, escalating construction cost, and strong negative public perception are among the main factors leading to a slowdown in nuclear energy developments. Post-Fukushima, nuclear energy remains an important option for addressing energy security and decarbonization for developing economies, especially those in the Association of South East Asian Nations (ASEAN). However, a Fukushima-scale accident occurring in ASEAN could lead to severe trans-boundary impacts to several ASEAN members due to close geographical proximity. With the emergence of small modular reactors (SMRs), the conceivable advantages of SMRs over large reactors in the ASEAN context is yet to be assessed. In response, this study provides an analysis on the economic, safety, and other aspects of SMRs, and a review on the developments in nuclear energy in ASEAN. Findings from this study suggest SMRs as a strategic option in ASEAN's long-term energy planning. While SMRs are still under design and development (some under demonstration), ASEAN needs to build up competence in nuclear energy through training and education, and international and regional cooperation.

1. Introduction

The development of nuclear energy started with the first pressurized water reactor (PWR) constructed by Westinghouse in the 1950s at Shippingport. According to data published by the Nuclear Energy Agency (NEA, 2013), the International Energy Agency (IEA, 2015a), the Energy Information Administration (EIA, 2013c), and Enerdata (2016), the global electricity generating capacity from nuclear energy has increased steadily across the 1960s and 1970s suppling nearly 18% of world's electricity at its peak just after the Chernobyl accident until the 1990s followed by a steady decline (Fig. 1). The slow-down is primarily due to high and potentially escalating cost of reactor construction (Grubler, 2010; Koomey and Hultman, 2007), increased requirements for safety and safeguards (Qian, 1986) and strong negative public perception.

The size of a nuclear reactor was small and less than 300 MWe in the early development of nuclear energy. In the pursuit of the economies of scale, the size of a nuclear reactor has quickly increased to more than 1000 MWe. The increase in size and complexity has led to increased risks associated with construction time overrun and hence cost escalation (Escobar-Rangel and Lévêque, 2015; Grubler, 2010; Koomey and Hultman, 2007). Although nuclear energy is economically competitive when measured by the levelized cost of electricity (LCOE) as seen in (IEA, 2015b), the construction of large sized reactors still faces the risks associated with high capital commitment and uncertainties during construction.

Decades after the Three Mile Island and Chernobyl accidents, the Fukushima Daiichi nuclear accident has again raised skepticism about nuclear safety. Despite the strong negative reactions seen in Germany and Switzerland post-Fukushima, developing economies such as China, India, and several members of the Association of South East Asian Nations (ASEAN) remain interested in nuclear energy. There are ten member states in ASEAN, namely, Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. Driven by fast economic development, Southeast Asia is on track to become a “net energy importer” by 2035 (ADB, 2013; IEA, 2013a). Further analysis by the IEA (2015c) shows that coal may play an important role in the electricity sector fuel mix in ASEAN to address affordability and diversification.

The use of coal is against the objective to rein the rising carbon emissions. Under the business-as-usual projections by the EIA (2013b), world carbon emissions in 2040 will be around 42% higher than in 2013. The Intergovernmental Panel on Climate

E-mail address: nian@nus.edu.sg.

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Nomenclature

Abbreviations

ARPA-E	Advanced Research Projects Agency – Energy (USA)
ASEAN	Association of South East Asian Nations
BATAN	National Nuclear Energy Agency (Indonesia)
BAPETEN	National Nuclear Energy Regulatory Agency (Indonesia)
BDBA	Beyond design-basis accident
BWR	Boiling Water Reactor
CCGT	Combined cycle gas turbine
CCS	Carbon capture and sequestration
CGNPC	China General Nuclear Power Corporation
CHP	Combined Heat and Power
CRANE	Center for Research and Applications of Nuclear Energy (Malaysia)
EIA	Energy Information Administration (USA)
EMA	Energy Market Authority (Singapore)
FNR	Fast-neutron reactor
GAIN	Gateway for Accelerated Innovation in Nuclear (USA)
GWD	Gigawatt-day
GWe	Gigawatt of electricity
HLW	High level waste
HTR	High temperature reactor
iPWR	Integral pressurized water reactor
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LCOE	Levelized Cost of Electricity
LOCA	Loss of coolant accident
MCCI	Molten corium-concrete interaction
MINT	Institute for Nuclear Technology Research (Malaysia)
MSFR	Molten salt fast-neutron reactor
Mt	Million tonnes
MWe	Megawatt of electricity
MWt	Megawatt of thermal energy
NEA	Nuclear Energy Agency (OECD)
NRC	Nuclear Regulatory Commission (USA)
O&M	Operations and Maintenance
PUSPATI	Tun Ismail Atomic Research Center (Malaysia)
PWR	Pressurized water reactor
SMR	Small modular reactor
TINT	Thailand Institute of Nuclear Technology
WNA	World Nuclear Association

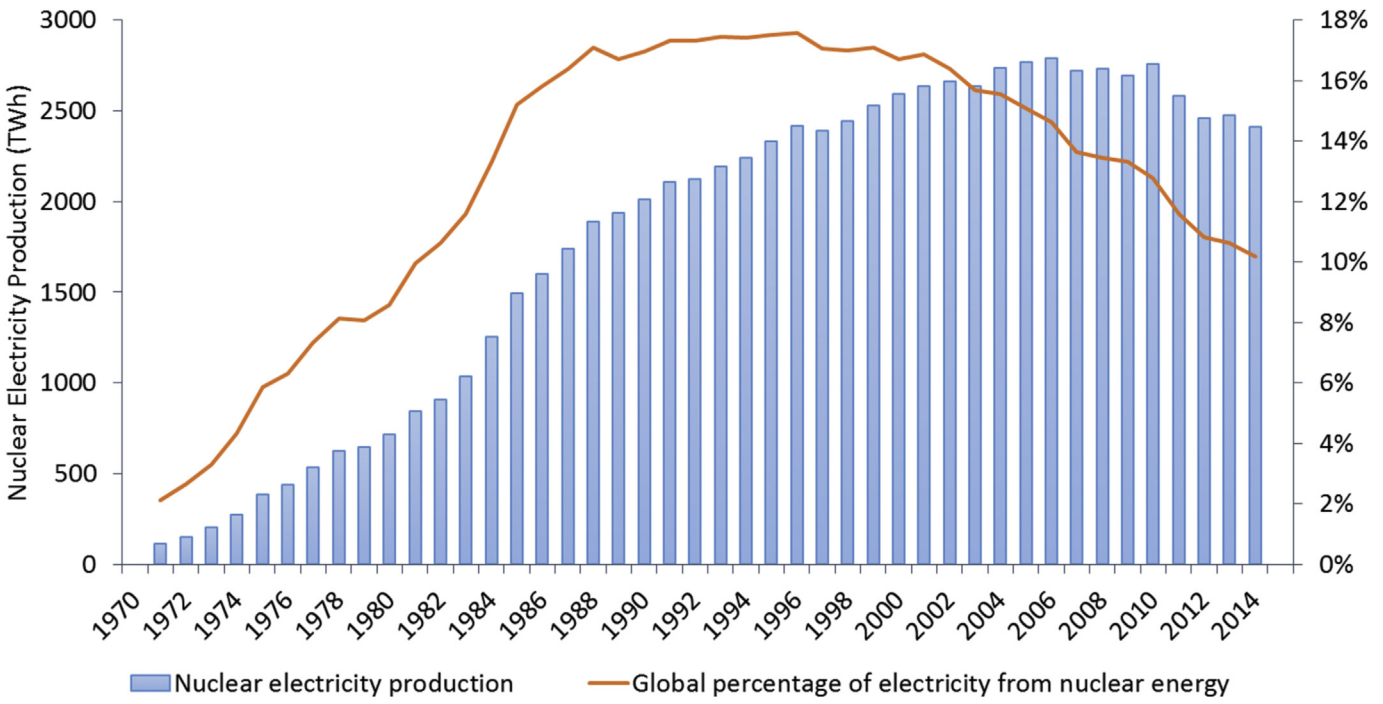

Fig. 1. Global electricity generation from nuclear energy.

Change (IPCC, 2013) predicts that these carbon emissions will likely result in the atmospheric carbon dioxide concentration reaching 500 ppm by 2040. With rising sea levels and intensified climatic and weather events, the IPCC (2014a) further outlines the importance of nuclear energy in achieving zero emission worldwide by 2100. In the context of ASEAN, the carbon emission from electricity generation is expected to increase from 450 million tonnes (Mt) in 2015 to 673 Mt in 2020, and to 1220 Mt in 2040 (IEA, 2015c). In the absence of practically feasible advanced energy technologies, nuclear energy remains a strategic option in addressing both decarbonization and energy security in ASEAN (Nian and Chou, 2014).

Vietnam had been the most active ASEAN member in advancing towards the construction of the first few nuclear reactors with a plan for 4600 MWe of nuclear capacity from 2020. Several other ASEAN members, such as Indonesia, Malaysia, and Thailand have also been actively studying the feasibility of nuclear energy. However, Vietnam has recently reached a decision to scrap the plans on

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