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Abstract

Ensuring nuclear safety has been an ongoing and significant concern worldwide. Although the Fukushima Daiichi nuclear power plant accident has undermined public confidence in its safety, many of Asia's emerging economies still have plans to introduce nuclear energy. This paper analyzes the possible development of nuclear energy in Asia's emerging economies and considers the implications for nuclear safety. The analysis reveals that insufficient financial, technical, and institutional capacities could be complemented by external support and assistance and that public acceptance is vital for launching nuclear power programs. While Asia's emerging economies expect regional or international cooperation and assistance from potential supplier countries, the regional cooperation framework for nuclear safety is underdeveloped and Asian supplier countries have insufficient capabilities, particularly in legal and regulatory aspects. An effective regional cooperation mechanism needs to be established to ensure nuclear safety, which requires immediate action from Japan.

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1. Introduction

Nuclear safety is concerned with achieving and maintaining a high level of safety for nuclear facilities and activities to protect individuals, society, and the environment against radiation risks. Safety also denotes preventing accidents and mitigating their consequences (IAEA 2007a). Ensuring nuclear safety has been a serious concern worldwide, particular since the Fukushima Daiichi nuclear power plant accident triggered by the massive earthquake and tsunami on March 11, 2011. The accident released considerable amounts of radioactive materials into the environment and over one hundred thousand people were reportedly evacuated from the vicinity of the plant (JICE 2012). The long-term health, environmental, and economic impacts have yet to be fully assessed, but the event reminded us that severe nuclear accidents potentially have transboundary consequences. The overall performance of nuclear power plants had steadily improved in many countries over the two decades preceding the accident. From the mid-2000s, rising demand for energy, the need to tackle climate change, and the quest for energy security spurred a renewed interest in nuclear energy development, and a growing number of countries began to consider incorporating nuclear energy into their electricity generation mix. An International Atomic Energy Agency (IAEA) report in September 2010 indicated that some 65 countries were expressing interest in introducing nuclear power (IAEA 2010a).

However, the Fukushima accident undermined public confidence in the safety of nuclear energy and consequently prompted a reconsideration of energy policies together with in-depth nuclear reactor safety reviews and a reevaluation of safety regulations. Several European countries have announced plans to phase out or cancel all of their existing and future reactors[1]. While some countries decided to slow the construction of nuclear power plants, many emerging economies still

[1] Germany decided to phase out nuclear power by 2022 (BBC 2011a); Italy accepted a referendum opposing the government's plans to resume nuclear power generation (BBC 2011b); Switzerland approved plans to phase out its nuclear plants by 2034 (AFP 2011); Spain remained opposed to new nuclear plant construction (WNA 2011f); Belgium plans to phase out nuclear power (BBC 2011c).

plan to introduce nuclear energy.

Estimate levels vary in the latest energy projections published by the IAEA, World Nuclear Association (WNA), and International Energy Agency (IEA), but all indicate that projected growth is highest in Asia. The IAEA's conservative projection sees the world's installed nuclear power capacity expanding from 375 GWe (gigawatt-electric) in 2010 to 501 GWe in 2030, while the higher projection has it growing to 746 GWe (IAEA 2011b). The number of operating reactors increases from the current 435 to 528 and 789 in those same estimates (IAEA 2011c). The WNA's conservative projection to 2030 sees reactors increasing to 602 (WNA 2011a, Table 1). The IEA Low Nuclear Case, which assumes that countries reconsider existing energy policies[2], has nuclear power capacity falling 15% from the end-of-2010 level, to 335 GWe in 2035 (IEA 2011). The New Policies Scenario, which assumes that recent government commitments are implemented cautiously, sees nuclear generation growing about 70% over the period from 2010 to 2035. Looking at nuclear reactors under construction by region (Table 2), Asia dominates future growth, accounting for more than two-thirds of construction worldwide, which raises an important question: Is the current nuclear safety framework capable of managing such a substantial increase of nuclear power plants in Asia? What measures are being taken to ensure that plants are operated safely?

The IAEA provides expert safety review services at a member state's request and one of the leading types of review missions is the Operational Safety Review Team (OSART) missions that conduct in-depth reviews of the operational safety performance of nuclear power plants. Over 160 such missions have been conducted since 1982, but a comparison between the number of reactors operable and the number of past OSART missions (Tables 1 and 2) reveals that Asian countries have invited far fewer missions than the countries in Latin America, Europe, and Africa have. Although the United States has also hosted fewer missions, the Institute for Nuclear Power Operations (INPO),

[2] The IEA's Low Nuclear Case assumes that no new OECD reactors are built, non-OECD countries build only half of the additions projected in the New Policies Scenario, and that the operating lifespan of existing nuclear plants is shortened.

a non-profit organization established by the US nuclear power industry in 1979 following the Three Mile Island accident, conducts evaluations of all nuclear power plants every 18-24 months. By facilitating the sharing of best practices and conducting peer reviews, the INPO has helped improved the performance of US plants. US nuclear operators take the INPO's reviews so seriously that they initiate changes when peer reviews yield low INPO ratings (Joskow and Parsons 2012). The World Association of Nuclear Operators (WANO), a non-profit organization established in 1989 in response to the Chernobyl accident, has also conducted 496 operating station peer reviews in 34 countries/areas since 1992 (WANO 2012). WANO's goal is to conduct a peer review at each nuclear unit at least once every six years, but this has yet to be achieved. Hence, US plants are actually evaluated more frequently and rigorously than those in other countries.

Expectations following the Fukushima accident are that safety standards will be upgraded, the regulatory framework strengthened, and life extension of nuclear power plants shortened. The new regulatory requirements are likely to contribute to increased construction costs, operator liability, national liability, and insurance (UBS 2011). Will Asia's newcomer countries be able to deploy nuclear energy in the face of these costly changes? If so, what impact will nuclear expansion have on the global nuclear safety framework? And what can be done to strengthen nuclear safety? Motivated by these questions, this study analyzes the capacities of Asian newcomer countries in order to explore their possible development to 2030, considers the implications for the global nuclear safety framework, and seeks to identify the gaps vis-à-vis recent international efforts to enhance nuclear safety.

In recent years, research into nuclear energy has been increasingly diverse in its approaches. Some studies analyze supporting factors and barriers for nuclear energy development to provide insights into future prospects. For example, Valentine and Sovacool (2010), by analyzing the socio-cultural, political, and economic conditions of nuclear power programs in Japan and South

Korea, identify six common supporting factors, including strong state involvement in economic development and low levels of civic activism. Jewell (2011a) assesses 52 newcomer countries in terms of their capacities and motivations for developing nuclear power programs by identifying indicators for these factors and comparing these capacities and motivations to those of countries with established nuclear energy programs (NP countries[3]). The study suggests that the majority of newcomer countries may face significant barriers in developing technical and institutional infrastructure since they have smaller economies and less efficient institutions than NP countries. Jewell (2011b) developed this analysis to evaluate in what form and under what conditions nuclear energy could be introduced in North African countries and found that external conditions such as technical and financial assistance are nearly as important as domestic development. This paper uses some of Jewell's methodologies and examines other factors including state participation in relevant international treaties to analyze the possible development of nuclear energy in Asian newcomer countries. The first observation is largely similar to the study on North African countries: Asian newcomers lack adequate capacity and will thus need external cooperation and assistance to deploy nuclear power. A striking difference is that following the Fukushima accident, public acceptance is found to be vital for launching a nuclear power program. Public opposition is presenting difficulty for newcomer countries with relatively high capacities as they seek to proceed with nuclear energy. In this sense, future developments in Asia will hinge on how and when public confidence in the use of nuclear energy will be restored, which also depends on how the global nuclear safety framework will be strengthened.

Findlay (2011) analyzed drivers of and constraints on nuclear energy development, considers the implications of the nuclear energy revival for global governance in the areas of safety, security, and non-proliferation, and provides recommendations for strengthening global governance.

[3] Jewell referred to "established NP countries" but in this paper countries operating nuclear power plants are simply called "NP countries."

His analysis suggests that global expansion of nuclear energy up to 2030 will be slower and less extensive than that indicated in many forecasts, but he argued that global governance arrangements need to be reformed since many aspects of nuclear regimes are not optimally effective or are under threat. His work proved to be so comprehensive and insightful that some of his recommendations are now being adopted, with several others expected to be implemented over the medium to long term. However, a pressing need to strengthen nuclear safety has surfaced following the Fukushima accident and it is imperative to implement measures in the region where the greatest nuclear power growth is expected.

The Fukushima accident reinforced the view that nuclear safety is a transnational issue requiring international cooperation, and a number of international initiatives designed for improving safety were taken in response. For instance, in September 2011, the world's leading nuclear power plant vendors adopted the Principles of Conduct, which reflect global best practices in connection with the export of nuclear power plants. This initiative was led by the Carnegie Endowment for International Peace and at the launch of the principles, Richard Giordano, chairman of the Board of Trustees for the Carnegie Endowment, said:

> Whatever lessons particular countries draw from Fukushima over time, new nuclear plants will continue to be built, some in countries that have only recently begun to utilize nuclear power. It is therefore imperative that nuclear energy is implemented safely and responsibly in both emerging and developed markets (Carnegie Endowment 2011).

Japan is reviewing its energy policy and the accident investigation committee is slated to release a final report at the end of July 2012. The government intends to develop a new energy policy by summer 2012 but has already stated that it would minimize its dependency on nuclear energy over the medium to long terms (METI 2011). Even though Japan decided to move away from nuclear energy, it needs to consider means of strengthening nuclear safety since the country is responsible for decommissioning all its nuclear power plants and managing radioactive waste over the long term. As Hans Blix, then head of the IAEA, pointed out, “The image of nuclear safety is international; a serious accident anywhere affects the public’s view of nuclear power everywhere” (IAEA 1996). Thus, strengthening nuclear safety will impact the public view worldwide. The next section of this paper applies quantitative indicators and qualitative information to analyze Asian newcomers’ capacities to deploy nuclear power. Section 3 examines participation in the relevant international conventions and treaties of both Asian newcomers and all NP countries. Section 4 analyzes the possibilities surrounding development of nuclear energy by Asian newcomers. Section 5 considers the implications of nuclear expansion in Asia for the global nuclear safety framework. Section 6 provides a brief overview of international cooperation in the area of nuclear safety in response to the Fukushima accident and seeks to identify gaps in this cooperation. This study concludes with recommendations for strengthening the global nuclear safety framework.

2. Asian newcomers’ capacities for developing nuclear energy

Many Asian countries plan to introduce nuclear energy, and this section analyzes the capacities and motivations of ten Asian newcomer countries covered in the WNA’s report “Emerging Nuclear Energy Countries” (WNA 2011e): Bangladesh, Indonesia, Kazakhstan[4], Malaysia, Mongolia, the Philippines, Singapore, Sri Lanka, Thailand, and Vietnam. Table 3 summarizes governments’ announced plans and policies as well as recent IAEA missions. The IAEA, in its publication *Milestones in the Development of a National Infrastructure for Nuclear Power,* advises states considering the introduction of nuclear power to initiate the following activities: develop a comprehensive nuclear legal framework; establish an effective regulatory system; develop human resources; ensure adequate financial resources; develop a program for all aspects of operation, decommissioning, and radioactive waste management; manage nuclear materials for the long term;

[4] Kazakhstan operated one nuclear power reactor from 1972 to 1999 but this study includes it as a newcomer.

and communicate with the public and the neighboring states openly and transparently (IAEA 2007b: 3-4). The IAEA's Integrated Nuclear Infrastructure Review (INIR) is designed to assist member states, at their request, in evaluating the status of their national infrastructure for the introduction of a nuclear power program. Bangladesh, Indonesia, Thailand, and Vietnam have hosted INIR missions, and the IAEA made numerous recommendations to help them further develop their national infrastructure. Although it is not possible to comprehensively analyze all of the above activities, this section uses quantitative indicators to assess the financial, technical, and institutional capacities of Asian newcomers, and qualitative information to consider other factors affecting nuclear energy development.

2.1. Methodologies

The analysis of capacities and motivations of Asian newcomer countries takes an approach similar to Jewell's (2011b) study and uses the indicators she identified for these factors, with the exception of those for energy security motivation. First, it is assumed that newcomers will build a 1 GWe or greater nuclear power plant (NPP). The reasons are as follows: The average reactor size in operation in 2010 was 850 MWe (megawatt-electric) (IAEA 2010a) and since 2004 construction has begun on a total of 12 small- and medium-sized reactors[5] (SMRs) in just four countries – India, Pakistan, China, and Russia (IAEA 2012a). Although interest in small reactors has been growing because of the potential they offer for reduced capital costs and the suitability of their use in smaller grids, there remain development challenges to overcome and regulatory approvals to obtain before they can be deployed (Lokhov et al. 2011). Since Kazakhstan and Mongolia are considering SMR deployment and Indonesia plans to build a 200 KWe (kilowatt-electric) reactor[6], the possibility of SMRs is not

[5] The IAEA defines "small" and "medium" respectively as under 300 MWe and up to 700 MWe.

[6] The Indonesian government gave initial approval for the construction of a 200 KWe plant and a 2 MW plant in late-November 2011, though its long-term development plans did not include such small-scale plants.

entirely excluded from this analysis. However, to avoid complications resulting from different assumptions, analysis of the capacities is based on the assumption of a 1 GWe or greater reactor.

Financial capacity

The high complexity and capital intensiveness in constructing a nuclear power project necessitates long lead-time and substantial investment. Construction costs for nuclear power plants have escalated dramatically since the mid-1980s. A study of the overnight capital costs (i.e., the costs of a construction project if no interest is incurred during construction) for nuclear power plants indicates that the costs for completed plants in the 1970s and early 1980s ranged from $1,000/kW to $3,000/kW and in the late-1980s to early 1990s were about $2,000-$7,000/kW (Cooper 2009). According to recent data[7] since 2008, these costs are $2,500-$6,200/kW in North America, $2,000-$5,800/kW in Europe, and $1,500-$3,800/kW (i.e., $1.5 billion-$3.8 billion for a 1 GWe NPP) in Asia (Barkatullah 2012). For most of the Asian newcomers, export financing and local or foreign commercial financing are the likely instruments for a nuclear power project. A country's GDP[8] is used to assess its financial capacity for deploying nuclear energy. GDP per capita measured at purchasing power parity (PPP) in fixed 2005 international dollars is also used to compare the financial capacity of Asian newcomer countries to that of NP countries at the time of starting construction on their first NPP[9]. As Jewell indicates, the GDP of NP countries at the time of construction ranged from 13 billion USD_{2000} (constant 2000 US dollars) to over 2 trillion USD_{2000} (Jewell 2011a: 1048). The GDP per capita PPP of NP countries at the time of construction ranged from $700 to $22,200 GDP per capita (Appendix 1). Given the recent sharp increase in construction

7 All data are in 2008 US dollars.

8 GDP at international exchange rates is used since newcomers in Asia will import nuclear technology and expertise to construct their first NPP; therefore, the market exchange rate is relevant to financial capacity (see Jewell study [2011a: 1044] for more details).

9 As in the case of Jewell's study, only NPPs of greater than 100 MWe are considered in order to exclude reactors built solely for research purposes.

costs, the low boundary of GDP and GDP per capita PPP of NP countries at the time of construction is too low for newcomers to actually deploy nuclear power. Pakistan is the only NP country that started construction with GDP below 50 billion USD_{2000} (Table 4). Pakistan, India, and China are the only three NP countries with a GDP per capita PPP of less than $2,000 at the time of construction. Therefore, the historical benchmarks for GDP and GDP per capita PPP are set to 50 billion USD_{2000} and $2,000, excluding the exceptionally low cases mentioned above. Looking at the current GDP and GDP per capita of Asian NP countries, Pakistan's level remained the lowest. Accordingly, a GDP of 120 billion USD_{2000} and GDP per capita of $2,600, equivalent to the figures for Pakistan, can be set as the current benchmarks.

Technical capacity

The IAEA advises that a single power plant represent no more than 5-10% of the total electricity installed capacity (IAEA 2007b: 39). Since it is assumed that a newcomer will introduce a 1 GWe or greater nuclear power plant, its electricity grid needs to be larger than 10 GWe, otherwise the international power grid needs to be connected. The existing grid size of newcomers is first examined by using data from the US Energy Information Administration (EIA 2010) on total electricity installed capacity. If it is less than 10 GWe, the number of years in which the size is projected to exceed 10 GWe, assuming compound linear growth, is calculated. For countries where the grid size is not projected to exceed 10 GWe, the latest status of international grid connections are considered.

Institutional capacity

It takes at least 10-15 years from the time of its initial policy decision for a state considering nuclear power to start operating its first NPP (IAEA 2007c: 3). With this initial implementation period, a time frame of at least 100 years should be considered for operation, decommissioning, and radioactive waste management. Therefore, adequate institutional capacity is required for newcomers not only to attract private and/or foreign investment in nuclear power, but also to manage such a long-term project. The Worldwide Governance Indicators (WGI) measure six dimensions of governance, of which the following three indicators are considered relevant to the development of nuclear power: government effectiveness (GE), measuring “perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies;” political stability and absence of violence/terrorism (PS), measuring “perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism;” and control of corruption (CC), capturing “perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as ‘capture’ of the state by elites and private interests” (World Bank 2011). Changes in governance over short year-to-year periods are typically quite small, but to understand recent trends, the average score of the three years from 2008 to 2010 is used for the Asian newcomers. Since the WGI data are only available from 1996, this three-year average is also used for NP countries (Appendix 2). To attract private investment in an NPP, newcomers are likely to need at least the same level of institutional capacity as NP countries with privately or jointly owned and operated NPPs (private NP countries). For the GE ranking, 92% of private NP countries fall in the top quartile (75-100). For PS and CC rankings, no private NP countries fall in the lowest quartile. More than 25 of the 30 NP countries are ranked above the second percentile (25-49) in PC and CC. Hence, the benchmarks for GE, PS, and CC are set to 50, 25, and 25, respectively.

Energy demand motivation

As Jewell suggests, the NP countries' experience shows that the lack of financial, institutional, or technical capacities can be overcome by a powerful motivation to develop nuclear energy. Specifically, 24 of 25 NP countries had high growth rates in electricity consumption, at over 5%, in the period preceding construction of their first NPP (Jewell 2011a). The indicators that Jewell identified are used for the motivations of newcomers: the average annual electricity consumption growth rate and the number of years it would take to consume electricity from a new 1 GWe NPP. This study calculates the number of years assuming a reactor with a load factor of 80%[10]. World Bank data for electric power consumption during 2003-2008 are used (Table 5a). In addition, per capita electricity consumption is considered for energy demand motivation. Bangladesh's electricity consumption per capita is the lowest among Asian newcomers, and currently only about 40% of the country's population has access to electricity. Though per capita energy demand is varied, reflecting the diversity in economic development level, industry structure, resource endowments and prices, and climate conditions, countries with low levels of electricity consumption per capita are likely to have stronger motivation to develop nuclear energy since they tend to have large shares of population without electricity access.

Energy security motivation

Rising fossil fuel prices and concerns over global warming have led to growing demand for nuclear energy. Diversifying the electricity generation mix is increasingly considered for strengthening the security of energy supplies. Accordingly, this study looks at the electricity generation mix of newcomer countries. A country with one or two types of fuel sources accounting for a large share of its energy mix (Table 5b) is likely to have strong motivation to introduce nuclear power. And this

[10] This figure is based on the fact that "worldwide, load factors now average more than 80%" (Thomas 2010).

strong motivation is also likely if fossil fuels are a substantial share of the energy mix since nuclear power yields low levels of carbon dioxide emissions.

Other supporting factors and constraints

To better understand the status of Asian newcomers' nuclear development, nuclear infrastructure, including research reactors and institutional infrastructure, is reviewed (Table 6) as well as nuclear cooperation agreements or arrangements between newcomers and potential supplier countries (Table 7). Many nuclear reactors are used for research, training, materials testing, and the production of isotopes for medicine and industry (WNA 2011h), so they can help newcomers develop the necessary technical infrastructure for starting nuclear power programs. The establishment of nuclear-energy-related institutions also demonstrates readiness for nuclear power. The IAEA advises that: "Crucial to the long term success of a national nuclear power programme is the experience of an independent and competent nuclear regulatory body. The confidence of the public and the international community depends on an effective regulatory body. The essential need for a competent and effective regulatory body should be understood and given high priority by the NEPIO [Nuclear Energy Programme Implementing Organization]" (IAEA 2007b: 34). Hence, a country that has already established an independent regulatory body can be considered as having met one of the important requirements associated with starting a nuclear power program.

The majority of Asian newcomers signed agreements or arrangements with potential supplier countries (Table 7), which is likely to enable the countries to acquire technical and financial support. For example, Vietnam and the United States in an arrangement signed in 2008 for exchange of information and cooperation on nuclear safety matters agreed to: provide training for the Vietnam Agency for Radiation and Nuclear Safety and Control (VARANSAC), provide an opportunity for Vietnam to strengthen its nuclear regulatory infrastructure, and develop VARANSAC's capacity to serve as an independent regulatory body.

While nuclear infrastructure and cooperation agreements are supporting factors, public opposition to nuclear energy is evidently one of the major constraints on nuclear energy development. Several countries have developed plans but not yet committed partly because they face public opposition, which increased following the Fukushima accident. This factor is therefore considered along with the above supporting factors to assess the capacities of Asian newcomer countries.

2.2. Analysis of capacities and motivations

Table 4 summarizes the results of the comparative analysis of Asian newcomer countries and Asian NP countries using quantitative indicators. The GDP of Asian NP countries at the time of constructing their first NPP ranged from 13 billion USD_{2000} to 750 billion USD_{2000} and the GDP per capita ranged from $700 to $6,100. While Mongolia, Sri Lanka, and Kazakhstan have GDPs of less than 50 billion USD_{2000} (below the historical benchmark), all newcomers except Bangladesh have a relatively large GDP per capita (above the historical benchmark). Five countries, Indonesia, Malaysia, the Philippines, Singapore, and Thailand, have higher financial capacity than both the historical and current benchmarks.

Regarding technical capacity, seven of ten Asian newcomers have sufficiently large electricity grids. Bangladesh is likely to have a grid that exceeds 10 GWe before 2030, but the grids in Mongolia and Sri Lanka will not reach that mark. As for international grid connections, Sri Lanka and India agreed on conducting a feasibility study for electricity grid interconnections between the two countries. A proposal has also been made for interconnections between Mongolia and China. However, neither plan has been officially endorsed or refers to nuclear energy.

Institutional capacity of Asian newcomers is diverse from the WGI top to lowest quartile in government effectiveness, political stability, and control of corruption. Malaysia and Singapore are above the benchmark measured by these three indicators and much higher than three of the Asian NP countries: China, India, and Pakistan. Malaysia and Singapore are likely to be able to attract private investment in their NPPs. In addition to these two countries, Indonesia, Kazakhstan, Mongolia, the Philippines, Sri Lanka, Thailand, and Vietnam are ranked higher than Pakistan in three areas.

All Asian newcomers apart from the Philippines and Singapore are experiencing a high growth rate in electricity consumption, above 5% (Table 5a). Given the world annual average growth rate of 4% during 2003-2008, the rates in Bangladesh and Vietnam are very high at 12%. Most of the Asian newcomers would only need a few years to consume the electricity produced from a new 1 GWe NPP, assuming that the NPP generates 100% capacity consumption of the electricity. The Philippines and Singapore would consume the electricity generated from a new NPP within six years. Sri Lanka would take 13 years. Only Mongolia is not likely to consume the electricity generated from a new 1 GWe NPP by 2030 given its very low electricity consumption of 3,891 million kWh in 2008. Seven newcomer countries are below the world average in levels of per capita electricity consumption. Considering these factors, all the Asian newcomer countries need to develop some energy sources to meet the rising demand though such sources cannot be limited to nuclear energy.

Concerning the electricity generation mix, each Asian newcomer is different but fossil fuels account for more than 85% of the energy mix for seven countries, with Sri Lanka, the Philippines, and Vietnam as the exceptions. Those seven countries could therefore have strong motivation to develop nuclear power. For Sri Lanka and Vietnam, about 40% of electricity generation came from hydropower in 2010. Since heavy reliance on hydropower makes electricity generation vulnerable to weather patterns, these two countries could also be interested in introducing nuclear power to diversify their energy mix.

Thus, measured by quantitative indicators, Bangladesh and Vietnam should have very strong motivation to deploy nuclear power. Since other Asian newcomers are also likely to have strong motivation, the next section focuses on the analysis of the capacities of each country.

2.3. Analysis of capacity of individual newcomer countries

Bangladesh has a GDP above the historical benchmark, with the lowest GDP per capita among Asian newcomers and low institutional capacity. The existing electricity installed capacity lacks sufficient size but will be expanded to have enough capacity by 2029. Although public support for nuclear power fell from 64% to 51% after the Fukushima accident, opposition is still at a low 34% (WIN-Gallup International 2011). Bangladesh has a long history of nuclear power development with 25 years operating experience of a research reactor. The project of building a nuclear power plant in Rooppur was first conceived in 1961, and Bangladesh has signed nuclear cooperation agreements with China and Russia, which could reinforce its ability to develop nuclear energy.

Indonesia has relatively high financial and technical capacities. Its GDP and GDP per capita exceed both the historical and current benchmarks. The country has a sufficiently large grid and three research reactors. More importantly, the Nuclear Energy Regulatory Agency, an independent regulatory body was established there in 1997. Indonesia has also signed agreements with three potential supplier countries – Russia, Japan, and South Korea. The country is, however, ranked very low in political stability and control of corruption, and environmentalists and community activists have opposed nuclear power projects on the grounds that Indonesia sits amid the Pacific Ring of Fire, an area especially prone to earthquakes and seismic activity (*New York Times* 2011). In November 2010, 60% of the public supported nuclear power but this fell to 49.5% in November 2011 (FNCA 2011b). Thus, low institutional capacity and public opposition are considered to be major constraints on nuclear power development.

Kazakhstan's nuclear infrastructure is well developed largely because the country operated a nuclear power plant from 1972 to 1999. While its GDP is below the benchmark, GDP per capita is the third highest among the Asian newcomers, above both the historical and current benchmarks. The country's existing grid is of sufficient scale. Kazakhstan has signed cooperation agreements with seven potential supplier countries. While its political stability is rated second highest after Singapore, the rating of its control of corruption is quite low, which suggests that it will be difficult to attract private investment for a nuclear power project.

Malaysia is the second wealthiest country among Asian newcomers as measured by GDP per capita, and has relatively high institutional and technical capacities with 30 years of experience operating a research reactor. The Malaysia Nuclear Power Cooperation (MNPC) was established to serve as the Nuclear Energy Program Implementing Organization (NEPIO) in January 2011. Public support of nuclear power declined from 60% to 34% in the aftermath of the Fukushima accident (FNCA 2011a), and in order to promptly launch a nuclear power project, MNPC has made public acceptance its first priority (MNPC 2012).

Mongolia has limited financial capacity with a GDP below the historical benchmark. While political stability is rated high, government effectiveness and control of corruption are rated low. The existing grid size is the smallest in the region and it is not likely to be expanded beyond 10 GWe by 2030. While the country's nuclear infrastructure is underdeveloped, Mongolia has already signed nuclear cooperation agreements with five countries. These agreements may be able to help Mongolia overcome challenges stemming from its inadequate capacity.

The Philippines has a sufficiently large grid and relatively well-developed organizational infrastructure but its political stability and control of corruption are rated very low. In response to the 1973 oil crisis, the Philippines decided to develop nuclear energy and began constructing the two-unit Bataan nuclear power plant (BNPP) in 1976. The BNPP was completed in 1984 but was never put in use due to technical and political reasons including public opinion against operating the plant in a seismically active area. In the aftermath of the Fukushima accident, public support for the BNPP declined further. In May 2011, the government announced it would turn it into a tourist attraction. Public opposition appears to be a major constraint in this country.

Singapore has a mature economy with the largest GDP per capita in Asia. While Singapore has not developed a research reactor or established an institution dedicated to nuclear power development, it is ranked highest in terms of the three aspects of the WGI. Since Singapore is a small island country, it faces constraints on site selection. However, Singapore has international grid connections with Malaysia, which could lead to joint development.

Sri Lanka has a small GDP below the benchmark and a low political stability ranking, but its GDP per capita is higher than both the historical and current benchmarks. The country's existing grid is small and it is not projected to expand beyond 10 GWe by 2030. Sri Lanka has no research reactor and has signed no nuclear cooperation agreements. Located near the nuclear power plants in South India, Sri Lanka found it necessary to establish an independent regulatory body that would address security concerns on radioactive sources and deal with radiation emergencies. In June 2011, the Sri Lankan cabinet approved establishment of the Atomic Energy Regulatory Council (Nation 2011). This could be a major step forward to nuclear energy development for the country.

Thailand has a large GDP and per capita GDP that exceed both the historical and current benchmarks. The country has well-developed nuclear infrastructure with 50 years of experience operating of a research reactor, and the country also has a very large grid. Government effectiveness and control corruption are rated higher than the benchmark while political stability is rated quite low. Thailand decided to delay the development of nuclear power due in part to recent comments from the IAEA which said it did not believe Thailand was ready for nuclear power because of certain issues including Thai laws and regulations, and the opposition of local people to plant construction (*Wall Street Journal* 2011). Opposition was quite strong even prior to the accident. A 2010 survey found that 24% of the public consented to having a nuclear power plant in its community, while 66% was opposed, and 64% of the public consented to having a plant in Thailand, with 32% opposed (Karasuddhi 2012). Public opposition therefore seems to be Thailand's biggest challenge.

Lastly, Vietnam has a relatively small economy. Its GDP is above the historical benchmark but below the current benchmark and its per capita GDP narrowly exceeds the current benchmark. The country has a sufficiently large grid. Political stability is rated moderate and it has signed nuclear cooperation agreements with numerous potential supplier countries. Nuclear infrastructure is well developed. Following the Fukushima accident, public support for nuclear power in the country fell from 62% to 57% and unfavorable views increased from 26% to 34% (WIN-Gallup International 2011). Since the majority of the public still favors nuclear power, public opinion is not likely to heavily affect nuclear energy development.

Overall, Indonesia, Malaysia, and Thailand have higher capacities than the other Asian newcomers. Nuclear infrastructure is relatively well developed in these three countries and in Kazakhstan. The financial and institutional capacities of Bangladesh and Vietnam are not necessarily adequate, but both countries have signed agreements with potential supplier countries and have been developing nuclear infrastructure comparable to the above four.

3. State Participation in International Conventions and Treaties

This section examines state participation in international conventions and treaties concerning nuclear safety, nuclear security, and safeguards. Although the focus here is on the international legal instruments for nuclear safety, those for nuclear security and safeguards are also considered because there is growing recognition that a mutually reinforcing relationship between these three and measures to strengthen any of them can positively affect the others. International conventions for nuclear liability are also considered since the potential transboundary effects of a nuclear accident require an international nuclear liability regime, which is vital for sustaining public confidence in nuclear energy by ensuring that those affected are sufficiently compensated.

Table 8 summarizes the participation status of all NP countries and Asian newcomers. The Convention on Nuclear Safety (CNS) is the most important legally binding instrument adopted under the auspices of the IAEA in the area of nuclear safety. Its objectives are achieving and maintaining a high level of nuclear safety worldwide, establishing and maintaining effective defenses at nuclear installations against potential radiological hazards, and preventing accidents from having radiological consequences and mitigating those consequences. The CNS entered into force in 1996 and as of April 5, 2012, 74 states and one regional organization, the European Atomic Energy Community, are party to it. The IAEA strongly recommends that a state starting a nuclear power program participate in the global nuclear safety regime, especially the Convention on Nuclear Safety (IAEA 2007b). Iran is the only state that started operating a nuclear power plant without ratifying the CNS. This is an incentive instrument, based on the contracting parties' common interest in achieving higher levels of safety, which is to be developed and promoted through regular meetings. The CNS obligates parties to submit reports on the implementation of their obligations for peer review and attend review meetings[11] to discuss the reports. Among the Asian newcomers, Malaysia, Mongolia, and Thailand have not yet signed nor ratified the CNS. At the 5th Review Meeting on the CNS held April 4-14, 2011, though all the NP countries attended and submitted a national report, eight parties, including Kazakhstan and Sri Lanka, did not submit reports and 11 parties, including Bangladesh and Sri Lanka, did not attend (IAEA 2011f).

Another incentive-based nuclear safety instrument is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (RADW). The objectives of this convention are achieving and maintaining a high level of safety worldwide in spent

[11] The date for the next meeting is determined at each review meeting. The interval between review meetings must not exceed three years.

fuel and radioactive waste management; ensuring there are effective defenses against potential hazards to protect individuals, society, and the environment from harmful effects of ionizing radiation during all stages of spent fuel and radioactive waste management; and preventing accidents from having radiological consequences and mitigating these consequences (IAEA 2011g). The contracting parties are required to submit a national report for peer review and attend review meetings. At the 3rd Review Meeting held on May 11-20, 2009, countries considering launching a national nuclear power program were strongly recommended to take into account the safety of spent fuel and radioactive waste management from the very beginning of their consideration (IAEA 2009b). Nonetheless, among Asian newcomers, only Indonesia and Kazakhstan have ratified the RADW, and the Philippines has signed it. Of the Asian NP countries, neither India nor Pakistan has signed.

The other two key conventions in the area of nuclear safety are the Convention on Early Notification of a Nuclear Accident (ENC) and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (AC). Both were adopted in 1986 following the Chernobyl accident. While the former establishes a notification system for nuclear accidents, the latter sets out coordination of emergency response and assistance in the event of accidents or radiological emergencies. All NP countries and Asian newcomers are parties to these two conventions.

International instruments for nuclear security are mostly voluntary and nonbinding. The Convention on the Physical Protection of Nuclear Material (CPPNM) is the only internationally legally binding instrument adopted under IAEA auspices in this sphere of physical protection. Five Asian newcomer countries are parties and the other four are in the process of ratifying the convention. While the obligations for physical protection under the CPPNM cover nuclear material during international transport, the Amendment to the Convention on the Physical Protection of Nuclear Material (CPPNM-AM) extends the scope by covering physical protection of nuclear material in domestic use, in storage and during transport, and of nuclear facilities used for peaceful purposes. The amendment also provides for expanded cooperation between and among states with regard to implementing rapid measures to combat and prevent nuclear theft, sabotage, or terrorism. The amendment will take effect after two-thirds of the States Parties to the CPPNM (i.e., 97 states) ratify it (IAEA 2011e). As of March 23, 2012, 55 countries are contracting states. Most European NP countries have approved or ratified it. In Asia, China, India, Indonesia, and Kazakhstan have ratified while South Korea, Malaysia, the Philippines, Singapore, and Vietnam are in the process of ratifying the amendment (Seoul NSS 2012).

The International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT) is another important legal instrument in the area of nuclear security. The United Nations General Assembly adopted the convention in 2005, aiming to improve the global legal framework for countering terrorist threats. All NP countries except Pakistan and Iran have signed or ratified. Among Asian newcomers, Indonesia and Vietnam have not yet signed.

Safeguards are activities by which the IAEA can verify that a country is living up to its international commitments to use nuclear material and facilities only for peaceful purposes. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) requires that all non-nuclear-weapon states party to the treaty conclude a comprehensive safeguards agreement (CSA) with the IAEA (IAEA 2011i). As of December 31, 2010, 167 states have concluded CSAs. Five NPT nuclear-weapon states have concluded voluntary offer safeguards agreements and three non-parties to the NPT (India, Pakistan, and Israel) have concluded INFCIRC/66/Rev.2-type agreements. Additional Protocols (APs) enable the IAEA to provide assurance about both declared nuclear material and undeclared nuclear material and activities. Hence, in countries with both CSA and AP in force, the IAEA is able to optimize implementation of all available safeguards measures. As of October 31, 2011, 112 countries have brought APs into force. In Asia, Pakistan and Sri Lanka have not yet signed an AP.

The earlier-mentioned CNS indicates that primary responsibility for the safety of a nuclear installation rests with the nuclear power plant operators and that the state needs to ensure that each operator meets its responsibilities. Operators are liable for any damage they caused, so they usually take out third-party liability insurance (WNA 2011g). International conventions, national legislation, and the pooling of insurance capacity govern such insurance (UBS 2011). Before 1997, the international liability regime primarily consisted of two instruments: the IAEA's Vienna Convention on Civil Liability for Nuclear Damage (VC) and the OECD's Paris Convention on Nuclear Third Party Liability in the Field of Nuclear Energy (PC). While the parties to the VC are largely Eastern European and Latin American countries, the parties to the PC include Western European countries and Slovenia. Although the VC and PC were based on the same principles, they existed in isolation from each other, which raised a potential problem of the conflict of law (Rautenbach et al 2006). The Joint Protocol Relating to the Application of the Vienna Convention and Paris Convention (JP) was adopted in 1988 aiming at establishing a link between these two conventions and entered into force in 1992. In Asia, Kazakhstan and the Philippines are parties to the VC and the Philippines has signed the JP.

In 1997, significant efforts were made to reinforce the existing liability regime. One is the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (PAVC), which was adopted to broaden the scope of nuclear damage[12] and increase the amount of compensation available. Another is the Convention on Supplementary Compensation for Nuclear Damage (CSC) aimed at establishing a worldwide liability regime in which all states, regardless of they are party to the VC or PC, may join and at providing additional funds to supplement the compensation available under the VC or PC, or under national law, but it has not yet entered into force. Fifteen countries

[12] This includes certain types of economic loss, the costs of measures of reinstatement of impaired environment, and the costs of preventive measures.

have signed the CSC but only four have ratified it. To enter into effect, the CSC must be ratified by at least five countries with a minimum of 400,000 units (or roughly 400 GW thermal) of installed nuclear capacity (IAEA 2011g). Among Asian newcomers, Indonesia and the Philippines signed the CSC in October 1997 and March 1998, respectively. India signed it in October 2010. While Japan and South Korea have their own national legislation, they are not parties to any international nuclear liability convention. Neither Pakistan nor China is a party to an international convention and neither has its own legislation, although China is an active member of the international insurance pooling system. In the area of nuclear liability, Asian NP countries, with the exception of India, are far behind the NP countries in Europe and the Americas[13], as well as three Asian newcomers – Indonesia, Kazakhstan, and the Philippines.

4. Possible development of nuclear energy in Asian newcomer countries

The Asian newcomers vary in terms of capacity and nuclear infrastructure development, as well as adherence to relevant international conventions, while they are alike with respect to their apparent motivations. The latest developments show some interesting trends. Nuclear power projects are not proceeding in proportion to countries' financial, technical, and institutional capacities as measured by indicators. Nuclear infrastructure development and nuclear agreements with potential supplier countries play a more important role in developing nuclear energy. Newcomers with strong motivation have been conducting preparatory work on infrastructure issues and developing cooperative relationships with potential supplier countries. Following the Fukushima accident, public acceptance also seems to have become critical for launching nuclear power programs. Bangladesh, for instance, currently has insufficient financial, technical, and institutional capacities and has not yet ratified the relevant international conventions such as the RADW and the

13 All NP countries in Europe and Latin America (Argentina, Brazil, and Mexico) are parties to the conventions. The US ratified the CSC and Canada is not a party to any international liability convention but has own legislation.

Amendment to the CPPNM, yet through external assistance it has been more rapidly pushing forward with nuclear energy development than other Asian newcomers have. In February 2011, Bangladesh signed an agreement with the Russian state corporation Rosatom to construct two 1,000 MWe reactors at Rooppur. In November 2011, another intergovernmental cooperation agreement was signed for the Rooppur plant to be built by Rosatom's subsidiary Atomstroyexport and the Bangladesh Atomic Energy Commission. Along with financial support, Russia will provide technical support in developing the necessary infrastructure and training personnel. The total cost of the project is $1.5-$2 billion. Construction will start in 2013 and the first reactor will go online by 2018 (Banglanews24 2011). Considering that construction delays and running over budget are typical in the nuclear industry (Findlay 2011: 44), the actual timeline might be delayed. However, since nuclear power is still largely acceptable to the local people (FNCA 2011b), it is highly likely that Bangladesh will begin operating the first nuclear power plant by 2030.

Similarly, Vietnam has limited financial capacity but has already signed two contracts. In October 2010, the first was signed for Atomstroyexport to build the two-unit Ninh Thuan 1 plant. Construction of the first reactor will begin in 2014 and be commissioned by 2020. Russia is prepared to supply the fuel and take back the used fuel for the life of the plant. The second contract was signed in October 2011 between Electricity of Vietnam (EVN) and a consortium of Japanese companies to design, build, and operate the Ninh Thuan 2 plant. Each plant will cost approximately $11 billion, whereby Russia and Japan are expected to gather 85% of the finance through a mixture of export credits, loans, and insurance while EVN will raise 15% of the equity capital (Kidd 2011, Pate 2011). Vietnam is currently in the final stage of procedures to adhere to the CPPNM (Seoul NSS 2012). It is highly likely that the country will deploy four reactors by 2030 since it has committed to the plans and a majority of the public supports nuclear power.

In contrast, Singapore has sufficient financial, technical, and institutional capacities but is far behind other Asian newcomers. While several countries are conducting or have completed feasibility studies, Singapore is currently working on a pre-feasibility study. It is in the process of amending its domestic legislation, which will enable the country to fully implement the provisions of the CPPNM and its amendment. Given constraints on site selection and the advantage of a grid connection with Malaysia, Singapore is unlikely to deploy a nuclear power plant in the country. It is more likely that it will join Malaysia in a nuclear power project there.

The latest developments in Bangladesh and Vietnam suggest that external support, usually from supplier countries, can complement insufficient financial, technical, and institutional capacities. Each newcomer country has a number of challenges to overcome before embarking on a nuclear power project. If Asian newcomers in fact overcome the challenges, all of them could potentially introduce nuclear power by 2030. Both Mongolia and Sri Lanka, where the existing grid size is small and nuclear infrastructure is underdeveloped, are not likely to construct a 1 GWe or greater plant. If small nuclear reactors can be technically proven in the near future, it is also possible that these two countries will develop nuclear energy by 2030. Public opinion so far is mixed. Since neither country has developed concrete plans, it seems to be too early for the public to clearly discern between the pros and cons of introducing nuclear energy.

Indonesia, Malaysia, and Thailand have relatively high financial, technical, and institutional capacities with extensive preparatory work on infrastructure issues. They also signed agreements with potential supplier countries. Nevertheless, they face difficulties due to public opposition. Berger (2011) argues that, “Perhaps the least democratic is also the least inhibited by popular sentiment in the race towards operational nuclear capacity.” While Vietnam and Bangladesh are ranked 143rd and 83rd on the Economist Intelligence Unit’s Democracy Index 2011, the respective rankings of Indonesia, Malaysia, and Thailand are 60, 71, and 58 (EIU 2011), the highest among Asian newcomers excluding Sri Lanka at 57. Gaining public acceptance will not be easy for these three countries but will be essential for launching a nuclear power program.

Despite strong public opposition, the Indonesian government approved the construction of a 200 KWe nuclear power plant and a 2 MWe plant[14] in November 2011 (*Jakarta Post* 2011). The capacity of both plants is so small that the media scarcely covered the public reaction. Indonesia has implemented the relevant international legal instruments with the exception of ICSANT and intends to start the ratification procedures in accordance with its constitutional processes. Indonesia has also already established an independent regulatory body. Given considerable developments in the legal and regulatory aspects, it is likely that the first two small-scale plants will be constructed in one or two decades. Construction of two 1,000 MWe units will depend on changes in public perception of nuclear energy.

Thailand, being fully aware of the need for open and timely interaction and communication regarding all aspects of nuclear power development, has been implementing public communication programs over the last several years. Moreover, it is working toward ratification of the relevant international treaties such as ICSANT and CPPNM (Seoul NSS 2012). Other challenges identified are the need to overcome its political instability, develop national laws and regulations, and establish an independent regulatory body. Malaysia has similar challenges and has also been implementing public communication programs. It is in the final stages of revising its national nuclear law, which would facilitate its implementing international conventions and agreements including its accession to the CPPNM and ratification of the ICSANT and AP. Since both Thailand and Malaysia are steadily taking the required actions, future nuclear development there will hinge on public acceptance.

The Philippines has lower financial and institutional capacities than Indonesia, Malaysia, and Thailand but has the experience of completing construction of a nuclear power plant. The

[14] Indonesia's long-term development plans did not include such small-scale plants.

government is working on amending the Human Security Act of 2007 to cover the provisions of ICSANT and the Amendment to the CPPNM. Ratification of the CNS and RADW are underway. The future of nuclear energy will depend on public acceptance since public opposition to nuclear power has been strong in the Philippines over the years.

Kazakhstan has ratified the relevant international treaties and its nuclear infrastructure is well developed. A project for building Russian-designed nuclear reactors has been under consideration for several years and feasibility studies have been conducted. Construction of a nuclear power plant is seen as a long-term objective and nuclear power is expected to represent 4% of the country's electricity generation by 2030 (*Turkish Weekly* 2012). Public opposition to nuclear power is seen but it is not as strong as in the four previously mentioned countries. Given the well-developed nuclear infrastructure and legal framework, as well as cooperation agreements with seven potential supplier countries, the future for nuclear power seems to be a matter of political decision.

In sum, it is highly likely that Bangladesh and Vietnam will deploy nuclear power by 2030. If public confidence in the use of nuclear power is restored and public view becomes more positive, Indonesia, Malaysia, Thailand, and the Philippines are also likely to introduce nuclear power by 2030.

5. Implications of nuclear expansion in Asia

To overcome the obstacles toward nuclear energy development, Asian newcomers need regional or international cooperation and assistance from potential supplier countries. Bangladesh, for instance, expects assistance in infrastructure development and establishment of safety culture as well as human resource development (FNCA 2011b). Thailand expects assistance concerning training for its utilities and regulatory body, sharing of technical experience in regulation, operation, decommissioning, and waste management, as well as guidance on public communication (Takabut 2012). Nevertheless, the current regional cooperation framework in Asia is underdeveloped and an international cooperation framework has yet to be established in some important areas. Asian NP countries also lack sufficient capabilities or adequate competence particularly in legal and regulatory aspects.

First, three Asian NP countries have yet to establish an effective independent regulatory body though designation of such a body is required for states first embarking on nuclear power programs. In China, neither the National Nuclear Security Administration nor the China Atomic Energy Authority is independent. The former is attached to the Ministry of Environmental Protection and the latter is under the Ministry of Industries and Information Technology (Kong and Lampton 2011, Xu 2012). Japan intended to establish an independent Nuclear Regulatory Agency in April 2012 but the establishment will be delayed by at least two months since the opposition parties do not agree on the core details of the bill that would establish it (Nikkei 2012). India in September 2011 introduced a bill to create an independent nuclear regulator, the Nuclear Safety Regulatory Authority, to replace its Atomic Energy Regulatory Board and is currently in the process of establishing it. South Korea only recently created its Nuclear Safety and Security Commission, an independent regulatory body, in October 2011. Although the Pakistan Nuclear Regulatory Authority was established as a competent and independent regulatory body in 2001, there is little possibility that Pakistan will provide assistance in this area for newcomers since the country does not participate actively in the regional cooperation framework and is not a supplier country.

Second, Asian NP countries have not yet ratified some of the relevant international treaties despite the significance of achieving universal adherence to such treaties. At first glance, the fact that Pakistan is not party to the RADW, Amendment to the CPPNM, or ICSANT looks problematic, but the fact that Japan and South Korea have not yet ratified a nuclear liability convention is more problematic since both are major supplier countries and operate the largest nuclear electricity generation capacity in Asia. China began exporting reactors to Pakistan and is likely to do business with Southeast Asian countries and Vietnam (Goncharuk 2011). India is on the way to becoming a nuclear supplier and is considering Kazakhstan, Thailand, and Vietnam as potential buyers of its small reactors (WNN 2010b, Maitra 2011). Findlay (2011: 156) pointed out that, "As to the newcomers, safety will depend on how well they are drawn into the web of treaties, peer review process, and assistance mechanisms." Hence, newcomers should accede to the relevant treaties but it is more important for NP countries to ratify the relevant international treaties as soon as possible. In particular, the CSC aimed at creating a global nuclear liability regime needs at least one more state with over 90 GWt (gigawatt thermal) of installed capacity[15] to enter into force. Japan began to consider joining the CSC only after the Fukushima accident (Reuters 2011). Since the domestic liability law needs to be revised, Japan will ratify the CSC sometime after summer 2012 (*Asahi Shimbun* 2012). If it does so, the CSC will go into effect on the 90th day after its date of ratification. Daniel Poneman, the U.S. Deputy Secretary of Energy, also said during his visit to Japan in last December, "I encourage Japan once again to take an international leadership position by ratifying the CSC" (U.S. Department of Energy 2011).

Third, the regional cooperation framework for nuclear safety in Asia is underdeveloped in comparison to Europe, where a network of chief regulators of 17 countries, the Western European Nuclear Regulators Association (WENRA), and an independent, authoritative expert body consisting of regulators of all 27 EU member states, the European Nuclear Safety Regulators Group (ENSREG) are established. In Asia, the Forum for Nuclear Cooperation in Asia (FNCA), a Japan-led cooperative framework for peaceful use of nuclear technology, and the Asian Nuclear Safety Network (ANSN), a knowledge network to pool, analyze, and share nuclear safety information and practical experience in Asia have been promoting regional cooperation in capacity building and

[15] See p. 24 for the minimum requirement. Each 3 MWt (megawatt thermal) corresponds to about 1 MWe when electricity is generated (WNA 2009). As of March 2012, the contracting states of the CSC are Argentina (installed capacity: c., 3 GWt), Morocco (0 GWt), Romania (c., 4 GWt) and the US (c., 303 GWt). Japan's capacity is c., 134 GWt.

infrastructure development to strengthen nuclear safety. On the other hand, in Europe, the WENRA seeks to develop a common approach to nuclear safety and to provide independent ability to examine nuclear safety in applicant countries. The WENRA has contributed to the improvement of national nuclear safety requirements through the formulation of common safety reference levels and has created a platform for information exchange among regulators (WENRA 2009). The ENSREG also helps in establishing conditions for continuous improvement and reaching common understanding in the areas of nuclear safety and radioactive waste management. This kind of regional cooperation mechanism has yet to be created in Asia.

Most importantly, while nuclear energy expansion will lead to increased amounts of spent fuel and nuclear waste, a long-term solution for high-level radioactive waste management has yet to be achieved. Progress has been made in reducing the amount of low- to intermediate-level radioactive waste, but the implementation of deep geological disposal remains a key challenge for the industry and for governments (NEA 2011b). No country has successfully opened a repository for high-level radioactive waste. Only Finland and Sweden currently have plans to open repositories in 2020, followed by other several European countries and Canada in the 2020s or 2030s. In November 2010, the European Commission proposed a directive on the management of spent fuel and radioactive waste, which would require that all member states specify when, where, and how they will construct and manage the repositories (NEA 2010). The WENRA's Working Group on Waste and Decommissioning also finalized the safety reference levels for radioactive waste storage facilities and published a report in November 2011. Asian countries trail European countries in long-term radioactive waste management. China, for instance, will complete repository site selection by 2020 while Japan and South Korea have yet to open even interim storage facilities (WNA 2011b). For newcomer countries with one or two reactors, establishing their own repositories is likely to be prohibitive on the grounds of cost and capacity (Findlay 2010). External assistance is therefore needed but Asian NP countries lack sufficient capabilities and no international cooperation framework in this area has been established.

6. International cooperation in response to the Fukushima accident

It has been recognized that international cooperation in nuclear energy must be strengthened in order to cope with the expected rise in nuclear power plants. Nevertheless, prior to the Fukushima accident, the civilian nuclear industry tended to maintain distance from regimes, while governments and international organizations often failed to consult or engage with industrial and other stakeholders (Fréchette and Findlay 2010). Not only in nuclear energy but also in the energy sector as a whole, "What has been lacking to date is a concerted effort to develop better habits of collaboration, to learn from experience, and to develop the organizational infrastructure needed for progress" (Florini 2010: 176). Since the Fukushima accident, however, collective action in strengthening nuclear safety has come to the fore. The international community has adopted a number of initiatives to draw and act upon the lessons from the accident. The European Union (EU), for instance, launched a process of carrying out comprehensive risk and safety assessments, so-called stress tests, for all 143 of its nuclear power plants. National reports were submitted to the EU Commission by the end of 2011 and are currently under peer review. The final results will be unveiled in June 2012 (European Commission 2011). At the commission's request, neighboring states Switzerland and Ukraine also joined stress tests. Russia, Belarus, Croatia, Armenia, and Turkey also began conducting comparable assessments with different timescales. The EU is taking the Fukushima accident as a catalyst for enhancing nuclear safety and strengthening its role in the nuclear field, arguing that issues of nuclear safety are best addressed jointly at the EU level, not separately by member states (Raetzke 2011).

The 5th Review Meeting of the Contracting Parties to the CNS was held April 4-14, 2011 in Vienna, wherein member states reaffirmed their commitment to achieving and maintaining a high level of nuclear safety worldwide through strengthening national measures and international cooperation. They discussed a range of issues related to nuclear safety, including emergency management and preparedness, training of plant operators for severe accident scenarios, and communications in emergency situations. The contracting parties decided to hold an Extraordinary Meeting in August 2012, aiming at strengthening safety through reviewing and sharing lessons learned and actions taken in response to the Fukushima accident, as well as reviewing the effectiveness of the CNS provisions (IAEA 2011f).

In June 2011, the nuclear regulatory authorities of the G8 countries, OECD Nuclear Energy Agency member countries, and associated countries including Brazil, India, Romania, South Africa, and Ukraine gathered in Paris to discuss insights gained from the Fukushima accident and follow-up actions at the international level.

North America also responded to the Fukushima accident swiftly and forcefully. The US Nuclear Regulatory Commission (NRC) undertook a comprehensive review of all 104 domestic nuclear units and created a task force to identify lessons learned from the accident. The task force issued a report titled “Recommendations for Enhancing Reactor Safety in the 21st Century” in July 2011. One of its 12 recommendations is “establishing a logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations” (US NRC 2011). In November 2011, the INPO published a special report to provide an accurate, consolidated source of information regarding the Fukushima accident. The Canadian Nuclear Safety Commission (CNSC) also established a CNSC Fukushima Task Force in April 2011 to review its nuclear power plants’ ability to withstand extreme events. In the report published in October 2011, the task force makes a number of recommendations for strengthening defense-in-depth, bolstering emergency response, and improving regulatory oversight (CNSC 2011).

Efforts to ensure nuclear safety have been increasing in Europe, North America, and worldwide. In September 2011, the Action Plan on Nuclear Safety was adopted by the IAEA's Board of Governors and was unanimously endorsed by the 55th General Conference. This is the first time since the IAEA's inception in 1957 that its 151 member states put together all nuclear safety tools in a comprehensive program to strengthen the global nuclear safety framework at the national, regional, and international levels. The plan consists of 12 main actions, such as strengthening IAEA peer reviews to maximize the benefits to member states, strengthening the effectiveness of national regulatory bodies, and improving the effectiveness of the international legal framework, in particular, establishing a global nuclear liability regime (IAEA 2011d).

The nuclear industry and a private non-profit organization have also taken collective action. In September 2011, the world's leading nuclear power plant vendors based in Canada, France, Japan, Russia, South Korea, and the United States adopted the Principles of Conduct that reflect global best practices in connection with the export of nuclear power plants. The Carnegie Endowment for International Peace has led this initiative since October 2008. Over the past three years, representatives from the major exporters have crafted these principles, which reflect some lessons learned from the Fukushima accident. The principles incorporate the requirements of international treaties[16], conforming to the IAEA guidelines. They also state that exporters will cooperate with their customers to inform and consult with nearby communities about the potential social and environmental effects of planned project activities. The nuclear vendors are to meet regularly to review progress in applying the principles and to update them.

On October 23-25, 2011, the WANO held its 11th WANO Biennial General Meeting, with more than 600 participants gathering and pledging to increase their commitment to nuclear safety. Key decisions made at the meeting were to strengthen peer review activities, improve the quality and consistency of all WANO activities and services, and increase the number of experienced staff

[16] For details, see Table 8. The vendor will have made a reasonable judgment that the customer state is either a party to the underlined treaties or will become a party in a timely manner.

annually over the next three years. WANO will take the initiative in working with other key organizations such as the IAEA, WNA, and INPO to integrate its plan with their plans. For example, coordination between WANO peer reviews and IAEA OSART missions will be strengthened. Moreover, a pre-startup peer review[17] team office will be set up in Asia to ensure that all new nuclear plants receive such a review before initial criticality (WANO 2011).

Thus, international cooperation for improving nuclear safety has been strengthened as the distance between the IAEA and the nuclear industry shrinks. Diverse stakeholders, from industry to research institutions, have been making concerted efforts. However, unlike the non-proliferation regime in which the IAEA is described as the nuclear watchdog, the nuclear safety regime relies not on multilateral monitoring and verification but on peer reviews (Findlay 2011: 198). The CNS aims at achieving a high level of nuclear safety through application of fundamental safety principles rather than of detailed safety standards. Each state bears full responsibility for the safety of its nuclear facilities and there is no nuclear safety regulatory authority at the international level. In fact, soon after the Fukushima accident, Pierre Gadonneix, chairman of the World Energy Council (WEC) suggested, "the time may now have come for the world to progressively set up an international cooperation and governance on nuclear safety" (EER 2011). The results of the WEC Survey conducted after the Fukushima accident show that adoption and convergence of international safety regulations are increasingly supported but support for the international enforcement of safety standards seems to be comparatively lower (WEC 2012). Since it is unlikely that binding international safety standards will be created in the near future, a regional cooperative framework should be put in place to ensure effective safety regulations and best safety practices.

In November 2011, the top nuclear safety regulators of Japan, China, and South Korea reaffirmed their intent to adopt the trilateral "Cooperative Nuclear Safety Initiative" aimed at

[17] WANO offers pre-startup peer reviews for new entrants to the nuclear industry that are moving toward fuel loading in their first reactor.

establishing a practical and tangible framework for cooperation. Although this initiative seeks to promote international cooperation in nuclear safety across the entire Asian region, it aims to develop a harmonized approach to nuclear safety and regulation within the three countries with reference to the IAEA safety standards. This can be regarded as the beginning of the initial process of establishing a regional regulatory network, albeit with only three countries.

In Japan, the Federation of Electric Power Companies (FEPC) has decided to establish a new organization designed to build a mechanism for Japanese electric power companies not only to comply with regulations but also to take the initiative in improving safety through collaboration with overseas organizations such as the INPO. This collaboration will greatly help Japanese electric power companies improve nuclear safety and will enable lessons learned from the Fukushima accident to be shared internationally.

At the Seoul Nuclear Security Summit held on March 26-27, 2012, South Korea played a critical role in strengthening international cooperation in nuclear security. Representatives from more than 53 countries and international organizations participated in the summit, where synergies between nuclear safety and security were highlighted. The summit yielded practical outcomes to reduce the threat of nuclear terrorism. For instance, participating countries were encouraged to join and ratify ICSANT and the Amendment to the CPPNM and agreed to make collective efforts to bring the Amendment to the CPPNM into effect by 2014 (Seoul NSS 2012). The amendment is extremely important for both nuclear security and safety since it is an effective anti-terrorism instrument. Thus, the agreement at this summit will also lead to the strengthening of nuclear safety.

7. Conclusions

This study suggests that public acceptance has become critical for launching a nuclear power program. It is highly likely that Bangladesh and Vietnam, where a majority of the public supports nuclear power, will develop nuclear energy by 2030. For Indonesia, Malaysia, Thailand, and the Philippines, which face public opposition, future development of nuclear power will hinge on how and when public confidence in the use of nuclear energy is restored. While international cooperation in the area of nuclear safety has been strengthened, an effective regional cooperation mechanism has yet to be established in Asia. Reyners (2011) pointed out that nuclear safety is not defined in a static way but is an ongoing process of good practices, behaviors, and rules. Accordingly, it is important to establish an international cooperative framework that encourages all stakeholders to continually make improvements that strengthen nuclear safety. In the coming decade, with nuclear expansion expected in Asia, it will be essential to establish a regional regulatory network. Prior to this, Japan, the Asian country with the most experience operating nuclear power plants and the largest installed nuclear capacity, needs to take actions in the following areas. First, it should establish an independent nuclear regulatory agency as soon as possible. Organizational restructuring alone will not be enough to improve effectiveness in Japan's regulatory functions. Professionals with many years of experience in Japan's nuclear energy program pointed out that regulatory deficiencies in Japan were ultimately rooted in the lack of accountability in its "nuclear culture" and low tolerance in Japanese society for challenging authority (Acton and Hibbs 2012). Intensified effort will be needed to correct these root causes.

Second, Japan needs to accelerate the CSC ratification process. As mentioned earlier, Japan's participation allows the CSC to enter into force, which will pave the way for establishing a global nuclear liability regime.

Third, Japan should ratify the Amendment to the CPPNM. Japan did not refer to the amendment in its national progress report submitted to the 2012 Nuclear Security Summit, at which more than ten countries showed their commitment to ratification, but since Japan agreed at the summit to make collective efforts to bring the amendment into force by 2014, it should act accordingly.

In Asia, a regional regulatory network needs to be established to promote regional cooperation in nuclear safety. The top nuclear regulators of China, South Korea, and Japan have adopted a trilateral initiative on nuclear safety to establish a cooperative framework, and this would be more effective if India, Pakistan, and Asian newcomers joined. Thailand recently proposed the idea of establishing a nuclear regulatory network among nuclear regulatory bodies in Southeast Asia. To share information and experience in Asia, a regional regulatory cooperation framework should be open to India and Pakistan as well as interested newcomers, including ASEAN countries. Given that Pakistan and India are outside the NPT, developing a harmonized approach with these two countries might be a complicated task. In Europe, the top nuclear regulators of 10 countries created the WENRA in 1999 and now 17 countries are represented. It would be desirable for an Asian regulatory network to start with three countries and later expand membership. Under this kind of regional cooperation framework, the issue of long-term radioactive waste management should also be addressed. The results of a global public opinion poll show that the primary factors for opposition to nuclear power are concerns over waste disposal solutions (91%) followed by the safety of power plant operation (90%) and decommissioning nuclear power plants (80%) (Accenture Newsroom 2009). Finding a long-term solution to high-level radioactive waste management is critical to building public confidence in the use of nuclear energy.

Lastly, the creation of an international emergency accident response team will bolster emergency response capabilities. In May 2011, the INPO called for creation of a rapid response team that would be dispatched to major nuclear accidents in the United States and other countries (Platts 2011a). At the 55th IAEA General Conference, France also proposed creating an international rapid response team for nuclear emergencies (Platts 2011b). This proposal has not yet materialized but creating such a team is one of the lessons from the Fukushima accident, namely that it is extremely important to mitigate the consequences of the accident by responding to it as rapidly as possible. Therefore, Japan should work toward the creation of an international rapid response team in collaboration with the United States, France, other countries, and the IAEA. Asian newcomers may not have adequate capacity to deal with a major nuclear emergency, and Japan's participation in an international team is significant given its proximity to other Asian countries. Moreover, through regular meetings and training, international team members would be able to share valuable experience and knowledge, which would lead to strengthening of the global nuclear safety framework.

In Asia, where use of nuclear energy will rise in the coming years, a regional cooperation mechanism needs to be established to encourage continuous improvement of nuclear safety. Richard Meserve, president of the Carnegie Institution for Science, said: "In the nuclear business you can never say, 'The task is done.' It is an inherent responsibility to explore, examine, and assess the significance of nuclear safety and security vulnerabilities continuously" (IAEA 2012b). Constant and concerted efforts will be essential for strengthening nuclear safety.

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Table 1: Nuclear Power Reactors in Asia

Country	Number of past OSART[i] missions	Reactors operable*	Reactors under construction*	Reactors planned*		Reactors proposed*		WNA 2030 Low	WNA 2030 High	IAEA 2030 Low	IAEA 2030 High
				No.	MWe gross	No.	MWe gross				
Bangladesh		0	0	2	2000	0	0	0	10		
China	11	15	26	51	57480	120	123000	50	200		
India	0[#]	20	6	17	15000	40	49000	20	70		
Indonesia		0	0	2	2000	4	4000	2	6		
Japan	5	51	2	10	13772	5	6760	55	70		
Kazakhstan		0	0	2	600	2	600	0	2		
Korea, North		0	0	0		1	950				
Korea, South	6	23	3	6	8400	0	0	25	50		
Malalysia		0	0	0		2	2000	0	10		
Pakistan	5	3	1	1	340	2	2000	10	20		
Philippines		0	0	0		0		1	10		
(Taiwan)		6	2	0		1	1350				
Thailand		0	0	0		5	5000	2	10		
Vietnam		0	0	4	4000	6	6700	2	15		
Asia	27	118	40	95	103592	188	201360	167	473		
World	161	435	60	163	181645	329	376255	602	1350	528	789

Sources: WNA (2012a), WNA (2011a), (IAEA 2011c), (IAEA 2012c)
countries in bold: nuclear newcomer countries
*: as of March 1, 2012
i: IAEA's Operational Safety Review Team (OSART) missions, status of April 2012
[#]: The OSART mission was officially requested by India. (planned in 2012)

Table 2: Nuclear Power Reactors by Region

Country	Number of past OSART missions	Reactors operable*	Reactors under construction*	Reactors planned*	Reactors proposed*
North America					
Canada	3	17	3	3	3
USA	7	104	1	11	19
subtotal	10	121	4	14	22
Latin America					
Argentina	1	2	1	2	1
Brazil	6	2	1	0	4
Chile		0	0	0	4
Mexico	4	2	0	0	2
subtotal	11	6	2	2	11
Eastern Europe					
Armenia	1	1	0	1	0
Belarus		0	0	2	2
Bulgaria	6	2	0	2	0
Czech Republic	9	6	0	2	1
Hungary	2	4	0	0	2
Lithuania	2	0	0	1	0
Poland		0	0	6	0
Romania	3	2	0	2	1
Russia	7	33	10	17	24
Slovakia	6	4	2	0	1
Slovenia	3	1	0	0	1
Ukraine	14	15	0	2	11
subtotal	53	68	12	35	43
Western Europe					
Belgium	2	7	0	0	0
Finland	3	4	1	0	2
France	23	58	1	1	1
Germany	6	9	0	0	0
Italy		0	0	0	10
Netherlands	3	1	0	0	1
Spain	5	8	0	0	0
Sweden	7	10	0	0	0
Switzerland	4	5	0	0	3
Turkey		0	0	4	4
United Kingdom	3	17	0	4	9
subtotal	56	119	2	9	30
Africa					
Egypt		0	0	1	1
South Africa	4	2	0	0	6
subtotal	4	2	0	1	7
Middle East					
Iran	0#	1	0	2	1
Israel		0	0	0	1
Jordan		0	0	1	0
Saudi Arabia		0	0	0	16
UAE		0	0	4	10
subtotal	0	1	0	7	28
Asia subtotal	**27**	118	40	95	188
World	161	435	60	163	329
Asia/World Raito	0.17	0.27	0.67	0.58	0.57

Sources: WNA (2012a), (IAEA 2012c)

*: as of March 1, 2012

#: The OSART mission was officially requested by Iran. (planned in 2013)

Table 3: Plans for Nuclear Power Reactors in Asia

Country	Governments' announaced policies and plans	IAEA missions
Bangladesh	Agreed with Russia to build two 1000 MWe reactors at Rooppur. Construction will start in 2013 and the first reactor is expected to begin operation by 2018.	Integrated Nuclear Infrastructure Review (INIR), November 2011 (The mission concluded that Bangladesh has mostly met the conditions for knowledgeable decision-making and made 50 recommendations and 20 specific suggestions.)
Indonesia	Plans to build four nuclear plants of total 6000 MWe by 2025, starting with two 1000 MWe units in Bangka-Belitung. The government has $8 billion earmarked for four plants. In November 2011, the government approved construction of a 200 KW nuclear power plant and a 2MW plant.	INIR, November 2009 (The mission concluded that there is good progress in the development of the national infrastructure in many areas and made recommendations in several areas.); Emergency Preparedness Review (EPREV), 2004
Kazakhstan	Plans to build a large reactor in the southern region, smaller units in the western region, and smaller cogeneration units in regional cities.	
Malaysia	Plans to deploy two 1000 MWe nuclear power plants by 2023 (the first unit by 2021). The final site selection is scheduled to be completed by the end of 2012. The government has a RM21.3 billion (c., $7 billion) budget to build the two-unit plant.	Human Resource Management and Knowledge Transition, July 2009; EPREV, 2009
Mongolia	Tentatively plans to develop nuclear power, using either Korean Smart (100 MWe) reactors or Toshiba Super-Safe, Small & Simple types from 2021.	
Philippines	Decided to turn an unused Bataan Nuclear Power Plant into a tourist attraction. Apart from Bataan, the government is considering two 1000 MWe Korean Standard Nuclear Plant units.	EPREV, July 2010
Singapore	Is considering the prospects of using nuclear power by conducting pre-feasibility study.	
Sri Lanka	Is conducting a pre-feasibility study of using nuclear energy for power generation from about 2025.	
Thailand	Decided to delay the commercial startup of five planned nuclear-power plants of total 5000 Mwe over 2020-2028 by three years after receiving advice from the IAEA.	INIR, December 2010 (The review team identified several gaps and made recommendations to address these gaps.); EPREV, 2010
Vietnam	Agreed with Russia to construct the Ninh Thuan 1 nuclear power plant using two 1000 or 1200 MWe reactors (the first unit is expected to be operating in 2020). Agreed with Japan to build the Ninh Thuan 2 plant with two 1000 MWe reactors to go online in 2024-25.	INIR, December 2009 (The review team identified that there are no major gaps for phase 1 activities, and made recommendations mainly for the phase 2 activities.)

Sources: (WNA 2011c), (WNA 2011d), (WNA 2011e), (IAEA 2009a), (IAEA 2011j), (IAEA 2011k), (CNN 2011), (*Wall Street Journal* 2011), (*Jakarta Post* 2011), (National Nuclear Energy Agency of the Republic of Indonesia 2011), (IAEA 2010b), (VAEA 2011)

Table 4: Capacities of Asian Newcomer Countries

Country	Financial capacity		Technical capacity				Institutional capacity		
	GDP 2010 (constant 2000 US$)[i] (billions)	2009 GDP/capita PPP (fixed 2005 international dollars)[ii]	Existing grid size 2008 [iii] (GWe)	Year (grid is projected to be over 10 Gwe)	Electricity installed capacity[iii] annual growth rate, 2003-2008 (%)	Existing linkage of power grid in Asia[vi] (proposal)	Government Effectiveness[v]	Political Stability[v]	Control of Corruption[v]
Bangladesh	82	1492	5.45	2029[iv]	3.0		23	9	16
Indonesia	274	3818	27.80	Now			47	19	27
Kazakhstan	40	10612	18.73	Now			43	67	17
Malaysia	146	12388	22.97	Now		Malaysia - Singapore, Malaysia - Thailand	81	48	60
Mongolia	2	3205	0.83	not likely	0	(Mongolia-China, Mongolia-Russia)	33	65	27
Philippines	129	3204	15.68	Now			53	8	24
Singapore	162	43526	10.95	Now		Singapore - Malaysia	100	92	99
Sri Lanka	27	4254	2.65	not likely [2048][iv]	3.4	(Sri Lanka-India)	50	14	45
Thailand	187	7376	40.67	Now		Thailand - Malaysia, Thailand - Lao PDR, Thailand - Cambodia	60	13	45
Vietnam	63	2679	13.85	Now			46	51	33
Benchmark	**50[a], 120[b]**	**2000[a], 2600[b]**	**10**				**50**	**25**	**25**
Country	GDP at the start of construction[i] (billions)	GDP/capita PPP at the start of construction[ii]	Current (2010) GDP[i] (billions)	Currnet (2009) GDP/capita PPP[ii]	Year (started construction of their first NPP)[vii]	Ownership and operation	Government Effectiveness	Political Stability	Control of Corruption
China	304	1217	3243	6022	1985	Mixed	60	27	37
India	104	702	971	2731	1968	State-owned and operated	54	12	41
Japan	750	6094	5064	29681	1961	privately owned and operated	88	78	88
Pakistan	13	933	116	2603	1966	State-owned and operated	26	1	15
South Korea	71	3031	800	23875	1972	State-owned and operated	83	51	69

Sources: [i] (World Bank 2011a), [ii](Gapminder 2010), [iii](EIA 2010), [iv]Author's calculation assuming compound linear growth of grid capacity (based on the capacity annual growth rate), [v](World Bank 2011b) [vi] (Hermawanto 2011), (Ceylon Eelectricity Board 2011), [vii] (Jewell 2011a)

a: historical benchmark; b: current benchmark

Shaded: below the benchmark

Table 5a: Energy Demand of Asian Newcomer Countries

Country	Electric power consumption (2003-2008) annual growth rate (%)[a]	Number of years to consume electric power from a 1 GWe NPP[b]	(2009) Electricity consumption/population (kWh/capita)[c]
Bangladesh	12	2	228
Indonesia	7	1	609
Kazakhstan	5	2	4506
Malaysia	5	2	3677
Mongolia	6	not likely	1432
Philippines	3	5	592
Singapore	3	6	7948
Sri Lanka	5	13	416
Thailand	5	1	2073
Vietnam	12	1	904
World average	4		2730
NP countries	**5>**		

Sources: a: (World Bank 2011a), b: Author's own calculation assuming compound linear growth of electric power consumption (based on the capacity annual growth rate 2003-2008)*, c: IEA (2011) Key World Energy Statistics
Note: * The number of years it would take to consume electricicty from a 1 GW NPP is calculated assuming 100% capacity consumption of the electricity generated from the NPP. The number of years is calculated assuming a reactor with a load factor of 80%.

Table 5b: Electricity Generation Mix of Asian Newcomer Countries

Country	Coal (%)	Oil (%)	Natural gas (%)	Hydro (%)	Renewable*(%)	Others (%)	fossil fuels (%)
Bangladesh (2006)	3.0	8.0	86.0	3.0	0	0	97.0
Indonesia (2010)	26.3	47.6	21.4	0	4.7	0	95.3
Kazakhstan (2005)	70.3	7.4	10.7	11.6	0	0	88.4
Malaysia (2010)	40.2	0.4	54.2	5.2	0	0	94.8
Mongolia (2008)	95.5	0	0	3.4	1.1	0	95.5
Philippines (2007)	28.0	9.0	32.0	14.0	17.0	0	69.0
Singapore (2010)	0	16.9	77.2	0	0	5.9[a]	94.1
Sri Lanka (2010)	0	58.0	0	42.0	0	0	51.0
Thailand (Jan-Nov 2011)	18.7	1.1	66.7	11.8	1.6	0.1[b]	86.5
Vietnam (2010)	19.0	6.0	33.0	40.0	2.0	0	42.0

*: Renewable: renewable energy other than hydro

a: sythetic gas, diesel and refuse incineration

b: import from Malaysia

Sources: (Power Cell 2006), (GBG 2011), (Doi 2010), (MNPC 2012), (Bumtsetseg 2009), (Philippine Department of Energy 2008), (Singapore Government 2012), (Ceylon Electricity Board 2011), (Takabut 2012), (Muriel 2011)

Table 6: Nuclear Infrastructure of Asian Newcomer Countries

Country	Research reactors	Institutional infrastructure (year of establishment) (underlined: independent regulatory body)
Bangladesh	1 research reactor ‣Triga Mark II, 3 MW, 1987	Bangladesh Atomic Energy Commission (1973), Atomic Energy Research Establishment (1975)
Indonesia	3 research reactors ‣Triga Mark II, Bandung, 250 kw, 1965 (upgraded to 2 MW, 2000) ‣Kartini Research Reactor, 100 kW, 1979 ‣GA Siwabessy Multi-purpose Reactor, 30 MW, 1987	Atomic Energy Council (1958), Atomic Energy Institute (1958, now called National Nuclear Energy Agency [BATAN]), Nuclear Technology Research Centre of Pasar Jumat (1966), Nuclear Technology Research Centre of GAMA (1967), <u>Nuclear Energy Regulatory Agency</u> (1997)
Kazakhstan	3 research reactors ‣Alatau, 10 MW ‣Kurchatov, 60 MW ‣Kurchatov, Impulse Graphite Reactor, 50 MW	Institute of Nuclear Physics (1957), Institute of High Energies Physics (1970), Physical-technical Institute (1990), Almaty Department of Atomic Energy Institute (1993), National Nuclear Center (1993), Committee of Atomic Energy (1992)
Malaysia	1 research reactor ‣Triga Puspati, 1 MW, 1982	Tun Ismail Atomic Research Centre (1972, renamed Malaysian Institute for Nuclear Technology Research, 1994; re-branded as Malaysian Nuclear Agency, 2006), Atomic Energy Licensing Board (1985), Nuclear Power Development Steering Committee (2009), Malaysia Nuclear Power Corporation (2011)
Mongolia		Nuclear Energy Commission (1962), Nuclear Energy Agency (2008)
Philippines	(One research reactor was shut down in 1988.)	Philippine Atomic Energy Commission (1961, reconstituted as the Philippine Nuclear Research Institute, 1987), Nuclear Power Steering Committee (1995)
Singapore		(no institution dedicated to nuclear power development)
Sri Lanka		The Sri Lankan cabinet approved the establishment of the <u>Atomic Energy Regulatory Council</u> in June 2011.
Thailand	1 research reactor ‣Thai Research Reactor 1 / Modification 1, 1962	Thai Atomic Energy Commission (1957), Office of Atomic Energy for Peace (1961, renamed as Office of Atoms for Peace in 2002) Thailand Institute of Nuclear Technology (2006), Nuclear Power Infrastructure Establishment Cooperation Committee (2007)
Vietnam	1 research reactor ‣DaLat Research Reactor, reactivated 1984	Vietnam Atomic Energy Commission (1976), Nuclear Energy Programme Implementation Organization (2002), Vietnam Agency for Radiation and Nuclear Safety and Control (2004), Vietnam Atomic Energy Agency (2010)

Sources: (WNA 2011e), (IAEA 2011h), (*Nation* 2011), (Uyanga 2010)

Table 7: Nuclear Agreements between Asian Newcomers and Potentail Supplier Countries

Country	Agreements
Bangladesh	nuclear cooperation agreement: China (2005), Russia (2009)
Indonesia	nuclear cooperation agreement: Russia (2006), US (2006); memorandum of cooperation: Japan (2007); memorandum of understanding: South Korea (2007)
Kazakhstan	nuclear cooperation agreement: Russia (2006), Japan (2010), India (2011), China (2007), Canada (2007), South Korea (2010); nuclear security agreement: US (2011)
Malaysia	memorandum of cooperation: Japan (2010)
Mongolia	memorandum of understanding: Russia (2009), Japan (2009), India (2009), France (2009), China (2010), South Korea (2011)
Philippines	
Singapore	
Sri Lanka	
Thailand	memorandum of understanding: China (2009), Japan (2010)
Vietnam	arrangement for the exchange of information and cooperation in nuclear safety matters: US (2008); nuclear cooperation agreement: France, China (2009), South Korea, Canada, Japan (2010), Russia (2002); memorandum of understanding: India (1999), US (2010)

Sources: (*Economic Times* 2011), (Universal Newswires 2011), (WNA 2011e), (WNN 2009, 2010a), (Uyanga 2010), (UPI 2011)

Table 8: Participation in International Treaties of Asian Newcomers and NP Countries

		nuclear safety				nuclear security			nuclear liability							safeguards	
	Country	CNS	RADW	ENC	AC	CPPNM	CPPNM-AM	ICSANT	VC	PAVC	PC	BS	JP	CSC	CSA/VOSA	AP
Asia	China	P	Pr	Pr	Pr	Pr	CS	P							VOSA	P
	India	P		Pr	Pr	Pr	CS	P						S	#	S
	Japan	P	P	P	Pr	P		P							CSA	P
	Pakistan	P		Pr	Pr	Pr									#	
	South Korea	P	P	P	Pr	Pr	**	S**							CSA	P
North America	Canada	P	P	Pr	Pr	P	**	S**							CSA	P
	USA	P	P	Pr	Pr	P		S						CSr	VOSA	P
Latin America	Argentina	P	P	Pr	Pr	Pr	CS	S	P	P			S	CS	CSA	
	Brazil	P	P	P	P	P	**	P	P						CSA	
	Mexico	P		P	P	P	**	P	P						CSA	P
Eastern Europe	Armenia	P		P	P	P	**	P	P						CSA	P
	Bulgaria	P	P	Pr	P	P	CS	S	P				P		CSA	P
	Czech Republic	P	P	P	P	P	CS	P	P	S			P	S	CSA	P
	Hungary	P	P	P	P	P	CS	P	P	S			P		CSA	P
	Romania	P	P	Pr	Pr	Pr	CS	P	P	P			P	CS	CSA	P
	Russia	P	P	Pr	Pr	P	CS	P	P						VOSA	P
	Slovakia	P	P	Pr	Pr	P		P	P				P		CSA	P
	Slovenia	P	P	P	P	P	CS	P			P		P		CSA	P
	Ukraine	Pr	P	Pr	Pr	P	CS	P	P	S			P	S	CSA	P
Western Europe	Belgium	P	P	P	P	Pr		P			P	P	S		CSA	P
	Finland	P	P	P	Pr	Pr	CS	P			P	P	P		CSA	P
	France	P	P	Pr	Pr	Pr	**	S**			P	P	S		VOSA	P
	Germany	P	P	Pr	Pr	Pr	CS	P			P	P	P		CSA	P
	Netherlands	P	P	Pr	Pr	Pr	CS	P			P	P	P		CSA	P
	Spain	P	P	Pr	Pr	Pr	CS	P	S		P	P	S		CSA	P
	Sweden	P	P	P	Pr	Pr	CS	S**			P	P	P		CSA	P
	Switzerland	P	P	P	P	Pr	CS	P			P	S	S		CSA	P
	United Kingdom	P	P	Pr	Pr	Pr	CS	P	S		P	P	S		VOSA	P
Africa	South Africa	P	P	Pr	Pr	Pr	**	P							CSA	P
Middle East	Iran			Pr	Pr										CSA	S
Newcomers in Asia	Bangladesh	P		P	P	P		P							CSA	P
	Indonesia	P	P	Pr	Pr	Pr	CS	**		S				S	CSA	P
	Kazakhstan	P	P	P	P	P	CS	P	P	P					CSA	P
	Malaysia			Pr	Pr	**	**	S**							CSA	S**
	Mongolia			P	P	P		P							CSA	P
	Philippines	S**	S**	P	P	P	**	S**	P	S			S	S	CSA	P
	Singapore	P		P	P	**	**	S**							CSA	P
	Sri Lanka	P		Pr	Pr			P							CSA	
	Thailand			Pr	Pr	**		S**							CSA	S
	Vietnam	P		Pr	Pr	**	**								CSA	S
status as of mm/dd/yy		04/05/12	09/26/11	11/11/11	11/11/11	09/29/10	03/23/12	03/25/12	03/29/11	03/29/11	06/10/09	05/05/10	07/28/09	09/20/11	12/31/10	10/31/11
no. of parties		75	63	113	108	145	55 CS	79	38	9	16	12	26	4 CS	167 / 5	112

CNS: Convention on Nuclear Safety

RADW: Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

ENC: Convention on Early Notification of a Nuclear Accident

AC: Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

CPPNM: Convention on the Physical Protection of Nuclear Material

CPPNM-AM: Amendment to the Convention on the Physical Protection of Nuclear Material

ICSANT: International Convention for the Suppression of Acts of Nuclear Terrorism

VC: Vienna Convention on Civil Liability for Nuclear Damage

PAVC: Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage

PC: Paris Convention on Nuclear Third Party Liability in the Field of Nuclear Energy, 1964 Additional Protocol, and 1982 Protocol

BS: Brussels Supplementary Convention, 1964 Additional Protocol, and 1982 Protocol

JP: Joint Protocol Relating to the Application of the Vienna Convention and Paris Convention

CSC: Convention on Supplementary Compensation for Nuclear Damage

CSA: Comprehensive Safeguards Agreement

VOSA: Voluntary Offer Safeguards Agreement for NPT nuclear-weapon States

#: INFCIRC/66-type Safeguards Agreement, not party to the NPT

AP: Additional Protocol

underlined: incorporated into nuclear power plant exporters' Principles of Conduct (nuclear liability: either VC or PC and/or CSC)

P: party

S: signatory

r: existing reservation/declaration

CS: contracting state

(blank): non-party

**: committed to ratifying (stated in National Progress Report, 2012 Seoul Summit)

Sources: IAEA (2011a), (IAEA 2011g), (United Nations 2011), (NEA 2011a), (Seoul NSS 2012)

Appendix 1: GDP per capita PPP of NP Countries

Country	Year, start of construction of the first NPP>100 MWe[i]	GDP/capita PPP (fixed 2005 international dollars) at the start of construction[ii]
Argentina	1968	8284
Belgium	1969	14521
Brazil	1971	4555
Bulgaria	1970	6162
Canada	1960	12701
China	1985	1217
Czech Republic	(Former Czechoslovakia 1958)	(n.a.)
Finland	1971	13420
France	1958	8855
Germany	(East 1962) West1970	(n.a.) 17009
Hungary	1974	10893
India	1968	702
Iran	2011	n.a.
Japan	1961	6094
Mexico	1976	7631
Netherlands	1969	17147
Pakistan	1966	933
Romania	1982	9605
Russia	(Former Soviet Union 1958)	(n.a.)
South Africa	1976	8211
South Korea	1972	3031
Spain	1964	6766
Sweden	1966	14898
Switzerland	1965	22191
United Kingdom	1957	11283
USA	1957	14847

Sources: [i] (Jewell 2011a); [ii] (Gapminder 2010)

Appendix 2: GEI Ratings of NP Countries

Country	Electricity sector ownership and operation[i]	2008-2010 Government effectiveness[ii]				Political stability[ii]				Control of corruption[ii]			
		1-24	25-49	50-74	75-100	1-24	25-49	50-74	75-100	1-24	25-49	50-74	75-100
Argentina	state-owned and operated		47				42				39		
Armenia	state-owned and operated			52			48				32		
Belgium	mixed				91			72					90
Brazil	state-owned and operated			56			48					58	
Bulgaria	state-owned and operated			56				58				51	
Canada	mixed				97				84				96
China	mixed			60			27				37		
Czech Republic	state-owned and operated				80				82			67	
Finland	privately owned and operated				99				97				99
France	state-owned and operated				90			67					90
Germany	privately owned and operated				92				77				93
Hungary	state-owned and operated			74				69				69	
India	state-owned and operated			54		12					41		
Iran	state-owned and operated		34			10				24			
Japan	privately owned and operated				88				78				88
Korea, South	state-owned and operated				83			51				69	
Mexico	state-owned and operated			61		22					48		
Netherlands	privately owned and operated				95				80				98
Pakistan	state-owned and operated		26			1				15			
Romania	state-owned and operated		48					55				54	
Russia	state-owned and operated		43			19				12			
Slovak Republic	mixed				77				86			66	
Slovenia	state-owned and operated				84				75				79
South Africa	state-owned and operated			67			44					62	
Spain	privately owned and operated				79		36						81
Sweden	mixed				99				88				99
Switzerland	privately owned and operated				98				93				96
Ukraine	state-owned and operated	24					40			19			
United Kingdom	privately owned and operated				92			56					91
United States	privately owned and operated				89			57					88
no. of countries		**1**	**5**	**8**	**16**	**5**	**7**	**8**	**10**	**4**	**5**	**8**	**13**
ratio		0.03	0.17	0.27	0.53	0.17	0.23	0.27	0.33	0.13	0.17	0.27	0.43
no. of pr. countries*		**0**	**0**	**1**	**12**	**0**	**2**	**3**	**8**	**0**	**1**	**1**	**11**
ratio		0	0	0.8	0.92	0	0.15	0.23	0.62	0	0.8	0.8	0.84

Souces: i(Jewell 2011a), (WNA 2012b); ii(World Bank 2011b)

*: NP countries with mixed or private ownership