ESI-CIL Nuclear Governance Project
A multidisciplinary research project by the Energy Studies Institute & Centre for International Law

Event Reports of the ESI-CIL Nuclear Governance Project Conference Series

The Evolving Global Nuclear Energy Landscape: Emerging Challenges and Opportunities

Singapore, 11 - 12 April 2018

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ABOUT THE PROJECT

The Energy Studies Institute (ESI) and the Centre for International Law (CIL) of the National University of Singapore are undertaking a three-year Nuclear Governance Project, beginning on 4 January 2016 and now extended until 30 June 2019. The Project is staffed by a multidisciplinary academic team carrying out research and capacity building in the governance of nuclear safety, security and civil liability for nuclear damage.

Growing interest in the use of nuclear energy world-wide and particularly in Asia raises a number of safety and security concerns. Some of these concerns arise in part from an apparent lack of a unified global governance regime and complexities due to multiple levels of governance in Asia. At present, Singapore is seeking to gain further knowledge and expertise in order to play a part in strengthening nuclear governance. The project aims to carry out multidisciplinary research into the international, regional and national governance regimes for the safe and secure uses of nuclear energy, with an aim of proposing recommendations for strengthening current regimes.

Dr Philip Andrews-Speed, Senior Principal Fellow at ESI is the principal investigator for the project. Associate Professor Robert Beckman, Head of Ocean Law and Policy at CIL, is the co-principal investigator.

For more information on the project, see the Project website at http://www.nucleargovernance.sg/.

ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
ASEANTOM	ASEAN Network of Regulatory Bodies on Atomic Energy
CIL	Centre for International Law, National University of Singapore
CNS	Convention on Nuclear Safety
EPR	Emergency Preparedness and Response
ESI	Energy Studies Institute, National University of Singapore
EU	European Union
IAEA	International Atomic Energy Agency

ESI-CIL NUCLEAR GOVERNANCE PROJECT CONFERENCE SERIES

THE EVOLVING GLOBAL NUCLEAR ENERGY LANDSCAPE: EMERGING CHALLENGES AND OPPORTUNITIES

Singapore, 11 and 12 April 2018

SUMMARY OF DISCUSSIONS

A. Introduction

The Energy Studies Institute (ESI) and the Centre for International Law (CIL) co-organised a half-day public conference and a one-day closed-door workshop titled '"The Evolving Global Nuclear Energy Landscape: Emerging Challenges and Opportunities'.

Discussions during the two events revolved around the current context, challenges and opportunities emerging from the changes taking place in the nuclear energy landscape. The focus of debate was on the governance implications for existing international and national legal, regulatory and institutional frameworks, particularly for nuclear safety and security. Of particular interest for participants were the governance challenges and opportunities for newcomer[1] developing countries and emerging nuclear vendors. In this context, relevant issues in project and supply chain management were also considered.

B. Main Conclusions

Some of the key conclusions from deliberations over the two days are as follows:

- Two main energy policy concerns are driving the current interest in nuclear energy. The principal rationale is almost always the need for countries to develop energy and electricity supply policies that support long-term economic growth. The other is the desire for a large-scale, low-carbon energy source that yields little atmospheric and air pollution. Other pertinent motivations often include the personal ambitions of certain political leaders, national prestige, or the desire to enhance the scientific base of the country. In some countries, a nuclear science community that has been nurtured for decades and has itself become a political actor, is a key stakeholder in driving energy policy in favour of nuclear power.
- Participants agreed that there are unique challenges posed by nuclear power. The recognition of these challenges is what has led to the development of a global regime governing nuclear energy issues, centred on the International Atomic Energy Agency (IAEA). Such a comprehensive and sophisticated international governance arrangement covering nuclear safety, security and safeguards issues lacks an equivalent in any other industry.
- As embodied in the global regime, each new build country is responsible for its own nuclear power programme. A number of countries are working toward making a formal national decision on a nuclear power programme, which may see a new wave of new build construction

[1] Newcomers are defined in IAEA documents as countries that are considering, planning or starting nuclear power programmes but have not yet connected a first nuclear power plant to the grid. They also include countries that have expressed an interest in nuclear power, participated in some nuclear infrastructure-related IAEA activities, and/or are involved in IAEA-supported technical cooperation projects on energy planning. International Atomic Energy Agency, *International Status and Prospects for Nuclear Power 2017*, GOV/INF/2017/12-GC(61)/INF/8 28 July 2017 (IAEA 2017).

in developing rather than developed countries. In 2016, the IAEA identified 49 newcomers, out of which 41 are developing countries across the political and socio-economic spectrum.

- At the same time, Russian, Chinese and South Korean vendors have ambitious international expansion plans. These countries have already built significant domestic nuclear energy programmes and seem to be in a perfect position to control the newcomer export market as it develops. These State-supported vendors are filling the void left by ailing Western vendors such as Westinghouse (from the USA), GE Hitachi Nuclear Energy (USA) and Framatome (previously Areva, from France) that were dominating the nuclear industry landscape in the 1960s and 1970s.

B.1. Key Governance Challenges for Newcomers

Participants agreed that the majority of, if not all, newcomer countries are active participants in the global regime centred on the IAEA and, in many cases, voluntarily follow best international practices. However, as identified by the IAEA, the unique features of nuclear energy provide newcomer governments with significant challenges, especially those in developing countries. At a high level these include:

- Raising the capital needed for such a capital-intensive project.
- Presenting a clear rationale for nuclear energy as a viable option.
- The complexity of adherence to and implementation of the global regime including for safety, security, safeguards and liability.
- Establishing the necessary infrastructure, particularly to develop the capacity and skills to effectively regulate the design, siting, construction and operation of the plant and the supply chain that supports it. This includes developing the capacity to oversee the regulatory and promotional aspects of the programme, cultivating a nuclear safety and security culture, ensuring coordination across government agencies and the industry, as well as ensuring broad public support.

B.2. Key Governance Challenges for Emerging Vendor Countries

Participants agreed that efforts to continue strengthening the global nuclear governance system are essential to maintain the position, role and relevance of nuclear energy in the global energy mix. Additionally, the nuclear governance system directly affects nuclear operations. Key challenges discussed include:

- The fact that the economic case for nuclear is continuously challenged worldwide.
- The nature of the inter-State relationship between the emerging vendors and newcomer countries, especially if there is a large imbalance in political power, economic development and/or technological prowess between the countries.
- The demand for increasingly rigorous national safety and security requirements following the Fukushima Daiichi nuclear accident and the USA terrorist attacks of 11 September 2001 are evidence of the global regime at work. However, there are some limited examples where strengthened requirements have resulted in increased costs and delays for key projects. This has been detrimental to the industry.[2]

B.3. Key Governance Challenges in Project and Supply Chain Management

The underlying debate during the events is whether emerging vendors from Russia, China and South Korea will apply industry best practices to the management of projects and supply chains in the export market as they grow their export businesses. On the one hand, it can be argued that these companies

[2] Pietro S Nivola, 'The Political Economy of Nuclear Energy in the United States' (1 September 2004) <https://www.brookings.edu/research/the-political-economy-of-nuclear-energy-in-the-united-states/> accessed 19 December 2018.

are all very experienced and have generally good records of performance. On the other, a perception exists that transparency may not be sufficient, especially in Russia and China. There is no clear evidence to show that the emerging vendors are less reliable in managing their supply chains than the established vendors. However, some key concerns raised include:

- Emerging vendors are targeting partner governments and companies in newcomer countries that have very little expertise and experience in the nuclear industry. This may increase the likelihood of bad practices arising.
- Some construction projects have highlighted weaknesses in supply chain management and oversight. They have exposed quality issues along the supply chain, as well as in relation to counterfeit, fraudulent and suspect items. Corruption, both at the government level and in the supply chain, was also highlighted as a key issue if not properly regulated and managed. Similarly, the multiplicity of actors in the supply chain allows for an avoidance of direct responsiblity, and this too needs to be properly regulated and managed. The key message is that safety culture must be strong along the full supply chain and this is difficult to achieve.
- Participants discussed two transnational factors that are complicating the management of supply chains. The first is the variability of standards between countries that complicates verification. The second is the need for more transparency, sharing and cooperation within the industry.
- Some newcomer countries insist on a proportion of the supply chain being localised, a step that may increase the risks of poor quality management and corruption.

C. Background

Participants agreed that following the Fukushima Daiichi nuclear accident, the prospect of new build construction has been uncertain in some countries due to the persisting negative public perception of nuclear safety as well as competition from other forms of energy. Yet a number of reputable international organisations (including the IAEA), industry associations and studies commissioned by national governments continue to project a steady growth for the industry. This is owing to the need for carbon-free energy in the face of rapidly increasing energy demands for economic growth.

Eleven consolidated nuclear reactor vendors remain in the market. Although established domestically, some vendors are facing strong economic, financial and political challenges that threaten their future, impairing their ability to make significant progress in the newcomer export market. This presents an opportunity for nuclear vendors from Russia, China and, to a lesser extent, South Korea. Participants opined that as State-supported enterprises, these emerging vendors are able to offer operational and financing support that commercial vendors are not able to compete with and which may be particularly attractive to newcomers, especially those from developing countries. The Project's own research to date has uncovered that these three countries have secured roughly half of the known inter-governmental agreements that have been signed with newcomers on nuclear power cooperation – out of which more than a third of them have resulted in agreements with specific vendors.[3] Thus, it appears that they are poised to dominate the newcomer export market.

As far as newcomers are concerned, a number of countries are working toward making a formal national decision on a nuclear power programme, which may see a new wave of new build construction in developing rather than developed countries. The UAE, Bangladesh, Belarus and Turkey have become the first newcomers in almost three decades to begin construction of their first nuclear power plants, respectively.

Discussions during the events centred around such changes in the global nuclear industry landscape and its ramifications for existing international and national legal, regulatory and institutional

[3] ESI-CIL Nuclear Governance Project data, 2018.

frameworks. Of particular interest for participants were identifying these governance challenges and opportunities, specifically for newcomer developing countries and emerging nuclear vendors. In this context, relevant issues in project and supply chain management were also considered.

C.1. The Governance Regime for Nuclear Safety and Security

Nuclear energy is governed by an extensive and elaborate global regime of hard and soft laws. Participants acknowledged the key role of the IAEA, which inter alia establishes safety standards and nuclear security guidance, and provides for their application through advice and support to national governments, in the form of expert peer reviews and advisory missions. Some of the more significant changes or additions to this governance regime have been made after serious nuclear accidents such as those at Three-Mile Island (1979), Chernobyl (1986) and Fukushima Daiichi (2011). Under the auspices of the IAEA, a number of treaties have been adopted, including in the areas of nuclear safety, security and liability.

Another relevant organisation is the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development. The Nuclear Energy Agency is an intergovernmental agency among Organisation for Economic Co-operation and Development countries that facilitates cooperation to seek excellence in nuclear safety, technology, science, environment and law. It was highlighted that the agency's clout in the global regime is a function of the fact that Organisation for Economic Co-operation and Development countries are often those with advanced nuclear technology infrastructures.

Other relevant international organisations include those set up voluntarily by the industry, including the World Nuclear Association, the World Association of Nuclear Operators and the recently created Nuclear Quality Standard Association, which were also identified as having key roles.

Despite the extensive nature of the global regime on nuclear safety and security, the responsibility for regulating nuclear energy lies principally with national governments.

C.2. Technological Developments

Almost two-thirds of all operating nuclear power plants in the world today are Generation II Light Water Reactors built in the 1960s – 80s.[4] The six Fukushima Daiichi units were Generation II reactors commissioned in the 1970s. More than two-thirds of reactors in the global fleet have been in operation for 30 years and above, with 87 having been in operation for 40 years and above.[5] Just prior to the Fukushima Daiichi nuclear accident, there was a sudden increase in the total number of Generation II reactors, mainly because of the serial construction of CPR-1000 reactors in China. However, with China now refocusing on marketing the Hualong One (a Generation III reactor), the CPR-1000s have become the last Generation II reactors entering the global fleet.

A growing interest in new, advanced and safer technologies after the Fukushima Daiichi nuclear accident has allowed all remaining nuclear vendors to continue developing their reactor designs (see Figure 1), giving potential customers, including newcomers, real choices. The main lines of research and development for current and future nuclear power plant designs that were discussed during the events were:

- Generation III Reactors: As Generation II units are gradually retired over the next two decades, the shift has begun towards Generation III reactor designs (originally from the 1990s) that have

[4] For purposes of this Report, unless relevant, no distinction is made between Generation II and II+ reactors as well as Generation III and III+ reactors. Generation III and III+ reactors have significant improvements on Generation II and II+ reactors in terms of safety mechanisms.

[5] International Atomic Energy Agency, *Nuclear Power Reactors in the World*, IAEA-RDS-2/37 (IAEA 2017).

since incorporated lessons learnt from the Fukushima Daiichi nuclear accident.[6] Although only 12 operational reactors in the world today are based on Generation III designs, 45 out of the 61 reactors under construction (led by China, Russia and India), as well as the majority of the 80 planned reactors (led by China, India, Russia, Japan and the USA), are Generation III reactors.[7] The first Generation III+ reactor unit, the Novovoronezh 2-1, came into operation in Russia in 2017, and others are under construction in China and Europe. The Project is of the opinion that Generation III Pressurised Water Reactors may remain relevant in the short-term regardless of the assumed maximum market potentials of Fast Neutron Reactors and/or High Temperature Reactors.

- Small Modular Reactors: These are reactors with capacities of less than 300 MW for deployment on land or at sea. The majority of the Small Modular Reactors under design, and all under demonstration, are based on Pressurised Water Reactor technology, which some participants predicted could become commercially deployable around 2030. Small Modular Reactors, especially the Generation IV High Temperature Reactor Pebble Bed Modules, Lead-cooled Fast Reactors and Sodium-cooled Fast Reactors, can help facilitate the development of indigenous nuclear technology competence for newcomers. In particular, any Generation IV reactors are envisaged as being 'intrinsically safe'.
- Fast Neutron Reactors: Fast Neutron Reactors and High Temperature Reactors are among the promising options under demonstration in Russia and China. However, it is argued that High Temperature Reactors are unlikely to make a strong competitor against Generation III Pressurised Water Reactors by 2050. As of December 2017, the only High Temperature Reactor demonstration project is the 200 MWe High Temperature Reactor Pebble Bed Module under construction in China[8].

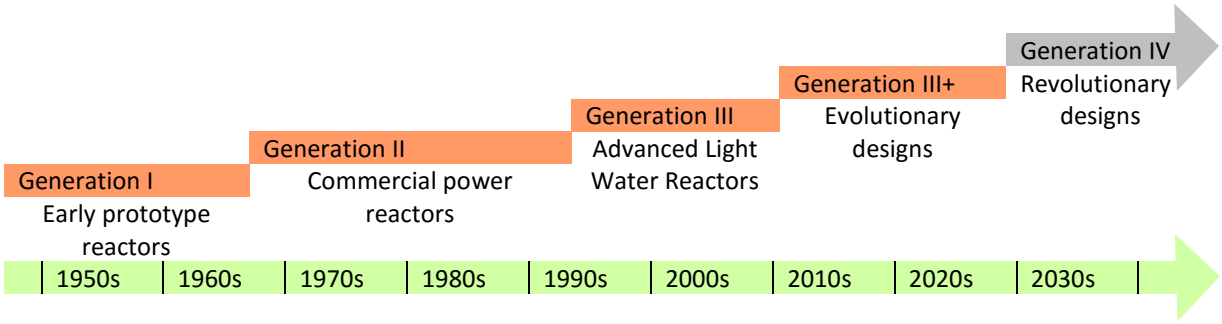

Figure 1*: Reactor Technology over the Decades.*

Source: Modified from Zohuri and Mcdaniel[9]

C.3. Construction, Plans and Ambitions After the Fukushima Daiichi Nuclear Accident

The evidence to date suggests that the prospect of nuclear power in most developed/ Organisation for Economic Co-operation and Development countries following the Fukushima Daiichi nuclear accident is uncertain and is facing considerable opposition, especially, in European Union countries,

[6] Victor Nian, 'Technology perspectives from 1950 to 2100 and policy implications for the global nuclear power industry' 105 *Progress in Nuclear Energy* 83.
[7] International Atomic Energy Agency (n5).
[8] Nian (n6).
[9] Bahman Zohuri and Patrick Mcdaniel, 'Nuclear fuel cycle' In Bahman Zohuri and Patrick Mcdaniel, *Thermodynamics in Nuclear Power Plant Systems* (Springer 2015), 539.

Japan and South Korea.[10] In fact, in the immediate aftermath of the accident, a number of these countries decided either to stop building new plants (e.g., Switzerland and South Korea) or even close down existing plants (e.g., Germany). The nature of the obstacles varies between countries, but participants agreed they include combinations of the following:

- public concerns over the safety of nuclear power plants;
- the ever more rigorous safety and security standards;
- rising costs and construction delays on some projects;
- the difficulty of gaining support for new build projects in liberalised electricity markets, for example, new build in the USA, the UK, Finland and France, compared to the scale up of new build in China and India;
- the decline of fossil fuel prices; and
- the declining costs of renewable energy and the potential development of large-scale energy storage.

In contrast, governments in a number of developing and emerging countries have concrete plans for, or aspire to, building their first nuclear power plants. Except for a few governments which have shelved their nuclear plans in the aftermath of the Fukushima Daiichi nuclear accident, most others have carried on unfazed. The total number of nuclear power plants under construction or under consideration globally, seven years after the event, is still significant. Prior to the Fukushima Daiichi nuclear accident, there was an increase in the number of reactors under construction, from 55 in 2009 to 65 in 2011. In 2016, 61 plants were under construction in 16 countries worldwide, a level of construction not seen since the early 1990s.[11] At the top of the list that year were China, Russia and India, with 33 out of the 61 new reactors under construction between them.[12]

Of the 49 newcomers listed by the IAEA in 2016, only eight were high-income countries.[13] Given the financial and often political hurdles that would need to be overcome by low-income countries, it is therefore possible that implementation of a nuclear programme in these countries will not match aspirations. However, this potential drawback has not slowed the ambitions of many nuclear reactor vendors. As of 2018, nearly 100 intergovernmental agreements on nuclear cooperation between vendor and newcomer countries have been identified, with more than half of these in the form of specific vendor agreements.[14] Four developing counties have now begun the construction of their first nuclear power plants, becoming the first newcomers in the market after a three decade-global hiatus. In April 2018, Turkey became the fourth newcomer to begin construction of its first nuclear power plant, following UAE, Belarus and Bangladesh.

C.4. Developing Country Newcomers

Participants agreed that UAE is a newcomer that is often held up as an example of a 'gold standard' for a nuclear energy programme, mainly due to its commitment to transparency and non-proliferation, including forgoing its right to enrich or reprocess nuclear fuel. However, they also discussed the exemplary nature of the programme in the following respects:

- The strong government commitment and financial support from the governments of UAE and South Korea as the vendor country;

[10] Two exceptions are the USA, which concretely renewed its commitment to nuclear power with the signing of the Energy Policy Act in 2005, and the UK, which affirmed its priority of building new nuclear capacity after the mid-2016 referendum to leave the European Union. However, even in these countries, new build projects struggle to get off the ground.
[11] International Atomic Energy Agency (n5).
[12] ibid.
[13] According to the World Bank, countries with a Gross National Income per capita of USD 12 476 (SGD 17 077) or more. For more information, see The World Bank, 'New country classifications by income level: 2016-2017' (1 July 2016) <https://blogs.worldbank.org/opendata/new-country-classifications-2016> accessed 19 December 2018.
[14] ESI-CIL Nuclear Governance Project data, 2018.

- The close cooperation with the IAEA and full and active participation in the international regime, including the relevant international legal instruments;
- The choice of vendor being based on a competitive tendering process;
- The use of substantial foreign expertise to build institutions, skills and capacity from a very low base;
- A high degree of transparency;
- A power purchase agreement for full plant output; and
- The delivery of all four reactor units likely to be on schedule and within budget.

C.5. Emerging Vendors in the Newcomer Market

With the exception of Russia, export sales for reactors have been in steady decline for most well-established nuclear vendors since the 1990s, and even more so since the Fukushima Daiichi nuclear accident.[15] Some of the challenges for Western vendors that were identified during the events included the decline of demand for new nuclear energy capacity domestically, due to difficulties selling into a competitive power market and raising finance for new nuclear power plant projects. Some participants argued that without domestic new build projects, over time, Western vendors will suffer in terms of credibility, capability and opportunity to build robust export programmes, especially in newcomer countries. Vendors have thus been heavily reliant on establishing programmes in other countries and on local vendors to build reactors abroad based on their technology. The Laguna Verde Nuclear Power Plant in Mexico, which entered service in 1989, was the last new build in a newcomer country supplied directly by a Western vendor – namely, GE Energy.

On the other hand, State-supported vendors in Russia,[16] China, and to a lesser extent, South Korea appear much better positioned to engage with the newcomer export market. These emerging vendors are:

- Russia: Rosatom (including AtomStroyExport);
- China: China National Nuclear Corporation, China General Nuclear Corporation and State Nuclear Power Technology Corporation; and
- South Korea: Doosan-Korea Electric Power Corporation

Their success in positioning themselves in the newcomer market is evidenced by the number of new intergovernmental agreements between these vendors and newcomer governments. In 2012, a consortium led by the Doosan-Korea Electric Power Corporation began construction of the UAE's Barakah Nuclear Power Plant, making the UAE the first newcomer in 27 years to begin construction of its first NPP.[17] Russia, following on South Korea's heels, began the construction of Belarus's Ostrovets

[15] Areva suffered major losses due to cost overruns from the construction of the Olkiluoto (Finland) and Flamenville (France) nuclear power plants and other projects. In 2016, Areva published a loss of EUR 665 million (SGD 1.0 billion). In 2017, the company restructured, with EDF (a UK energy company) taking the majority share in Framatome (previously Areva), the reactor business, at the behest of the French government. Japan Nuclear Fuel Limited and Mitsubishi became minority stakeholders in Orano (the non-reactor business of former Areva). In 2017, Westinghouse Electric Company filed for Chapter 11 bankruptcy protection, citing a yearly loss for its parent company, Toshiba, that could exceed USD 9 billion (SGD 12.3 billion), almost three times its previous estimate. In March 2018, a USA bankruptcy court approved the firm's business rehabilitation plan, and in April 2018, it was decided that the Canadian firm, Brookfield Asset Management Inc., would acquire Westinghouse Electric.

[16] Although Russia has been exporting nuclear energy technology for decades, it has only set its sights beyond former Warsaw Pact countries (i.e., Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland and Romania) in the last decade or so.

[17] Before the UAE, China was the last newcomer that started the construction of its first nuclear power plant in 1985.

Nuclear Power Plant in late 2013, [18] Bangladesh's Roopur Nuclear Power Plant in late 2017[19] and Turkey's Akkuyu Nuclear Power Plant in early 2018.

Participants discussed that some of the constraints facing their Western counterparts is part of the reason why these emerging vendors are more visible. Firstly, they are State-owned enterprises with soft-budgetary constraints. They typically have access to State finance as well as wider policy and diplomatic support. Moreover, although their motivations for internationalisation are generally commercial, they are able to take a long-term strategic approach. This involves accepting that some projects may not yield profits from the sale of electricity while recognising that a nuclear power plant provides more than 60 years of maintenance and supply business after the initial construction. The political support from the vendor government may, in some cases, determine the choice of destination.

Yet, there are significant differences between these vendors. Russia, through Rosatom, is the best established of the three vendor countries with the most experience in developing nuclear power plant projects, both at home and abroad. It has long-term ambitions and is positioning itself in the overseas markets through the initial conclusion of soft agreements such as Memoranda of Understanding on cooperation in the field of peaceful uses of atomic energy. However, the view emerging from the discussions was that while Rosatom is willing to offer newcomer countries generous financing arrangements, capital and human capacity, limitations brought about by its difficult current economic situation may constrain its ability to deliver more than a small number of projects simultaneously.

China's nuclear energy companies are well established at home, but they are relative newcomers on the international stage. The government provides them with strong industrial policy support as well as capital through the State-owned banks. However, with the exception of their involvement in the Chashma and Karachi nuclear power plant projects in Pakistan and a handful of others, China's companies are being more circumspect than Rosatom.[20] Some participants question whether China has the capacity to straddle the domestic and export markets simultaneously. Significant human resources will be needed to support the implementation of its aggressive nuclear power expansion policy, whilst managing ongoing demands in the domestic market. On the other hand, the anticipated slow-down at home may provide time to China to educate and train the qualified professionals it needs.

South Korea's Doosan-Korea Electric Power Corporation has long earned a reputation for building nuclear power plants on time and on budget domestically. In 2009, a consortium led by the Doosan-Korea Electric Power Corporation won its first overseas nuclear contract with the UAE, demonstrating South Korea's emergence as a nuclear exporter. However, the point was raised that the country's export strategy beyond this project is unclear, not least because of uncertainty around its domestic nuclear energy programme.

C.6. Key Governance Challenges

Discussions during the events highlighted that changing dynamics in the nuclear industry may raise several safety and security concerns. Of particular focus were: implications for newcomer developing countries and their capacity and willingness to fully participate in and rigorously implement the

[18] Russia began construction of Ostrovets Nuclear Power Plant in Belarus in 2013. Although Belarus is also a newcomer country, it is also a former Warsaw Pact country, thus this report does not consider it as part of the competitive export market.

[19] World Nuclear Association, 'Nuclear Power in Bangladesh' (September 2018) <http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/bangladesh.aspx> accessed 19 December 2018.

[20] Chinese companies are constructing reactors in Pakistan and Romania. China is scheduled to build nuclear facilities in Argentina, the UK and Iran and is bidding for further projects in Turkey, South Africa and Saudi Arabia.

international regime; new vendors and the nature of the deals they negotiate with new buyers; and the management of projects and their supply chains.

C.6.(a) For Newcomer Developing Countries

- Participants agreed that the majority of, if not all, newcomer countries are active participants in the global regime and in many cases, voluntarily follow best international practices. However, one challenge faced by newcomer countries is the increasingly complex web of international laws and regulations that form the global regime. Participants discussed that the number of these hard and soft laws can be overwhelming for a newcomer country. Some viewed the industry as being over-regulated, others emphasised the IAEA's lack of enforcement capacity, albeit that this applies to all United Nations system organisations. However, there was a general consensus among participants that the regime created by the IAEA provides powerful guidance, standards and incentives for national governments to learn and improve their management of nuclear energy.

- Moreover, as identified by the IAEA, embarking on a nuclear programme is a significant commitment for a developing country newcomer. A nuclear power plant project has a lifetime of 100 years or more, from construction to decommissioning, which is beyond the tenure of any government administration. The necessary investments need to be put in place years or even decades before the national decision to embark on a nuclear power programme is taken. It is therefore a process often fraught with political difficulties despite governments being deeply involved in all major decisions in the power sector in many newcomer developing countries, as well as the support given by the IAEA and the global regime, and in some cases, from the industry itself.

- Many newcomer countries have little experience with nuclear technology. Thus, participants agreed that the main governance challenge for newcomer countries is to develop the capacity and skills to effectively regulate the design, construction and operation of a nuclear power plant as well as the supply chains that support it. Even those countries that have had nuclear research reactor programmes for many years will find that stepping up to deliver a nuclear power plant programme is a major challenge. Newcomer governments must invest a significant amount of time and resources to allow for the development of the high-level technical expertise required to harness such a sophisticated technology. This is a process that needs to take place across government agencies and within the industry, taking anywhere between 10 to 15 years or more.

- A part of efforts to build capacity is also ensuring the effective independence of the regulatory body, including its competence to effectively assess an imported design. This was raised as a crucial task for newcomer developing countries. Yet, participants also agreed that human resource development in government, regulators and industry is a reflection of the nature of a country's economy, industry and education system.

- Lack of capacity notwithstanding, participants anticipate that demand for nuclear reactors from newcomers may place a strain on the existing system, particularly should newcomers choose from a range of new and advanced reactor technologies currently not on offer. This includes some of the Small Modular Reactor designs, including transportable nuclear power plants and fast breeder reactor technologies. It was certainly acknowledged that continuous improvements in advanced nuclear reactor technology (i.e., Generation III and, eventually, Generation IV reactors) means the probability of a nuclear accident has become increasingly low. Yet, participants also agreed that the consequences of a 'catastrophic' nuclear accident could still be significant whether through direct harm to human health and the environment, or indirectly, in the form of economic and reputational consequences, amounting to hundreds of

billions of dollars, not to mention the destruction of plant being the loss of a high capital asset.[21] In the case of the 2011 Fukushima Daiichi nuclear accident, the direct cost of the disaster in Japan has exceeded USD 75 billion (SGD 102 billion), and is expected to exceed USD 120 billion (SGD 164 billion).[22] Some participants opined that current institutions and legal and regulatory instruments are still inadequate to manage this kind of risk.

- Moreover, financing such a capital-intensive project is an incredible challenge, even in the wealthiest developed countries, and even more so for cash-strapped developing countries. To date, project financing has played no role in the development of new nuclear power plant construction as such projects cannot survive the full risk analysis carried out by commercial lenders. The construction of a nuclear power plant relies heavily on finance raised by the operator, which in turn, is typically underwritten by the State, as the risk of repayment default is considered high. This would be even more so the case in many newcomer countries where the major electrical power companies are State-owned and the market is heavily regulated. However, some participants were of the opinion that the situation may change if there is a large-scale commercialisation of Small Modular Reactors, as these can be deployed serially with a relatively low initial capital commitment. Yet the risk of repayment default remains. The IAEA has been acknowledged as being at the forefront of providing assistance on these matters to newcomer countries in many ways.

- Participants also identified the need to continue to cultivate and nurture nuclear safety and security culture within all organisations involved in the nuclear programme as a challenge for newcomer countries.

- The final factor is the variable and volatile nature of public opinion. In the aftermath of the Fukushima Daiichi nuclear accident, many countries changed policies to reduce reliance on nuclear energy. Germany immediately shut down its nuclear reactors with a complete phase out by 2022. France and South Korea now plan to reduce the use of nuclear energy, while Spain, Switzerland and Taiwan have since banned new nuclear constructions. Italy had previously planned to restart its nuclear energy programme but this decision was quickly reversed. Seven years later, most of Japan's fleet of 42 reactors still remain closed under more stringent safety requirements and overwhelmingly negative public opinion. Thus, stakeholder participation and transparency in the policy process was also identified as a key challenge for newcomer developing countries.

Notwithstanding the abovementioned challenges, participants agreed that the IAEA's phased Milestones Approach, which identifies 19 critical infrastructure issues, is crucial to deepen a newcomer's understanding of any weaknesses in the its nuclear programme, recommend remedial measures a newcomer can undertake and help newcomers demonstrate to the international community that the country is open and transparent about its plans for nuclear energy. The Milestones Approach includes:

- Training courses, fellowships and scientific visits;
- Expert missions to the newcomer country: several such missions have been organised by IAEA including to Saudi Arabia, Niger, UAE and Sudan in 2018;
- Advisory and peer review services: these include a suite of relevant services in the context of the Milestones Approach. Various review missions like the Site and External Events Design

[21] As an illustration, as of 2017, Fukushima Daiichi nuclear accident clean-up and compensation costs are estimated at USD 250 billion (SGD 342 billion).

[22] See Tokyo Electric Power company Holdings, 'Compensation for Nuclear Damages' <https://www7.tepco.co.jp/responsibility/revitalization/compensation-e.html> accessed 19 December 2018.

Review Service and the Integrated Regulatory Review Service are conducted at various phases of the nuclear programme; and

- Publications, e-Learning and networks of experts: the courses provide material on topics ranging from programme management to radioactive waste management.

C.6.(b) Partnerships with Emerging Vendor Countries

- Participants agreed that efforts to continue strengthening the global nuclear governance system are essential to maintain the position, role and relevance of nuclear energy in the global energy mix. Additionally, the nuclear governance system directly affects nuclear operations.

- It was acknowledged that very few countries have the infrastructure necessary to comprehensively design, supply and build nuclear power plants. Commercial nuclear vendors already find it hard to compete for the export market without government support. Moreover, the nuclear power industry has not been exposed to international competition to the same extent as other technology sectors. Compounded with the declining costs of fossil fuels, renewable energy and gradual breakthroughs in storage technology, the economic case for nuclear is continuously challenged worldwide.

- Participants discussed that State-supported vendors in Russia, China, and to a lesser extent, South Korea, appear to be poised to fill the void left by ailing Western vendors like Westinghouse, GE Hitachi Nuclear Energy and Framatome (previously Areva). As the nuclear industry landscape continues to evolve, and with emerging vendors aggressively pursuing the market, including by offering access to State finance and new and advanced technologies, there is a strong need to ensure that nuclear governance standards are not undermined to make way for short-term commercial gain.

- Although such a dynamic provides the basis for a long-term strategic engagement, there are concomitant future political dependency and risks, including potentially being locked-in to a specific vendor and technology on the basis of the availability of favourable financial terms or political relationships. This is especially relevant if the newcomer country lacks the expertise to assess the available technologies. Pakistan's nuclear programme was highlighted as an example of the country's growing dependency on China. There is therefore a need for newcomers to carefully balance safety, security, cost and political objectives when considering its nuclear power programme.

- It was also agreed that the demand for increasingly rigorous national safety and security requirements following the Fukushima Daiichi nuclear accident and the USA terrorist attacks of 11 September 2001 are evidence of the global regime at work. However, it is also resulting in rising costs and delays for some key projects. These have been detrimental to the industry, for both established and emerging vendors.[23] For example, in 2018, the completion of Ohma Nuclear Power Plant in Japan was delayed a further two years due to the regulator's ongoing review of enhanced safety measures.[24] Similarly, fuel loading of China's first AP1000 has been delayed due to safety concerns.[25] In 2016, the UK Government unexpectedly announced a review of the Hinkley Point C's investment decisions due to national security concerns that

[23] Nivola (n2).

[24] See World Nuclear News, 'Ohma start-up delayed by a further two years' (5 September 2018) <http://www.world-nuclear-news.org/Articles/Ohma-start-up-delayed-by-a-further-two-years> accessed 19 December 2018.

[25] See David Stanway, 'China nuclear reactor delayed again on 'safety concerns': China Daily' (13 February 2018, *Reuters)* <https://www.reuters.com/article/us-china-nuclear/china-nuclear-reactor-delayed-again-on-safety-concerns-china-daily-idUSKBN1FX02P> accessed 19 December 2018.

China may potentially be able to access some of the UK's technologies with potential military applications.[26] Viet Nam also postponed its nuclear power programme (with Russia as a vendor) in 2016 citing safety and cost concerns,[27] while other sources have attributed the delay to national security issues.[28]

C.6.(c) Management of Projects and Supply Chains

The underlying debate during the events is whether emerging vendors from Russia, China and South Korea will apply industry best practices to the management of projects and supply chains in the export market as they grow their export businesses. On the one hand, it can be argued that these companies are all very experienced and have generally good records of performance. On the other hand, a perception exists that transparency may not be sufficient, especially in Russia and China. Established commercial nuclear suppliers, for example those in the USA, Canada, France and Japan, have been the architects of the current system. Russia and China, on the other hand, do not have the same track record in developing and continuing to improve nuclear governance structures. There is no clear evidence to show that new vendors are less reliable at managing their supply chains than the traditional vendors. However, it can certainly be argued that in recent years China and Russia have become increasingly unpredictable in their foreign policy dealings. Some key concerns raised include:

- When emerging vendors are operating with partner governments and companies in newcomer countries that have very little expertise and experience in the nuclear industry, the likelihood of bad practices may rise. Some participants argued that the vendor should play an active role in helping a newcomer host country to ensure that it is fully prepared and has acceded to all the relevant treaties, if only to protect the vendor's reputation. It was with this in mind that the Carnegie Endowment for International Peace in Washington DC embarked on an effort to develop the *Nuclear Power Plant Exporters' Principles of Conduct* in 2008. A number of vendors from around the world took part in the deliberations that led to a final document in 2014[29]. It elicited the support of companies in the USA, Japan, France, South Korea, Argentina and Russia. However, it saw no participation from any vendor organisation from China. Unfortunately, the participation in this initiative is waning and the continuation seems unlikely.[30]

- Some nuclear power plant construction projects highlight weaknesses that can occur in supply chain management and oversight, if not regulated and managed properly. Supply chains for nuclear power plants are large (sometimes amounting to 1000 or more suppliers) and are progressively internationalising. They have exposed quality issues along the supply chain, such as in Flamanville 3 (France), Olkiluoto-3 (Finland) and Shin Kori 1 (South Korea),[31] as well as in relation to counterfeit, fraudulent and suspect items, including forgery, falsification or false submission of documents. These result from a wide spectrum of behaviours usually relating to companies taking short cuts in the manufacturing process or quality control. Corruption, both at the government level as well as in the supply chain, was also highlighted as a key issue. The factors that permit bad practice to occur vary between countries, depending on the political and economic context.

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[26] S Thomas, 'China's Nuclear Export Drive: Trojan Horse or Marshall Plan' 101 *Energy Policy* 683.

[27] See Mai Nguyen and Ho Binh Minh, 'Vietnam abandons plan for first nuclear power plants' (22 November 2016, *Reuters*) <https://www.reuters.com/article/us-vietnam-politics-nuclearpower-idUSKBN13H0VO> accessed 19 December 2018.

[28] See Nick Gallucci and Michael Shellenberger, 'Will the West Let Russia Dominate the Nuclear Market? What the Westinghouse Bankruptcy Means for the Future' (3 August 2017, *Foreign Affairs*) <https://www.foreignaffairs.com/articles/russian-federation/2017-08-03/will-west-let-russia-dominate-nuclear-market> accessed 19 December 2018.

[29] Carnegie Endowment for International Peace, *Nuclear Power Plant Exporters' Principles of Conduct* (Carnegie Endowment for International Peace 2014).

[30] Global Nexus Initiative Working Group, Evolving Nuclear Governance for a New Era: Policy Memo and Recommendations (Global Nexus Initiative 2017).

[31] Nuclear Energy Agency, *First Construction Experience Synthesis Report 2008-2011*, NEA/CNRA/R(2012)2 (OECD 2012).

- The multiplicity of actors in the supply chain also raises the risk of them avoiding responsibility, if not regulated and managed properly. The key actor responsible for overseeing standards in the supply chain is the national regulator of the host country. The operator carries out most of the routine work to check the supply chain, and the World Association of Nuclear Operators runs training for new operators. If the national regulations require it, the operator will be obliged to appoint an independent quality control agency (e.g., Bureau Veritas, Lloyds Register). Nevertheless, the other parties along the supply chain also have a responsibility for product quality, including the designer, the licensee, the contractor and the supplier. Participants agreed that safety culture must be strong along the full supply chain, and this is difficult to achieve.

- Participants discussed two transnational factors that are complicating the management of supply chains. The first is the variability of standards between countries that complicates verification. The Nuclear Quality Standard Association is trying to address this through the planned introduction of an ISO standard (ISO 19443). The second is the need for more transparency, sharing and cooperation within the industry.

- Another key concern highlighted during the events is the fact that some newcomer countries insist on a proportion of the supply chain be localised, a step that may increase the risks of poor quality management and corruption. Ideally, localisation should proceed slowly, and expand only after the first plant has been commissioned. The rate of localisation will depend on the pre-existing economic and industrial structure of the country.

GLOSSARY

Border	In relation to a nuclear power plant located close to a national border and up to 30 km away from the risk-exposed neighbour.
Close Proximity	In relation to a nuclear power plant located up to 100 km away from the risk-exposed neighbour.
Frontrunner	A nuclear newcomer with a steady progress in undertaking various activities within Phase 1 of the IAEA Milestones Approach.
IAEA Milestones Approach[1]	Refers to a phased comprehensive method for the International Atomic Energy Agency (IAEA) to assist countries that are considering or planning their first nuclear power plant.
Incident State[2]	The State within whose territory a nuclear incident has occurred. The territory of the incident State also includes any exclusive economic zone as long as the Depositary has been notified of such an area prior to the nuclear incident.[3]
Installation State[4]	In relation to a nuclear installation, installation State means the Contracting Party within whose territory that installation is situated or, if it is not situated within the territory of any State, the Contracting Party by which or under the authority of which the nuclear installation is operated.
Joint Protocol[5]	Is designed to establish treaty relations between the Contracting Parties to the Vienna Convention and the Contracting Parties to the Paris Convention, and to eliminate conflicts that may arise from the simultaneous application of both Conventions to the same nuclear incident.
New build	Refers to new nuclear power plants that are built, and applies both to new nuclear power plants that are built by States embarking on a nuclear programme (e.g., Bangladesh), or by States that currently generate nuclear power but are revamping their programme.
Newcomer[6]	Refers to a State introducing nuclear power for the first time.

[1] International Atomic Energy Agency, 'Milestones Approach' <https://www.iaea.org/topics/infrastructure-development/milestones-approach> accessed 8 November 2018.

[2] Based on the Convention on Supplementary Compensation for Nuclear Damage (adopted 12 September 1997 and entered into force 15 April 2015) INFCIRC/567 22 July 1998 (CSC), Article XIII (Jurisdiction). See also Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (adopted 12 September 1997, opened for signature 29 September 1997 and entered into force 4 October 2003) INFCIRC/566, 22 July 1998 (1997 Vienna Convention), Article XI.

[3] International Atomic Energy Agency, The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage — Explanatory Texts, STI/PUB/1768 (IAEA 2017) 53.

[4] CSC (n2), Article I(e). See also 1997 Vienna Convention (n2), Article 1(d).

[5] International Atomic Energy Agency, 'Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention', <https://www.iaea.org/topics/nuclear-liability-conventions/joint-protocol-relating-to-application-of-vienna-convention-and-paris-convention> accessed 8 November 2018.

[6] May Fawaz-Huber, 'How the IAEA Assists Newcomer Countries in Building Their Way to Sustainable Energy' (IAEA 30 January 2017) <https://www.iaea.org/newscenter/news/how-the-iaea-assists-newcomer-countries-in-building-their-way-to-sustainable-energy> accessed 8 November 2018.

Nuclear incident[7]	Any occurrence or series of occurrences having the same origin which causes nuclear damage or, but only with respect to preventive measures, creates a grave and imminent threat of causing such damage.
Nuclear material[8]	Refers to: 1) nuclear fuel, other than natural uranium and depleted uranium, capable of producing energy by a self-sustaining chain process of nuclear fission outside a nuclear reactor, either alone or in combination with some other material; and 2) radioactive products or waste.
Nuclear power plant[9]	Refers to a facility that converts atomic energy into usable power. In a nuclear electric power plant, heat produced by a reactor is generally used to drive a turbine which in turn drives an electric generator.
Party[10]	Refers to a State which has consented to be bound by the treaty and for which the treaty is in force
Ratification[11]	The international act whereby a State indicates its consent to be bound to a treaty. The period of time between signature and ratification grants countries the necessary opportunity to seek the required approval for the treaty on the domestic level and to enact the necessary legislation to give domestic effect to that treaty. Also called 'acceptance', 'approval' or 'accession' to a treaty.
Regulatory Body[12]	An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating the safety of nuclear installations, radiation safety, the safety of radioactive waste management and safety in the transport of radioactive material.
Safety[13]	Safety refers to the protection of people and the environment against radiation risks, and the safety of facilities and activities that give rise to radiation risks. It is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of accidents and incidents, as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation.

[7] CSC (n2), Article I(i). See also 1997 Vienna Convention (n2), Article 1(l).
[8] CSC (n2), Annex Article 1(c). See also 1997 Vienna Convention (n2), Article 1(h).
[9] Organization for Economic Co-operation and Development, 'Glossary of Statistical Terms' <https://stats.oecd.org/glossary/detail.asp?ID=1858> accessed 13 September 2018.
[10] 1997 Vienna Convention (n2), Article 2.
[11] See also Vienna Convention on the Law of Treaties (adopted on 23 May 1969, entered into force 27 January 1980) 1155 UNTS 331, Articles 2(1)(b), 14, 16, 18.
[12] International Atomic Energy Agency, *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection: 2016 Revision* (IAEA 2016), 146.
[13] International Atomic Energy Agency (n12), 155.

Security[14]	The prevention and detection of, and response to, theft, sabotage, unauthorised access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities.
Signature[15]	A means of authentication, also expressing the willingness of the signatory State to continue the treaty-making process. The signature qualifies the signatory State to proceed to ratification, acceptance or approval. It also creates an obligation to refrain, in good faith, from acts that would defeat the object and the purpose of the treaty.

[14] International Atomic Energy Agency (n12), 179.
[15] See also Vienna Convention on the Law of Treaties (n11), Articles 10, 14 and 18.