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

# Small Modular Reactors: The Outlook for Development

Singapore, 8 November 2017

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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 |
| **CIL** | Centre for International Law, National University of Singapore |
| **CNS** | Convention on Nuclear Safety |
| **ESI** | Energy Studies Institute, National University of Singapore |
| **EU** | European Union |
| **IAEA** | International Atomic Energy Agency |
| **SMR** | Small Modular Reactor |

# ESI-CIL NUCLEAR GOVERNANCE PROJECT CONFERENCE SERIES

# SMALL MODULAR NUCLEAR REACTORS: THE OUTLOOK FOR DEVELOPMENT

Singapore, 8 November 2017

## SUMMARY OF DISCUSSIONS

## A. Introduction

The Energy Studies Institute (ESI) and the Centre for International Law (CIL) co-organised a conference titled 'Small Modular Nuclear Reactors: The Outlook for Development' on Wednesday, 8 November 2017. The first public event held under the ESI-CIL Nuclear Governance Project Conference Series covered the advances in Small Modular Reactor (SMR) design and technology development, including for non-power related applications; advantages and drawbacks of SMR projects; financing of SMRs; and their legal and regulatory requirements.

Discussions addressed the prospects of SMR technology in the commercial nuclear reactor market[1], especially in relation to developing countries with smaller-sized grids; countries with distributed grids (e.g., archipelagic States); and more established nuclear power countries experiencing stagnant electricity demand.

The conference speakers were international experts Dr. Hadid Subki and Mr. Frederik Reitsma, both from the International Atomic Energy Agency (IAEA), Mr. Robert Armour from Gowling WLG, and Dr. Peter Bird from Rothschild Global Advisory.

The half-day event was well attended with more than 60 participants from government, academia and the business sector. Discussions took place under the Chatham House Rule.

## B. Background

Since the construction of the first nuclear reactor in the late 1950s, nuclear energy has become a major electricity source. Certainly, in the immediate aftermath of the 2011 Fukushima Daiichi nuclear accident, there were delays in global nuclear energy development due to increased regulatory requirements for safety, along with escalations in the capital cost of reactor constructions. The 'nuclear renaissance' – much alluded to by experts at the turn of the millennium – did not come to pass, however, the levelised cost of nuclear electricity remains competitive against other energy sources. Although total global electricity generation from nuclear power is at a decline compared to its 17.6 per cent peak in 1996, it has remained a stable 10-11 per cent in the last four to five years.

It would too early to completely rule out nuclear energy as a long term power source, especially considering the vested interest of emerging powerhouses such as China and India that are rapidly expanding their nuclear fleet. Countries in the Association of Southeast Asian Nation (ASEAN) region are also increasingly considering the prospects of a nuclear power programmes.

Opinions on nuclear power remain sharply polarised following the Fukushima Daiichi nuclear accident. Those in the pro-nuclear camp argue that nuclear power is safe, clean, cost-effective and should be expanded worldwide. Alternatively, some argue against the use of nuclear power, primarily due to its

[1] Excerpts from Sections C, D, E and H.3 of this report are reprinted from Victor Nian, 'The prospects of small modular reactors in Southeast Asia' 98 *Progress in Nuclear Energy* 131, Copyright (2017), with permission from Elsevier.

lack of safety, as demonstrated by the accident. Other concerns surround security, the unsolved problem of storage and disposal of nuclear waste, a lack of public support, the size of capital investments required, construction time overruns and service outages.

Yet, rising energy demand driven by rapid economic development makes nuclear energy an important low-carbon energy option. According to business-as-usual projections undertaken by the USA's Energy Information Administration, world carbon emissions will rise by around 42 per cent between 2013 and 2040 . The International Energy Agency has identified nuclear energy as an essential source of low-carbon energy to attain the '2°C Scenario'. The Intergovernmental Panel on Climate Change's 'zero emissions by 2100' projection further highlights the importance of nuclear energy among the energy sources required to decarbonise the electricity sector.

Many countries, especially China, also consider nuclear energy to be a method of reducing air pollution, as compared to coal-fired power plants. Moreover, nuclear energy remains an important option to address a country's energy security concerns, especially those heavily dependent on energy imports, such as Japan and South Korea.

The World Nuclear Association reported that the nuclear industry has been seeking alternative design approaches to minimise the risks of nuclear accidents since the Fukushima Daiichi nuclear accident.[2] These include reactor core designs in liquid state, SMRs and thorium fuel cycles. It is anticipated that Generation IV reactors could arrive as early as 2030.[3] Although SMR technologies have yet to be demonstrated commercially for industrial applications, the safety and economic prospects of SMRs may bring the development of nuclear energy back to its pre-Fukushima Daiichi nuclear accident trajectory, towards the previously alluded 'nuclear renaissance'.

## C. Why Small Modular Reactors?

Decades after the Three Mile Island and Chernobyl nuclear accidents, the Fukushima Daiichi nuclear accident has again raised concerns about nuclear safety. Construction of large-scale nuclear reactors, of 1 GW and above, still faces the risks associated with high capital commitment and uncertainties during construction. Yet, many developing countries, including those in the ASEAN region, remain interested in nuclear power.

There are practical challenges for ASEAN countries interested in nuclear energy. For one, ASEAN countries are situated in close proximity to one another. A nuclear accident of the scale of the Fukushima Daiichi nuclear accident occurring in any part of the region could lead to serious transboundary impacts. The larger the plant, the more difficult it would be to manage the accident, and the larger and more widespread the damage to the immediate and distant environment. Thus, smaller reactors, such as the currently proposed SMRs based on mature or more advanced and safer technologies could be a safer option for ASEAN countries.

An SMR is defined as an advanced reactor having an electricity generating capacity of less than 300 MWe, and which can be factory-built for on-site assembly and installation. Standardisation and modularity of SMRs allow for cost reduction through serial and modular production so as to offer better assurance over completion time. Some of the compact designs, such as the Integral Pressurised Water Reactors can also allow for flexible siting such that they can be placed close to users of electricity and heat. Most SMR designs are based on mature and commercially proven Pressurised

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[2] World Nuclear News, 'DOE funding for advanced reactor research' (4 November 2014, *World Nuclear News*) <http://www.world-nuclear-news.org/NN-DoE-funding-for-advanced-reactor-research-0411147.html> accessed 21 December 2018.

[3] Generation-IV International Forum, 'Generation IV systems' <https://www.gen-4.org/gif/jcms/c_59461/generation-iv-systems> accessed 21 December 2018.

Water Reactor technology. Moreover, many designs have further incorporated passive safety elements. Some of the SMRs are even designed with a core in a liquid state using molten salt, which can help address the issues of a core meltdown.

## D. Safety and Other Benefits of Small Modular Reactors

Safety has been the fundamental principle of designing, siting, constructing and operating commercial nuclear reactors. After the Three Mile Island and Chernobyl nuclear accidents, the nuclear industry has learnt to work with negative feedback systems, improved instrumentation and control, and redundancy in safety functions. Since the Fukushima Daiichi nuclear accident, there has been further emphasis on passive safety and inherent safety to mitigate beyond design-basis accidents. With the SMR concept, the industry aims to develop a suite of reactor technologies that are safe, small, self-contained, user-centric and transportable.

A smaller electricity generating capacity (e.g., 100 MWe) implies less fuel use inside the reactor core as compared to a large-scale reactor of 1000 MWe. Since the fuel quantity inside an SMR is small, there is less decay heat to be removed as compared to a large reactor. Certain SMRs are designed such that natural convection would be sufficient to remove the decay heat over an extended period of time in the event of a Loss-of-Coolant Accident. As such, a core meltdown can be prevented even if there is an extended station blackout as in the case of the Fukushima Daiichi nuclear accident.

With improved safety, SMRs allow for more flexibility in the siting of reactors. In the USA, the Nuclear Regulatory Commission stipulates a minimum ten miles (16 km) evacuation zone around a nuclear reactor. Following the Fukushima Daiichi nuclear accident, many argue that the ten-mile evacuation zone is insufficient. The evacuation zone should be determined based on the likely maximum affected area around the reactor in the event of a severe accident. Thus, the objective of the proposed safety features in SMRs is to restrict the maximum affected area to within the containment area or the plant itself. With the ability to operate for 30 years without on-site refuelling and significant reduction in the size of the required evacuation zone, SMRs can be deployed close to users. The close proximity to users can help facilitate the concept of a micro grid for electricity and heat distribution.

## E. Immediate and Future Applications of Small Modular Reactors

Based on the conceived technical characteristics and proposed applications, SMRs can be designed for deployment at remote locations and/or under extreme climatic conditions, such as in off-grid communities. The advantages of a long refuelling cycle lifetime can eliminate the need for handling spent fuel and highly radioactive waste by the operator. More importantly, there is no release of harmful pollutant or carbon emissions when producing electricity from SMRs as compared to diesel or biomass generators. All of these characteristics are important to ensure the sustainability of an energy source for addressing energy access in less developed regions and off-grid communities.

With technological innovation, compact SMRs may emerge as a competitive option for extra-terrestrial cogeneration or combined heat and power applications in the longer-term future. The fuel and oxygen requirements of an SMR are nearly negligible as compared to a fossil-fueled power plant. As a baseload combined heat and power technology, SMRs could demonstrate an alternative option for supplying energy to extra-terrestrial facilities. However, technological innovation is still needed to address the water requirement of SMRs for generating electricity.

The Advanced Research Projects Agency - Energy set up by the USA Department of Energy has initiated a programme to develop affordable SMRs of less than 10 MWe with high safety and security margins and the ability for autonomous operations. Possible areas of applications include powering remote locations, as a backup power source, international shipping, military installations and space missions.

Under the Gateway for Accelerated Innovation in Nuclear initiative, the Department of Energy has provided grants of up to USD 40 million (SGD 55 million) to X-energy for the development of the Xe-100 pebble-bed High Temperature Reactor, and Southern Corporation for the development molten chloride fast reactor in partnership with TerraPower and Oak Ridge National Laboratory. Just recently, the National Aeronautics and Space Administration announced its ambition to develop a 'kilopower' reactor (literally, no more than 10 kWe) that generates power using a 'Stirling Engine' for space missions.

## F. Small Modular Reactor Financing

The size of a typical nuclear project is simply too big for a single utility company. The project size tends to overwhelm the balance sheet of private contractors and private sector financiers such as banks and thus large nuclear power projects have primarily been financed by the public sector. In the case of China, Russia, South Korea, France and the United Arab Emirates, nuclear power plants are financed through State-owned utilities and/or companies. Government-to-government financing is also seen in the practice of Russian export projects to newcomer countries.

Financing such a capital intensive project solely through the private sector is difficult. Private sector utilities can only build nuclear power plants if the market and/or the regulatory environment can facilitate full cost pass-through (e.g., investor-owned utilities in USA and Japan). Moreover, traditional large nuclear power plants have long construction periods and in the past have run into completion time overrun, resulting in escalating costs. This has a knock-on effect of enhanced abandonment risk. This liquidity risk is a major issue for financing and insurance. The Okiluoto (in Finland) and Hinkley Point C (in the UK) projects are examples of the difficulties of constructing nuclear power plants on-time and on-budget.

SMRs are alluded to as an option to reduce the capital cost and on-site construction needs. A smaller capital cost reduces the burdens of engineering, procurement, and construction contractors. A smaller capital cost could also mean that lenders would be more willing to take the risks associated with construction projects. The lower capital cost and construction risks could also possibly eliminate the need for government or public equity in nuclear power plant projects. More importantly, the SMR concept might help reduce the construction period which in turn reduces interest during construction. These advantages could attract private sector investments.

The smaller capacity of SMRs could also lead to a larger fleet of the same reactor model, giving more scope for standardisation. Since the size of SMRs is generally much smaller than a conventional large scale reactor, SMRs can help reduce grid impact. With transportable SMR concepts, SMRs may allow for short-term electricity contracts as compared to the long-term contract required by a conventional large-scale reactor.

An additional benefit of SMRs is reduced back-end costs. Usually, back-end costs are borne by the utility company and are thus passed on to consumers. Back-end costs are subject to the decision (changes) of future governments and are inherently unpredictable. With mobile or floating nuclear power plants, the back-end processes and hence costs are removed from the host country. Since decommissioning and waste management are handled by the reactor manufacturer, mobile nuclear power plants have the potential to reduce both uncertain back-end costs and to mitigate political and/or environmental and public acceptance concerns.

## G. Legal and Regulatory Requirements for Small Modular Reactors

Potential future large-scale SMR deployment raises a number of fundamental questions such as how far host nations can delegate scrutiny and whether the current IAEA Milestone Approach is appropriate.

A major hurdle for newcomer countries is first establishing, and then implementing, a national nuclear legislative and regulatory framework within which responsibilities are clearly allocated and that incorporates the relevant international nuclear legal instruments (such as the Convention on Nuclear Safety[4], IAEA Safety Standards and IAEA Nuclear Security Guidance[5]), as well as international best practice. In this regard, a key challenge is establishing (and maintaining) an independent and competent national nuclear regulatory body with legal authority and adequate resources to fulfil its statutory obligations.

Current large reactor licencing processes are lengthy and exhaustive for each project. Regulators in different countries have different approaches and requirements for nuclear power plants. The high costs of licencing are prohibitive for small developments. There is uncertainty in some regulatory processes which could present barriers for large-scale SMR deployment worldwide.

Regulatory frameworks and licensing processes for most of the vendor countries are orientated towards reactor designs that are commercially deployed, particularly large water-cooled plants. Much work needs to be done, and is in fact on-going, to streamline regulatory and licensing processes in these countries. An design certificate applicable internationally is a long- term goal for large nuclear power plant designs, but this does not necessarily have to be the case for SMRs. SMRs can be seen as an early opportunity for seeking multilateral or international regulatory approvals. However, to facilitate large scale SMR deployment, the current legal and regulatory infrastructure should be adjusted. Essentially, a system designed for large plants needs to be adapted for decentralised, smaller units. Sustained government support is critical to getting SMRs to commercial viability. The legislative and regulatory frameworks for SMRs at the international and national levels will have a major impact on risk and economics.

## H. Small Modular Reactor Technology Developments

### *H.1. Land-based Small Modular Reactors*

The most significant technology development and proposals on land-based SMRs is summarised in Table 1. However, the majority of these technologies have yet to pass the conceptualisation stage.

**Table 1***: Notable technology developments and proposals for land-based SMRs.*

| Water-cooled SMRs | Gas-cooled SMRs | Liquid-metal-cooled SMRs |
|---|---|---|
| CAREM (Argentina) | HTR-PM (China) | PFBR (India) |
| SMART (Republic of Korea) | GTHTR300 (Japan) | PRISM (USA) |
| ACP100 (China) | HTMR100 (South Africa) | SVBR (Russia) |
| NuScale (USA) | $EM^2$ (USA) | 4S (Japan) |

[4] Convention on Nuclear Safety (adopted on 17 June 1994, opened for signature 20 September 1994 and entered into force 24 October 1996), INFCIRC/449, 5 July 1994 (CNS).

[5] The Safety Standards consists of three sets of publications: Safety Fundamentals, Safety Requirements and Safety Guides. While the first one of these establishes the fundamental safety objective and principles of protection and safety, the second set out the requirements that must be met to ensure the protection of people and the environment, both now and in the future. Safety Guides provide recommendations and guidance on how to comply with the requirements. There are some 150 Safety Standards compared to approximately 26 Nuclear Security series guidance publications.

### *H.2. Marine Small Modular Reactors*

OKB Gidropress from Russia has completed the construction of the very first KLT-40S, which is on schedule to start operation by 2019. China General Nuclear Power Corporation, in partnership with China Shipbuilding Industry Corporation, is currently building a first-of-a-kind ACPR50S. The French Alternative Energies and Atomic Energy Commission has announced plans to develop a submarine-derived SMR, Flexblue, as an immersed nuclear power plant. Nikiet has proposed a SHELF concept, which is also an immersed power plant design.

### *H.3. Other Notable Designs*

#### *H.3.(a) Integral Pressurised Water Reactors*

The Integral Pressurised Water Reactor is one of the popular concepts among the currently proposed SMR designs. There are five main features in the Integral Pressurised Water Reactor concept: the integrated reactor coolant system; multi-modules and modular construction; passive safety; advanced instrumentation and control system; and a longer refuelling cycle. These features can lead to a simplified, compact and light-weight reactor design, with enhanced maintainability and an extended technical lifetime, and hence cost competitiveness against large sized Pressurised Water Reactors. These features can also allow for better radiation control, which can translate to more flexible and efficient operation, and increased safety and reliability.

The Integral Pressurised Water Reactor features wide use of redundancy and passive safety. The objectives of these safety systems are to remove decay heat and to mitigate Molten Corium-Concrete Interaction. These measures include emergency pumps for water injection, refuelling water storage tank or in-containment refuelling water storage tank along with natural convection. Integral Pressurised Water Reactors also feature a containment flooding system for stabilising and cooling molten corium that may have spread onto the base of the containment in the event of reactor vessel failure. The features related to passive safety are designed to mitigate beyond design-basis accidents as a result of extreme external events such as tsunami or seismic and volcanic activates.

#### *H.3.(b) Multiple Module Small Modular Reactors*

SMRs can allow for multiple modules to be placed within a common building structure to form a multi-module plant. Although the risks associated with a multi-unit plant and a multi-module plant are similar, there are differences. According to the USA Nuclear Regulatory Commission, multi-unit plants are designed such that an accident condition in one unit would not cause initiating events in the other units. However, an accident condition in one module could potentially cause an initiating event in adjacent modules in a multi-module SMR plant sharing structures and/or systems. As such, the risks associated with radioactive effluent release remain important considerations for the licencing and construction of land-based SMRs.

#### *H.3.(c) Floating Small Modular Reactors*

An alternative approach is to place an SMR onto non-nuclear powered marine vessels, such as a ship, a barge or a semisubmersible. This type of marine SMR is different from those used in marine propulsion. Carried by non-nuclear powered marine vessels, marine SMRs can be mobilised towards users of electricity and heat, such as offshore oil rigs and remote islands. The KLT-40S designed by OKBM Afrikantov and the ACPR50S designed by China General Nuclear Power Corporation are examples of marine SMRs (see Section H.2 above). The mobility of a marine SMR can be critical to mitigating the impacts of severe accidents. In the emergency situation, the reactor can be quickly moved away to a safe distance, thereby reducing and possibly eliminating the need to activate off-site emergency response. In the event of a Loss-of-Coolant Accident, seawater becomes the ultimate heat sink and radiation shielding for preventing and mitigating a core meltdown. Compared with land-based reactors, marine SMRs can significantly reduce the risks associated with a severe accident situation.

### *H.3.(d) Generation IV Small Modular Reactors*

Following the Fukushima Daiichi nuclear accident, the development of Generation IV reactors (including SMRs) has gained momentum, especially the Molten Salt Fast-neutron Reactor and the High Temperature Reactor. Depending on the coolant types, the dominant neutron spectra, and other physical parameters, some Molten Salt Fast-neutron Reactor can be designed with a long refuelling cycle of 30 years.[6] In other words, there is no refuelling required over a 30-year design lifetime of the reactor. Another benefit of a Fast Reactor is the ability to burn plutonium for addressing safeguards. Further research and development works on Fast Neutron Reactors are also being carried out in the USA and Japan for destroying long-lived radioactive nuclei in the final waste.

Some of the Fast Reactor concepts feature a reactor core in liquid state and/or the use of liquid metal as alternative primary coolant, such as liquid sodium, lead and lead-bismuth. Japan has some experience in handling molten sodium since 1977 through the operation of the Joyo experimental reactor and the Monju prototype reactor. However, in 1995, there was a serious accident at the Monju reactor due to a major fire and resulting in the leakage of liquid sodium causing an emergency shutdown. Although there was no radiation leakage in the accident, the prospect of using liquid sodium as the primary coolant for Fast Neutron Reactors has become uncertain.

The development of High Temperature Reactors is an attempt to radically enhance safety and to extend the operating life of a plant up to 60 years. The current High Temperature Reactordesigns have the advantage of inherent safety characteristics by using graphite as moderator and helium as the primary coolant. The combined heat and power application can further improve the economic competitiveness of High Temperature Reactors.

[6] Toshiba Corporation and Central Research Institute of Electric Power Industry, *Super-safe, Small and Simple Reactor (4s, Toshiba Design)* (Toshiba Corporation and CRIEPI 2013).

# 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. |

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[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.

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[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.