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Nuclear Law

The Global Debate

International Atomic Energy Agency

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Preface

Nuclear law is an ever-evolving field, with the International Atomic Energy Agency (IAEA) at its centre. This highly specialized body of law permeates the entire nuclear sector, enabling the safe, secure and peaceful use of nuclear technology.

Because of it, we are able to enjoy the many life-saving benefits of nuclear science and technology, including cancer care, clean energy and better crop yields.

The IAEA and the international community have built a near universal safeguards regime that seeks to detect and deter the diversion of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons. Furthermore, we have built a safety—and security—first culture and adapted to new threats such as terrorism.

Nuclear science and technology evolve, driven by innovation and the need to address ongoing and emerging challenges, such as the COVID-19 pandemic and climate change, for example. Nuclear law must evolve with them. That is why we are publishing this book as part of the IAEA's First International Conference on Nuclear Law: The Global Debate.

In 2022, experts from around the world came together at this unique global forum to discuss key issues in nuclear law and to formulate a vision for the future. This collection of essays compiles insights from the world's thought leaders in this field. Some of the essays reflect on the history of nuclear law and its evolution, some focus on specific issues within the four main branches of nuclear law—safety, security, safeguards and nuclear liability—and others highlight some of the areas in which nuclear science and technology play an important role.

I am confident that this book will be useful to those developing and implementing policies and those writing laws and regulations. I believe it will be of interest to sister agencies within the United Nations system and other international and regional organizations whose mandates include peace and security and sustainable development. Some essays will be of particular interest to the legal and insurance industries involved in advising governments and industry on nuclear issues. For those in academia and civil society, the book may well prompt some thought-provoking scholarship and advocacy. I hope it will inspire and inform students and young professionals, especially women, who are pursuing careers in nuclear law, policy or industry.

But it is my goal that this collection proves insightful not only to those working on nuclear issues. I would like all of us who benefit from the life-saving power of nuclear science and technology to understand what goes into making it happen.

It goes without saying that this book is made possible through the generosity of the distinguished authors who made time to share their insights. I extend my sincere gratitude to them. I would also like to acknowledge the work of many colleagues in the IAEA's Secretariat who made this unique and important publication possible. These include the staff of the Office of Legal Affairs and of the Division of Conference and Document Services of the Department of Management; my advisers in the Director General's Office; as well as colleagues in the Department of Safeguards, the Department of Nuclear Safety and Security, the Department of Nuclear Energy and the Department of Technical Cooperation. Finally, I would like to express my particular appreciation for the support of IAEA Legal Adviser and Director of the Office of Legal Affairs, P. L. Johnson, and Section Heads in the Office of Legal Affairs, W. Tonhauser (who also served as Scientific Secretary for the Conference), I. Suseanu and J. Lusser. Special thanks to A. Wetherall, C. de Francia and I. Pletukhina of the IAEA Office of Legal Affairs for their indispensable assistance.

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Chapter 1
Nuclear Law: The Global Debate

Rafael Mariano Grossi

Contents

Abstract The International Atomic Energy Agency (IAEA) plays a unique role in the development and implementation of international nuclear law. This chapter contains a short examination of the regime of nuclear law and its four pillars, namely safety, security, safeguards and civil liability for nuclear damage. It examines how we got to where we are and where we can take the global debate, taking into account current and emerging peaceful applications of nuclear science and technology such as advanced reactors and nuclear fusion. The chapter also contains an invitation to all stakeholders in the global community, including international organizations, non-governmental organizations, industry, academia and civil society, as well as all those that will be responsible for shaping nuclear law in the future, to let the debate and dialogue on nuclear law begin.

Keywords International Atomic Energy Agency (IAEA) · International nuclear law · Nuclear safety · Nuclear security · Safeguards · Civil liability for nuclear damage · Peaceful applications (of nuclear science and technology) · Advanced reactors · Nuclear fusion

International instruments, standards and norms make up the framework of nuclear law on which we build the trust that nuclear will benefit us and our planet. At its heart stands the International Atomic Energy Agency (IAEA), which ensures this vital asset remains robust and agile in the ever-changing landscape of technology, opportunity and challenge.

Just as IAEA inspections make sure nuclear material is not misused to make weapons, or its scientists support Member States in using nuclear science and technology in medicine, agriculture, and the fight against plastic pollution and

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zoonotic diseases like COVID-19, nuclear law and those who shape it provide the indispensable normative framework to sustain the whole effort.

This critical framework on which we rely today was largely built through a series of reactions to major world events, beginning with the founding of the IAEA by those emerging from World War II with the realization of nuclear energy's awesome power to both save lives and destroy them. The IAEA's verification activities enable us to provide assurances that States adhere to their non-proliferation undertakings to use nuclear material and technology exclusively for peaceful purposes. This builds shared confidence that nuclear material is not being diverted to nuclear weapons and forms the bedrock of the international non-proliferation regime.

Beyond ensuring the IAEA is a tireless, firm, unbiased, fair and transparent watch-keeper of the world's safeguards system, there are three important tasks within the legal arena that I have set myself as Director General: to work actively towards making the legal and normative framework we have today as robust as possible; to help States adhere to the laws, standards and norms that keep us all safe and allow us to enjoy the many benefits of nuclear technology; and to make it possible for all those who, together with the IAEA, shape the international nuclear legal instruments of tomorrow to be as proactive as possible.

This book includes the thoughts and ideas of some of the most distinguished people in their field, many of them lawyers. This chapter will be informed by my own experience as a student of history, an Argentine diplomat and an international civil servant. As Edmund Burke said: "In history, a great volume is unrolled for our instruction, drawing the materials of future wisdom." A short examination of the regime of nuclear law, how we got to where we are and where we can take this global debate is a good way to start. Making the global debate in nuclear law accessible to a wider audience will ensure that informed decisions are made by States considering the views and contributions of the stakeholders in the global community including international organizations, non-governmental organizations, industry, academia and civil society.

Nuclear law has four main 'pillars': safety, security, safeguards and liability. These permeate the entire nuclear sector. They cover how we handle nuclear and other radioactive material, whether it is in the laboratory of a university in Paris or on a container ship travelling to a research reactor in Nigeria. Nuclear law is essential in realizing the benefits of the safe, secure and peaceful use of nuclear technology and its applications in our daily life.

The sharpest focus is understandably on nuclear power, which is essential as it becomes an ever more critical part of the low-carbon energy mix of countries looking to avoid the worst effects of climate change while providing the sustainable and reliable fuel for their economic growth, and as advances such as small modular reactors (SMRs) require special attention. But nuclear law does much more than address questions of safety, security, safeguards and liability related to nuclear power plants (NPPs). Other major challenges continue to face humanity today and can be expected to persist in the future, including food security, health care and management of water resources, together with the need for a cleaner and safer environment. Legal frameworks enable the use of nuclear technology to address these critical issues.

As participants in the nuclear community, we therefore need to ensure nuclear law remains fit for purpose.

The nuclear sector and the laws and norms that govern it are ever-evolving and so is the IAEA. In this chapter, I endeavour to describe how we are helping our Member States to embed the lessons of the past in order to anticipate the needs of the future.

A certain rigour is required to continually evaluate the legal frameworks in which nuclear activities take place. As the Director General of the IAEA, I am keenly aware of the years it takes to master the complexity of this area where scientists, engineers, lawyers, politicians and diplomats must speak a common language. To do this, we must understand the nuclear field and its attendant laws. For us to speak a common language in the global debate, we start our journey with a basic understanding of the origins, content and evolution of this field.

On Tuesday, 8 December 1953, against the backdrop of a developing nuclear arms race between the United States of America and the Soviet Union, diplomats gathered at the United Nations (UN) headquarters in New York to hear US President Dwight Eisenhower address the UN General Assembly. In what has since become one of the most famous speeches in history, he pledged that the US would help solve the "fearful atomic dilemma" and devote itself to "finding the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life." In his so-called 'Atoms for Peace' speech, President Eisenhower gave an outline of what would become the IAEA and set the stage for the future Treaty on the Non-Proliferation of Nuclear Weapons (NPT),[1] two cornerstones that still govern the world's approach to ensuring that its most powerful energy source is used only for peaceful purposes.[2]

Like a coin, the IAEA's mandate has two sides. It is the world's international nuclear watchdog and it is the central intergovernmental forum for scientific and technical cooperation in the nuclear field. In this regard, it works to ensure that the safe, secure and peaceful uses of nuclear science and technology help Member States advance towards meeting their Sustainable Development Goals.

In the more than six decades of its existence, the IAEA has faced many challenges in continually renewing its role as the preeminent independent science and technology based intergovernmental organization in the UN system, and has always been agile in responding to crises. The development of robust nuclear legal frameworks has evolved since the mid-1940s at the national, regional and international levels.

As described in this chapter, past events such as the Chernobyl accident in 1986, the discovery of a clandestine nuclear weapons programme in Iraq in 1991, and the terrorist attacks of 11 September 2001 led to the development of new and the strengthening of existing international legal instruments on nuclear and radiation safety, nuclear security, safeguards, and civil liability for nuclear damage. They were also significant catalysts for change within the IAEA, resulting in the strengthening of the organization's verification, safety and nuclear security roles.

[1] Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968, entered into force 5 March 1970 (NPT).

[2] Eisenhower 1953.

A basic feature of nuclear law is its focus on weighing the benefits of nuclear technology while minimizing risks. Its objective is to furnish a legal framework for conducting activities related to nuclear energy and ionizing radiation in a manner that adequately protects individuals, property and the environment in order that the public may obtain the benefits of this technology. This is done through complementary regimes dealing with safety, security, safeguards and liability.

The accident at the Chernobyl nuclear power plant (NPP) on 26 April 1986 was a wake-up call to the international community and resulted in the introduction of higher standards of nuclear safety at the international and national levels. Operators pored over their reactors and forged channels of communications that spanned even the Cold War's deeply divided political lines, creating a global safety-first culture we still benefit from today. Chernobyl led to the creation of an international legal framework in this field which today consists of four treaties adopted under the Agency's auspices. It was also a significant catalyst for the strengthening of the IAEA's role in nuclear safety.

Two conventions were adopted in September 1986 immediately after the Chernobyl accident, namely, the Convention on Early Notification of a Nuclear Accident (Early Notification Convention)[3] and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Convention on Assistance).[4] The purpose of the Conventions is to minimize the consequences of accidents or emergencies, by providing for the notification of accidents, the exchange of information and the prompt provision of assistance in the event of a nuclear accident or radiological emergency. The Early Notification Convention currently has 130 Parties and the Convention on Assistance, 124 Parties (as of September 2021).

While the status of adherence to both post-Chernobyl safety conventions is relatively high, there are still close to 50 IAEA Member States that are not yet party to these fundamental instruments. Our work is to continue to raise awareness about why all States should be party to these instruments. Significantly, the Conventions form the legal basis for the international Emergency Preparedness and Response (EPR) framework and are supported by operational arrangements which are the practical means by which the IAEA, its Member States and other international organizations maintain emergency preparedness and effectively respond to any nuclear or radiological incident or emergency.[5]

The cornerstone of the international legal framework for nuclear safety, the Convention on Nuclear Safety (CNS)[6] adopted in 1994, addresses the important subject of the safety of land-based NPPs (including storage, handling and treatment

[3] Convention on Early Notification of a Nuclear Accident, opened for signature 26 September 1986 (Vienna) and 6 October 1986 (New York), entered into force 27 October 1986 (Early Notification Convention).

[4] Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, opened for signature 26 September 1986 (Vienna) 6 October 1986 (New York), entered into force 26 February 1987 (Convention on Assistance).

[5] See IAEA 2017; IAEA 2018a; IAEA 2020a; IAEA 2020b.

[6] Convention on Nuclear Safety, opened for signature 20 September 1994, entered into force 24 October 1996 (CNS).

facilities directly related to the operation of the NPP). The CNS has 91 Parties and with limited exception all countries operating NPPs are party (as of March 2021).

As its name denotes, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management adopted in 1997 (Joint Convention)[7] addresses the back end of the nuclear fuel cycle and other radioactive waste, subjects that were not addressed earlier in the CNS. Although the Joint Convention entered into force two decades ago, it currently only has 86 Parties and more than half of all IAEA Member States are still not yet a Party to it (as of September 2021). This situation can be partly explained by the Convention's technical aspects and the need for increased awareness among decision makers of its relevance for countries with no nuclear fuel cycle-related activities. For example, nearly all countries generate radioactive waste, either from the production of nuclear electricity or from the use of radioisotopes in medical diagnosis and treatment, in industrial or agricultural applications, or in research. As such, the Joint Convention is relevant for all States.

The main innovative element of the CNS and the Joint Convention is the peer review process. At triennial meetings, officials, including regulators, subject their country's national safety practices as reflected in their national reports to a challenging but constructive peer review. Through this mechanism, they not only demonstrate commitment to applying stringent safety measures and to achieving high levels of safety but also have a unique opportunity for sharing experience and collective learning.

When we speak of nuclear law, we are referring to a body of law that includes not only legally binding international treaties, but legally non-binding instruments and standards of conduct which have a powerful norm-creating effect. Where consensus for a treaty is absent, such legally non-binding instruments can serve as a useful option with the possibility to be adopted and updated more quickly, offering simplicity and flexibility to respond to current needs. In particular, two Codes of Conduct adopted by the IAEA during the past two decades address the safety and security of radioactive sources and the safety of civil research reactors, respectively.[8] As a counterbalance to the legally non-binding nature of the Code of Conduct on the Safety and Security of Radioactive Sources of 2003[9] (and its two supplementary Guidance documents),[10] States have an opportunity to provide political support for the Code of Conduct pursuant to the relevant resolutions of the General Conference, the policy making organ of the IAEA on which each Member State sits and annually adopts resolutions that guide the work of the Agency.[11] Since 2006, a formalized process of information

[7] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, opened for signature 29 September 1997, entered into force 18 June 2001 (Joint Convention).

[8] IAEA 2004; IAEA 2006a.

[9] IAEA 2004.

[10] IAEA 2012a; IAEA 2018b.

[11] To date (September 2021), 140 States have made a political commitment to implement the Code of Conduct and 123 States have made a political commitment to the supplementary Guidance on

exchange, within the context of the Code of Conduct, on national approaches to controlling radioactive sources has been in operation.

Establishing high level principles, objectives and requirements, the conventions and codes of conduct are respectively underpinned by a comprehensive suite of detailed legally non-binding technical standards of safety, adopted on the basis of the IAEA Statute, which reflect an international consensus on what constitutes a high level of safety for protecting people and the environment. The standards, which apply to a broad range of facilities and activities, from nuclear installations to the use of radiation and radioactive sources in medicine, industry and agriculture, are developed in an open and transparent process led by the Commission on Safety Standards (CSS) with experts from Member States, in consultation with the UN and its specialized agencies.[12]

Most countries apply the Agency's Safety Standards on a voluntary basis. To facilitate national implementation, the instruments and standards are supported by voluntary practical implementation mechanisms such as the IAEA safety peer reviews and advisory services, which are carried out as an IAEA statutory function.[13] In addition, there are various other assistance activities, including the IAEA Legislative Assistance Programme, which help States to adhere to relevant international legal instruments and effectively implement them in comprehensive national nuclear legal frameworks.

The accident at the Tokyo Electric Power Company's Fukushima Daiichi NPP in Japan on 11 March 2011 was the second most impactful accident in nuclear energy's history even though leading international scientists have detected no radiation-induced health effects as a result of it.[14] Shortly after the accident, IAEA Member States unanimously endorsed an Action Plan on Nuclear Safety.[15] Further to the

Import and Export of Radioactive Sources and 44 States to the 2017 supplementary Guidance on the Management of Disused Radioactive sources.

[12] There are four Committees supporting the IAEA Safety Standards programme: in the area of nuclear safety, the Nuclear Safety Standards Committee (NUSSC); in radiation safety, the Radiation Safety Standards Committee (RASSC); in the safety of radioactive waste, the Waste Safety Standards Committee (WASSC); and in the safe transport of radioactive material, the Transport Safety Standards Committee (TRANSSC).

[13] IAEA safety peer review and advisory services include the Integrated Regulatory Review Service (IRRS), the Operational Safety Review Team (OSART), the Emergency Preparedness Review (EPREV) missions, the Site and External Events Design (SEED) review missions, the Technical Safety Review (TSR) services, the Occupational Radiation Protection Appraisal Service (ORPAS) missions, the Safety Aspects of Long Term Operation (SALTO) missions, the Peer Review of Operational Safety Performance Experience (PROSPER) missions, the Integrated Safety Assessment of Research Reactors (INSARR) missions, the Independent Safety Culture Assessment (ISCA) missions, the Advisory Missions on Regulatory Infrastructure for Radiation Safety (AMRAS), (which can also address security as the Advisory Mission on Regulatory Infrastructure for Radiation Safety and Security of Radioactive Material (RISS)), and the Education and Training Appraisal (EduTA) missions. In 2014, the IAEA launched the Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS).

[14] IAEA 2015a.

[15] IAEA 2011a. The Action Plan was approved by the IAEA Board of Governors on 13 September 2011 and endorsed by the IAEA General Conference during its 55th regular session in 2011.

Action Plan, several actions were taken aimed at improving the effectiveness of the international legal framework on nuclear safety and strengthening IAEA peer reviews and safety standards. The Parties to the CNS[16] also adopted the Vienna Declaration on Nuclear Safety in 2015[17] which is now an integral part of the CNS review process. The Declaration enhances the implementation of the objective of the CNS to prevent accidents with radiological consequences and to mitigate such consequences should they occur. Parties to both the CNS and the Joint Convention[18] also strengthened the Conventions' peer review processes. Further, utilization on a regular basis by Member States of IAEA safety peer reviews and advisory services was encouraged. The increased usage that followed, as well as the sharing of results, experiences and lessons learned, are positive steps that should continue. Additionally, the IAEA Secretariat was called upon to perform assessment and prognosis during a nuclear or radiological emergency.[19]

The Fukushima Daiichi NPP accident reminded the international community of the need for a common understanding among countries and, whenever possible, a common approach to EPR, even for those NPP accidents happening at great distance on the other side of the globe. Broad compliance with IAEA Safety Standards is acknowledged as a key step to achieving harmonization in EPR. The need for cross-border coordination and harmonization of EPR arrangements is established in the relevant international legal instruments and standards.[20] As more countries worldwide seek to launch new nuclear power programmes and construct NPPs, discussions to harmonize EPR strategies at bilateral and regional levels are important. A harmonized response across countries in the event of a nuclear accident is vital.

Since the 1970s, there has been a growing recognition that the operation of NPPs and management of radioactive sources requires high levels of both safety and security. At its root, nuclear security aims to ensure that nuclear and other radioactive material do not fall into the hands of non-State actors who could use it for malicious purposes. This requires, for example, making borders more secure by installing radiation monitors at ports and border crossings and ensuring that police, border guards and other officials are capable of detecting and preventing the smuggling of nuclear and other radioactive material. It requires improving physical protection at nuclear installations and hospitals, including guards and cameras, so that radioactive material is not stolen.

The interface between nuclear security and nuclear safety is an area of synergy in the global nuclear law debate. Both share the same goal: to protect individuals, the public and the environment from harmful effects of ionizing radiation. However, the

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[16] CNS, above n.6.

[17] IAEA 2015b.

[18] Joint Convention, above n.7.

[19] Further to the Action Plan, the IAEA General Conference during its 57th regular session in 2013 subsequently emphasized that the Secretariat's response role was to cover all nuclear and radiological emergencies. See IAEA 2013a, para 103.

[20] In particular, see the CNS and Joint Convention, as well relevant IAEA Safety Standards such as IAEA 2015c and other IAEA recommendations and guidance on EPR.

activities that address nuclear safety and nuclear security are different, and actions taken to strengthen one may affect the other positively or negatively. For example, controls to limit access to vital areas of an NPP not only serve a safety function by preventing or limiting exposures of workers and controlling access for maintenance to qualified personnel, but also serve a security purpose by inhibiting unauthorized access by intruders. There is therefore a continuing need to ensure that safety measures and security measures are designed and implemented in an integrated manner.

For 50 years, the Agency has been developing important nuclear security guidance, originally with a focus on recommendations for the physical protection of nuclear material.[21] The Agency's recommendations helped inform the discussions and negotiations of the Convention on the Physical Protection of Nuclear Material (CPPNM),[22] which was adopted in 1979 under IAEA auspices. But it was the terrorist attacks of 11 September 2001 in the United States of America that propelled a rapid and dramatic re-evaluation of the risks of terrorism in all its forms—including the threat of nuclear and radiological terrorism. This atrocity reinforced the urgent need to strengthen nuclear security without waiting for a watershed nuclear security event to provide the impetus for security upgrades and expanded international cooperation.

Following the terrorist attacks of 11 September 2001, States agreed to enhance existing international legal instruments, establish new ones to enhance nuclear security worldwide and reinforce the role of the IAEA. Specifically, agreement was reached in 2005 to adopt an Amendment to strengthen the CPPNM.[23] At the same time, the UN's International Convention for the Suppression of Acts of Nuclear Terrorism was adopted (ICSANT).[24]

Today, the legal framework for nuclear security comprises several complementary treaties, relevant resolutions of the UN Security Council and a number of legally non-binding instruments.[25] The instruments have not only been adopted by and under IAEA auspices but also by and under the auspices of the UN and its specialized agencies, notably the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO).[26] The framework includes two important resolutions of the UN Security Council adopted after the terrorist attacks of 11 September 2001 under Chapter VII of the UN Charter concerning Action with Respect to Threats

[21] IAEA 2011b.

[22] Convention on the Physical Protection of Nuclear Material, opened for signature 3 March 1980, entered into force 8 February 1987 (CPPNM).

[23] Amendment to the Convention on the Physical Protection of Nuclear Material, entered into force 8 May 2016 (Amendment to the CPPNM).

[24] International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 September 2005, entered into force 7 July 2007 (ICSANT).

[25] IAEA 2011c.

[26] A primary focus of most of the relevant treaties adopted outside of IAEA auspices is on criminalization of certain acts involving nuclear or other radioactive material, as well as related aspects, whereas the instruments adopted under IAEA auspices also cover legislative, administrative and technical measures to ensure the physical protection of materials and facilities, in addition to criminalization and international cooperation.

to the Peace, Breaches of the Peace and Acts of Aggression (Resolution 1540 (2004) and Resolution 1373 (2001)).[27] Both resolutions are binding on all (currently 193) UN Member States. The entry into force of the Amendment to the CPPNM in 2016 marked an important milestone for international efforts to strengthen nuclear security worldwide. Importantly, the CPPNM[28] and its Amendment remain the only internationally legally binding undertakings in the area of physical protection of nuclear material and of nuclear facilities used for peaceful purposes.

In order to support States, the IAEA produces guidance on nuclear security, which much like IAEA Safety Standards, aims at helping States develop, implement and maintain national nuclear regimes. This IAEA Nuclear Security Series includes the important guidance on physical protection which today also addresses nuclear facilities.[29] The Nuclear Security Guidance Committee (NSGC), which oversees the publication and review of all publications in the series, is composed of representatives from IAEA Member States and includes observers such as the World Institute of Nuclear Security (WINS). Through becoming mainstreamed norms, IAEA nuclear security guidance will enjoy the same status as IAEA Safety Standards. Similar to nuclear safety, the Agency's voluntary nuclear security advisory services, such as the International Physical Protection Advisory Service (IPPAS) and the International Nuclear Security Advisory Service (INSServ), play an important role in supporting States in establishing, sustaining and enhancing their nuclear security regimes.

Our work to maintain and enhance robust legal frameworks for nuclear security must continue. We live in a world in which the number of nuclear and other facilities and activities, including NPPs, laboratories and other locations concerned with this material, is increasing. Individuals and groups with malicious intent could attempt to exploit weak links in the global nuclear security regime to create fear and panic. Not only would this cause distress, but it would also undermine the public confidence critical to the continued use of nuclear science and technology for all kinds of important, life-saving applications.

Nuclear security, like nuclear safety, is the responsibility of individual countries. However, it is universally recognized that international cooperation is key in guarding against nuclear terrorism and that the IAEA serves as the inclusive global platform for this purpose. In addition to the technical guidance and recommendations that the IAEA establishes and supports Member States in the application thereof, another part of its work relates to the provision of radiation detection equipment, including personal detectors and radiation portal monitors for scanning vehicles and containers at seaports and border posts, and training of personnel. The IAEA also provides practical nuclear security support at major public events. In addition, the Agency's unique position allows it to bring together and integrate the many valuable efforts being made throughout the world, not just by governments, but also by think tanks, non-governmental organizations and others.

[27] United Nations 2004; United Nations 2001.

[28] CPPNM, above n.22.

[29] IAEA 2011b.

In order to eliminate weak links in the global nuclear security regime, it is essential for the relevant instruments to be universally adhered to and fully implemented.[30] We continue to promote the universalization of the Amendment to the CPPNM,[31] including through engaging with all relevant stakeholders at national, regional and international levels. We advise on the legal aspects to ensure understanding and awareness, as well as the benefits of becoming a Party to it. We also assist on technical aspects through practical assistance, expert advice, equipment and training.[32] Having a strengthened global international framework for combatting nuclear terrorism, a basis for ensuring that those involved in terrorist and other criminal acts involving nuclear material are brought to justice and denied safe haven, and stronger mechanisms for international and regional cooperation enhances the security of all States, whether they possess nuclear material or not.

In accordance with the CPPNM as amended, a Conference of the Parties to the Amendment to the CPPNM is being convened to review its implementation and adequacy in light of the situation prevailing at the time of the Conference. This Conference provides an excellent opportunity to consider the applicability of the amended Convention to contemporary challenges, including emerging issues, to discuss lessons learned in the implementation of the amended Convention, and to ensure the continued viability of the amended Convention as a living instrument going forward.

Emerging technologies, such as unmanned aerial systems and artificial intelligence, are an issue receiving ever greater attention and likely to remain a focus going forward. Such technologies and their applications present opportunities and challenges. On the one hand, emerging technologies are essential to improving operations and can be valuable for improving nuclear security. For example, technologies in areas such as artificial intelligence and big data have applications in detection, delay and response to a nuclear security event. On the other hand, there is a need to be mindful of the additional potential security risks that may accompany such technologies, especially those associated with information and computer security.

Attention to computer security has intensified in the last decade as clear and recurring proof of the vulnerabilities of computer systems has come to light. As more reliance is placed on artificial intelligence and digital control and safety systems, including those used to detect faults and shut down plants, recent events have reinforced the importance of heightened computer security. The IAEA plays an important role in supporting consideration of new technologies for nuclear security applications.[33] Adapting nuclear security to address emerging technologies means ensuring

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[30] The CPPNM has 164 Parties and the Amendment 127 Parties (as of September 2021).

[31] Amendment to the CPPNM, above n.23.

[32] See IAEA 2021a.

[33] See IAEA 2021a. The IAEA Nuclear Security Plan for 2022–2025 identifies that the Agency has a recognized a role in assisting States, upon request, to strengthen protection of computer-based systems, recognizing the threats to nuclear security and from cyberattacks at nuclear related facilities, as well as their associated activities.

that they meet security requirements and fall within legal and regulatory frameworks. This requires enhanced cooperation between the public and private sectors. Emerging technologies can be expected to continue to play an important role in the global debate, whether in the context of the Conference to review the CPPNM as amended, in the context of further developing the IAEA Nuclear Security Series guidance or in connection with important ministerial level conferences on nuclear security, which the Agency has been organizing since 2013.[34]

The Agency plays a recognized central role in strengthening the nuclear security framework globally and in coordinating international activities in this field, including cooperation with other international organizations and the various initiatives on nuclear security. It is vital that we all remain ahead of the curve in guarding against nuclear terrorism. The Agency's Nuclear Security Training and Demonstration Centre, soon to be operational, will reinforce the central role the Agency plays in this area of international importance by providing training at a state of the art facility.

The need for effective safeguards is a critical component of nuclear law, in addition to the high levels of safety and security discussed earlier. The evolution of the IAEA safeguards system started at a time of great fear that nuclear weapons would dominate the arsenals of many countries across the world. That this did not come to pass is a testament to the importance of the third major pillar of nuclear law, one that lies at the core of the Agency's mission and history, namely the task of safeguarding nuclear material and related technology for peaceful purposes. As a result, the establishment and administration of safeguards became a core function of the IAEA under its Statute.[35] The IAEA, through its safeguards work, has been recognized over the last 60 years as the international authority responsible for verifying and assuring that States are not developing nuclear weapons.

The IAEA's safeguards responsibilities and workload have increased steadily since the conclusion of the first safeguards agreement in 1959. From one nuclear facility under IAEA safeguards at that time, by 1971 there were 156 nuclear facilities under safeguards in 32 States. Fast forward five decades from 1970 when the NPT entered into force, and during the year 2020 the IAEA conducted 2034 inspections at more

[34] Such conferences are forums for ministers, policy makers, senior officials and nuclear security experts to formulate and exchange views on experiences and achievements, current approaches, future directions and priorities for nuclear security, including the legal framework.

[35] IAEA 1989, Article III.A.5; in 1957, it was also anticipated that the IAEA would play a major role as an intermediary for the purposes of securing the performance of services or the supplying of materials, equipment or facilities by one Member State of the IAEA for another. This did not happen on the scale that was originally anticipated, but instead through IAEA projects and the conclusion of so-called 'project and supply agreements', which require that IAEA safeguards be applied to the supplied items (see Ibid., Article XI). It should also be noted in this context that multilateral approaches to the nuclear fuel cycle have been developed with IAEA involvement. These have addressed the front end of the nuclear fuel cycle. The first, for example, is the International Uranium Enrichment Centre formally established by the IAEA and the Russian Government in March 2010, and which is owned and operated by the Russian Federation. The second is the IAEA Low Enriched Uranium (LEU) Bank, which is owned by the Agency and hosted by Kazakhstan, and which became operational in October 2019.

than 1300 facilities and locations outside facilities under safeguards in 183 States. Even in the most challenging of times, such as during the COVID-19 pandemic, the verification work of the IAEA does not stop for a single minute. An effective and robust legal framework is essential to ensuring a credible safeguards system on a global scale.

The IAEA safeguards journey started soon after its establishment, with the first safeguards agreement concluded with Canada and Japan in 1959. Under this agreement, the IAEA safeguarded a single small research reactor and its fuel. Between 1959 and 1971, 32 States concluded with the IAEA so-called 'item-specific'[36] safeguards agreements, under which the IAEA applied safeguards only to items specified in those agreements (i.e. nuclear material, facilities or equipment). While item-specific safeguards were the norm for about 15 years prior to 1971, today the Agency only implements safeguards pursuant to item-specific agreements for three States which are not party to the NPT or nuclear-weapon-free zone treaties: India, Israel and Pakistan.

The IAEA's safeguards work changed dramatically after the entry into force of the NPT[37] in 1970. Under the NPT,[38] non-nuclear-weapon States (NNWSs) Party must conclude so-called 'comprehensive' or 'full-scope' safeguards agreements (CSAs) with the IAEA, which apply to "all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere." These safeguards agreements enable the IAEA to verify the fulfilment of the NNWS's obligations under Article III of the NPT with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. CSAs are based on The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, which was approved by the Board of Governors in April 1971 (INFCIRC/153).[39] As of September 2021, CSAs were in force for 178 NNWSs Party to the NPT[40] and eight NNWSs Party to the NPT

[36] Item-specific safeguards agreements were an early type of safeguards agreement which was typically required by bilateral cooperation agreements between States. The safeguards agreement itself was concluded between the IAEA and the recipient State (and occasionally with the supplier State as well). Item-specific safeguards agreements have been concluded based on the safeguards procedures specified in a succession of documents: the first safeguards system, INFCIRC/26 (covering research reactors up to 100 MW thermal) and INFCIRC/26/Add.1 (covering all reactors); and the revised system, issued first as INFCIRC/66 (based on INFCIRC/26/Add.1) and expanded in INFCIRC/66/Rev.1 (adding reprocessing plants) and INFCIRC/66/Rev.2 (adding conversion and fuel fabrication plants) (IAEA 1961, 1964, 1965, 1967, 1968, respectively).

[37] Reproduced in IAEA 1970.

[38] NPT, above n.1.

[39] IAEA 1972.

[40] For 33 States, the CSAs are also in connection with the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Tlatelolco Treaty)—and for one State the CSA is also in connection with the Treaty of Bangkok. Two CSAs (reproduced in IAEA documents INFCIRC/193 (IAEA 1973) and INFCIRC/435 (IAEA 1994) include two or more States Parties and their regional safeguards organizations—the Brazilian–Argentine Agency for Accounting

had yet to bring into force CSAs required by that Treaty. CSAs are also required by regional treaties establishing nuclear-weapon-free zones.[41]

The five nuclear weapon States Parties to the NPT—China, France, Russian Federation, United Kingdom and the United States of America—have concluded 'voluntary offer safeguards agreements' (VOAs) with the IAEA. These VOAs were entered into for the purpose of encouraging widespread adherence to the NPT by demonstrating to NNWSs that they would not be placed at a commercial disadvantage by reason of the application of CSAs pursuant to the Treaty. The VOAs are also based on the document approved by the Board of Governors in 1971[42] and include the same safeguards procedures as a CSA, albeit with a different scope of application.[43] Large amounts of plutonium produced through the processing of spent fuel are safeguarded by the IAEA under VOAs in nuclear weapon States.

Several challenges have arisen in the implementation of safeguards over the course of the IAEA's existence. For the first 20 years of safeguards implementation in States with CSAs, the safeguards activities were primarily focused on verification of nuclear material and facilities declared by a State (i.e. on verifying the correctness of States' declarations and providing assurances that there is no diversion of declared nuclear material from peaceful nuclear activities in the State). Implementation of so-called 'traditional safeguards' during this period with respect to nuclear material and facilities declared by States under their CSAs was based on safeguards approaches and safeguards criteria which specify the scope, frequency and extent of the verification activities required to achieve the IAEA's inspection goals.

In the early 1990s, the discovery of Iraq's undeclared nuclear material and activities, including its clandestine nuclear weapons programme, underscored the need for the IAEA's safeguards activities to give greater consideration to a CSA State as a whole (i.e. to verify also the completeness of the State's declarations so that the IAEA could provide credible assurance that there was no undeclared nuclear material and activities in the State as a whole). That discovery coupled with the IAEA's detection of possible undeclared plutonium in the Democratic People's Republic of Korea (DPRK) in 1992, and experience from the IAEA's verification of the completeness of South Africa's declarations under its CSA in 1993, triggered efforts to strengthen the IAEA's capability to ensure that safeguards are applied as required by CSAs on all nuclear material in States with CSAs. The nearly simultaneous experiences in Iraq, the DPRK and South Africa played important formative roles in the subsequent work by the IAEA to strengthen the safeguards system.

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and Control of Nuclear Materials (ABACC) and the European Atomic Energy Community (EURATOM).

[41] Nuclear-weapon-free zones have already been established in Latin America and the Caribbean, the South Pacific, Southeast Asia, Africa and Central Asia.

[42] IAEA 1972.

[43] Under a VOA, the Agency applies safeguards to nuclear material in those facilities or parts thereof which have been offered by the State for the application of Agency safeguards and selected by the Agency from the State's list of eligible facilities in order to verify that such material is not withdrawn from safeguards except as provided for in the VOA.

The experiences in Iraq, DPRK and South Africa led directly to the launch in 1993 of 'Programme 93+2'. Historically, this was the most notable effort to further strengthen the effectiveness and improve the efficiency of IAEA safeguards, including the legal framework. The measures identified in this programme were designed to improve the IAEA's ability to detect undeclared nuclear material and activities in States with CSAs. Some of these measures (e.g. early provision of design information for new facilities, environmental sampling and the use of satellite imagery) could be implemented under the existing legal authority provided for in CSAs while others[44] required complementary legal authority. In May 1997, the Board of Governors approved the Model Additional Protocol,[45] which included the recommended measures and was the culmination of efforts to "strengthen the effectiveness and improve the efficiency of the safeguards system as a contribution to global nuclear non-proliferation objectives."

The Model Additional Protocol has significantly strengthened IAEA safeguards. Without it, what inspectors can do is limited. It gives inspectors the authority to search thoroughly, enabling the IAEA to more confidently reassure the world that no nuclear material remains unaccounted for, and none has been diverted. The additional information and broader access for the IAEA provided for in the Model Additional Protocol are designed to fill the gaps in information and access required under CSAs. The Model Additional Protocol is therefore essential for the Agency to obtain a more complete picture of the existing and planned nuclear programmes, nuclear fuel cycle related activities and nuclear material holdings of States with CSAs. Thus, the entry into force and implementation of an additional protocol (AP) in a State with a CSA is of vital importance for the IAEA to provide assurances about the exclusively peaceful nature of that State's nuclear programme.

For a State with both a CSA and an AP in force, the IAEA can provide credible assurance not only of the non-diversion of declared nuclear material from declared nuclear activities, but also of the absence of undeclared nuclear material and activities in the State as a whole and thereby draw a so-called broader conclusion for the State that all nuclear material remains in peaceful activities. As of September 2021, APs were in force for 138 States: 132 States with CSAs in force, five States with VOAs in force, and one State with an item-specific safeguards agreement in force. Forty-seven States have yet to bring into force APs to their safeguards agreements.

Changing requirements, assumptions and boundary conditions, as well as continuously improving technical capabilities and safeguards approaches, have all featured in the evolution of IAEA safeguards. The changing requirements for IAEA safeguards, along with corresponding modifications in the legal framework, have reflected the changing security needs of States over time. These security needs continue to evolve, and the IAEA continues to adapt to them.

[44] Such measures include provision of information by the State regarding research and development activities related to nuclear fuel cycle not involving nuclear material, uranium mines, uranium and thorium concentration plants, manufacturing of nuclear related equipment, processing of intermediate or high level waste, exports of specified equipment and non-nuclear material, and broader access to locations in the State.

[45] IAEA 1997.

A prominent example of the need to adapt to the times is the continuing evolution of safeguards involving small quantities of nuclear material, which may also pose a proliferation risk as technological capabilities to produce or process nuclear material increase. The original small quantities protocol (SQP) to a CSA was introduced by the IAEA in 1974 as a means to minimize the burden of safeguards implementation for those CSA States with minimal or no nuclear activities. However, the original SQP has long been considered a weakness in the IAEA safeguards system. Under the original SQP, the IAEA does not receive facility design information at an early stage of construction of a nuclear facility or an initial report on all nuclear material, nor can it conduct any in-field verification activities in the State. As a result, in 2005, the IAEA Board of Governors modified the SQP and called on all States with SQPs to amend or rescind their protocols, as appropriate, as soon as possible through exchange of letters. Under a modified SQP, the State is required to submit an initial report on all nuclear material and early design information, and the IAEA can conduct in-field verification activities in the State.[46]

The IAEA's ability to draw a credible and soundly based annual safeguards conclusion for States that have not yet amended or rescinded SQPs based on the original standard text has become increasingly difficult to sustain. The IAEA has therefore in 2020–2021 reinvigorated its efforts to strongly and actively call upon States that have not yet done so to amend or rescind their SQPs by exchange of letters. As of 24 September 2021, 96 States had operational SQPs in force to their CSAs, of which 69 were based on the revised standard text. Ten States had also rescinded their SQPs. There were 27 States that had yet to amend their operational SQPs based on the original text.

The IAEA must keep up with advances in nuclear technology for safeguards purposes. Currently, newly produced equipment and materials are used in nuclear fuel cycle-related activities but not subject to reporting to the IAEA. In order to keep pace with the evolution of nuclear technology, consideration might be given by Member States to updating the lists of nuclear equipment and non-nuclear material relevant for the nuclear fuel cycle[47] of the Model Additional Protocol. This would enable the IAEA to obtain a more complete picture of advances in technology and verify additional activities and items relevant to the nuclear fuel cycle and safeguards.[48]

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[46] IAEA 2006b.

[47] See IAEA 1997, Annexes I and II.

[48] Regarding Annex II of IAEA 1997, it is well known that since May 1997, when the Board approved the Model Additional Protocol, the members of the Nuclear Suppliers Group (NSG) have updated the NSG's Part I, or Trigger List, six times to reflect advances in nuclear equipment including with respect to reactors and components, non-nuclear material for reactors, and plants for reprocessing, fuel fabrication, the production of heavy water and the conversion of uranium and plutonium for use in the fabrication of fuel and the separation of uranium isotopes. The IAEA already noted more than 15 years ago that updating the lists would "ensure that the Agency's safeguards system keeps pace with developments in nuclear technology, and the information acquired as a result thereof would contribute to the transparency of a State's nuclear activities and the Agency's understanding of these activities. Such an update would contribute to increasing confidence that the additional activities identified in Annex I, and the additional specified equipment and non-nuclear material identified in Annex II, are being used only for peaceful purposes." See IAEA 2006c.

At the national level, ensuring that safeguards remain effective is largely a function of having a robust system of laws and regulations in place that reflects international safeguards obligations. The IAEA has been very active in providing legislative and regulatory assistance to States, including in this area of nuclear safeguards. The IAEA can complement this work by providing further assistance in strengthening State authorities in their regulatory functions, including through providing support on the development of safeguards-related regulations. The new COMPASS initiative contributes to the strengthening of national legal frameworks. Launched at the IAEA General Conference in 2020, the initiative involves partnering with States to help strengthen the effectiveness of their State authorities responsible for safeguards (SRAs) and systems of accounting for and control of nuclear material (SSACs).

The IAEA has developed important safeguards legal instruments which are in force for many States. However, not all States have adhered to these instruments. In the area of safeguards, the main obstacle to comprehensive safeguards reaching full effectiveness is the lack of universality. From the IAEA's point of view, universality will be achieved when all NNWSs Party to the NPT[49] have met their obligation under Article III.1 of the NPT to bring into force a CSA with the IAEA (eight NNWSs Parties have yet to do so); all States with a CSA in force have brought into force an AP to their agreements (47 States have yet to do so); and all States with CSAs and original SQPs have agreed to either amend or rescind their SQPs (27 States have yet to do so). The IAEA is increasing awareness of the importance of these instruments, assisting States to adhere to them and cooperating at the highest levels in their implementation. By continuing this work, I am confident that the IAEA will ensure that the credibility of its safeguards will be an enduring feature of the nuclear landscape.

An important final point on the IAEA's safeguards authority relates to compliance with safeguards agreements and to additional verification and monitoring activities. On several occasions, the Director General has reported to the Board of Governors safeguards implementation issues encountered in States with CSAs. In some of those cases, the Board found those States to be in non-compliance with their safeguards obligations, which was reported to the UN Security Council.[50] International agreement on confidence-building measures was reached in some instances, resulting in requests for the IAEA to perform enhanced verification and monitoring of a nuclear programme. Such activities were additional to those provided for in a safeguards agreement or related protocol.

The IAEA Statute has provided the basis for the IAEA to undertake 'other verification activities' to build confidence that nuclear activities remain peaceful, including in Iraq from 1991 to 2009 pursuant to relevant UN Security Council resolutions, verification of the 'freeze' of nuclear facilities in the DPRK under the US–DPRK Agreed Framework between 1994 and 2002, monitoring and verification activities in the DPRK between 2007 and 2009 in connection with the Six Party Talks, and

[49] NPT, above n.1.

[50] See IAEA 1972, para 19.

verification and monitoring of the Islamic Republic of Iran's nuclear-related commitments under the Joint Comprehensive Plan of Action. Consistent with its statutory authority, the IAEA performed a broad range of verification activities at the request of States and when approved by the Board of Governors, thereby contributing to the maintenance of international peace and security. As nuclear activities continue to expand worldwide, IAEA verification will continue to play a key role to ensure a peaceful nuclear future.

In addition to ensuring high levels of safety, security and safeguards, nuclear law also provides for mechanisms for adequate and prompt compensation in the rare event of a nuclear incident. This is the important area of civil liability for nuclear damage, the fourth pillar of nuclear law. This pillar was first developed in the 1960s as a recognition of the potential magnitude of nuclear damage, its cross-border effects, and the resulting need for a special liability regime to facilitate the compensation of victims and to address the economic concerns of the nuclear and insurance industries. The result was the Paris Convention[51] adopted in 1960 under the auspices of the then Organisation for European Economic Co-operation (OEEC) (now the Organisation for Economic Co-operation and Development (OECD))[52] and the Vienna Convention[53] adopted in 1963 under the auspices of the IAEA.

The conventions lay down uniform rules and are designed to facilitate compensation for transboundary damage. They are based on several general principles, including that of the exclusive liability of the operator of a nuclear installation, and that this operator is strictly liable for a minimum amount of liability, which in turn is guaranteed through mandatory financial coverage, typically in the form of insurance.

The 1986 Chernobyl accident also had an impact on the international nuclear liability regime, in addition to its impact on nuclear safety discussed earlier. States responded by modernizing the existing nuclear liability instruments of the 1960s, adopting new ones and linking them together.[54] Under the IAEA's auspices, the

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[51] Paris Convention on Third Party Liability in the Field of Nuclear Energy, opened for signature 29 July 1960, entered into force 1 April 1968 (Paris Convention).

[52] The so-called Paris regime consists of the Paris Convention, as amended by the Additional Protocol of 28 January 1964 and by the Protocol of 16 November 1982, concluded under the auspices of the OECD, open to OECD Member States and to other States if all Parties give their consent. The Paris Convention is supplemented by the 1963 Brussels Convention Supplementary to the Paris Convention, as amended by the Additional Protocol of 28 January 1964 and by the Protocol of 16 November 1982, that raises the level of monetary compensation for nuclear damage based on national and international public funds. Both conventions have been amended by Protocols adopted in 1964 and 1982, respectively.

[53] Vienna Convention on Civil Liability for Nuclear Damage, opened for signature 21 May 1963, entered into force 12 November 1977 (Vienna Convention).

[54] Under the IAEA's auspices States adopted: Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, opened for signature 21 September 1988, entered into force 27 April 1992 (Joint Protocol), (see also IAEA 2013b); the Vienna Convention; the Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage, opened for signature 29 September 1997, entered into force 4 October 2003 (1997 Vienna Protocol); and the Convention on Supplementary Compensation for Nuclear Damage, opened for signature 29 September 1997,

adoption of the 1997 Protocol to Amend the Vienna Convention and the 1997 CSC represented a major milestone in the development of an international nuclear liability regime. Both instruments contain important improvements in the amount of compensation available, the scope of damage covered and the allocation of jurisdiction.

More recently the 2011 Fukushima Daiichi NPP accident made evident the need for liability mechanisms to be in place before an accident occurs and the need for more States to be in treaty relations, thereby establishing a truly global nuclear liability regime. Further to the call in the 2011 IAEA Action Plan on Nuclear Safety, the International Expert Group on Nuclear Liability (INLEX), an advisory body of experts which reports to the IAEA Director General, adopted in 2012 recommendations on how to facilitate achievement of a global nuclear liability regime and how to provide better protection to victims of nuclear damage.[55] More than a decade on since the Fukushima Daiichi NPP accident and the adoption of the Action Plan, the IAEA's efforts remain focused on pursuing the establishment of such a regime.

The annual IAEA General Conference continues to encourage Member States to give due consideration to the possibility of joining the nuclear liability instruments, and to work towards establishing such a regime based on the principles of nuclear liability. With the entry into force in April 2015 of the 1997 CSC, the international community came one step closer. The 1997 CSC provides a framework for establishing a global regime with widespread adherence by nuclear and non-nuclear countries. It is now the single instrument covering the greatest number of nuclear power reactors worldwide. A regime that addresses the concerns of all States that might be affected by a nuclear incident is within our grasp and we therefore continue to promote greater adherence to the nuclear liability instruments adopted under IAEA auspices.[56]

Nuclear power is a 'cross-cutting' area of nuclear law of paramount importance, requiring the sharpest focus as it becomes an evermore critical part of the low-carbon energy mix. The operation of NPPs requires careful attention to safety, security and safeguards. Worldwide, more than 440 power reactors are in operation, accounting for about 10% of total global electricity generation and more than a quarter of the world's low-carbon electricity production. Out of more than 50 reactors currently under construction, nine are in countries building their first NPP. Some

entered into force 15 April 2015 (CSC) (see also IAEA 2020c). Under the auspices of the OECD, the Paris and Brussels Conventions will be further amended by Protocols adopted on 12 February 2004, which are expected to enter into force in early 2022: Protocol to Amend the Paris Convention on Nuclear Third Party Liability, opened for signature 12 February 2004, not yet in force (2004 Paris Protocol); Protocol to Amend the Brussels Supplementary Convention on Third Party Liability in the Field of Nuclear Energy, opened for signature 12 February 2004, not yet in force (2004 Protocol to the BSC).

[55] IAEA 2012b.

[56] The Vienna Convention, above n.53, only has 43 Parties; the 1997 Vienna Protocol, above n.54, 15 Parties; the CSC, above n.54, which finally entered into force in 2015, 11 Parties (but covering some 177 reactors) and the Joint Protocol, above n.7, 31 Parties. Most of the Paris Convention States are also party to the Joint Protocol but none of them are party to the CSC. Further, there are also a handful of countries with NPPs that are still not yet party to the instruments.

28 countries have expressed interest in nuclear power and are considering, planning or actively working to include it in their energy mix. Another 24 Member States participate in the IAEA's nuclear infrastructure related activities or are involved in energy planning projects through the technical cooperation programme.[57] To further encourage nuclear development, innovative approaches to financing and support policies, including from development finance institutions, are important to support the transition to a low-carbon economy.

A new nuclear power programme is a major undertaking requiring careful planning, preparation and investment in time, institutions and human resources. A decision to start a nuclear power programme should be based on a commitment to use nuclear power safely, securely and peacefully. The commitment includes joining all the relevant international legal instruments; this being a normative expectation of IAEA Member States. The international legal frameworks establish minimum obligations and provide a means of assurance of safety and security. Current new-build experience shows the importance of developing a sound national nuclear infrastructure, including a comprehensive and effective legislative and regulatory framework. It is important that the legal frameworks be robust to ensure that levels of safety or security remain high.[58]

The choice of an NPP site can be politically contentious, especially where the site is close to a border or shared waterway. It can give rise to specific legal and policy issues of concern, especially from neighbouring countries. As more countries worldwide seek to launch new nuclear power programmes and construct NPPs, enhanced discussions on effective and harmonized mechanisms addressing transboundary concerns, including environmental impacts, are needed. Such mechanisms can help to avoid or minimize disputes which can undermine the important role of nuclear energy.

Related to this issue are the topics of the rights of access to environmental information, public participation in the environmental decision making process and access to justice in environmental matters. A recent regional development in this context is the Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean (Escazú Agreement).[59] Significantly, it is the first international treaty in Latin America and the Caribbean concerning the environment.[60]

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57 IAEA 2021b.

58 The IAEA Milestones Approach is the leading publication for use by Member States in the development of new and expanding nuclear power programmes, IAEA 2015d. The Milestones Approach is supported by Integrated Nuclear Infrastructure Review (INIR) missions, which provide expert and peer-based evaluations, in helping requesting Member States to determine their nuclear infrastructure development status and needs.

59 Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean, opened for signature 27 September 2018, entered into force 22 April 2021 (Escazú Agreement).

60 This agreement was adopted by representatives of 24 countries of the Economic Commission for Latin America and the Caribbean (ECLAC) at the 9th meeting of the negotiating committee on 4 March 2018 in Escazú, Costa Rica. The agreement is open to 33 countries in Latin America

New technologies represent another important cross-cutting area of nuclear law, specifically with the introduction of advanced reactors including SMRs and transportable nuclear power plants (TNPPs). Across the world, several Member States continue to research, develop or deploy advanced fission reactors which consist of both evolutionary reactor technologies and innovative reactor technologies that may not use water as a coolant and moderator but rather use gas, molten salt or liquid metals.[61] These newer generation reactors are designed to generate typically up to 300 MW of electric power, and consist of components and systems that can be shop fabricated and then transported as modules to the sites for installation as demand arises. More than 70 SMR designs are currently in various stages of design and development and a few concepts are close to deployment.

Like large nuclear reactors, SMRs provide low-carbon energy, but they are smaller, more flexible and more affordable. They are an option to fulfil the need for flexible power generation for a wider range of users and applications and to replace ageing fossil fuel-fired power plants. They can be used on smaller power grids notably in developing countries and be built in hard-to-reach places like remote communities with less developed infrastructures where large reactors would not be practical. The driving forces in the development of SMRs are their specific characteristics: smaller size, use of novel technologies, modular design and more flexible deployment approaches. The novel approaches in the design and deployment of SMRs, as well as differences from traditional land-based NPP new-build projects such as factory manufacturing and testing, and new construction and commissioning methods, provide an opportunity to consider the need for tailor-made approaches, including for licensing. Although the IAEA Safety Standards can generally be applied to SMRs, global experts from the SMR Regulators' Forum are working on a tailor-made solution to help national authorities regulate this new class of reactor. To facilitate deployment of SMRs there are also calls in some fora for the harmonization of safety requirements, recommendations and guidance globally.

The IAEA supports its Member States through cooperation in SMR design, development and deployment and by serving as a hub for sharing SMR regulatory knowledge and experience. Recognizing the increasing global interest in SMRs, the IAEA recently established an Agency-wide SMR Platform to provide integrated support to Member States on all aspects of their development, deployment and oversight.

The IAEA is keenly aware of the challenges that SMRs and TNPPs pose for the implementation of safeguards and is working with stakeholders to consider how effective safeguards measures could be applied when such reactors are constructed,

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and the Caribbean. Of the 24 signatories, it has been ratified by 12. Following the accession of Argentina and Mexico on 22 January 2021, the Agreement entered into force on 22 April 2021. The objective of the agreement is to guarantee the full and effective implementation in Latin America and the Caribbean of the rights of access to environmental information, public participation in the environmental decision making process and access to justice in environmental matters, and the creation and strengthening of capacities and cooperation, contributing to the protection of the right of every person of present and future generations to live in a healthy environment and to sustainable development.

[61] IAEA 2020d.

exported, deployed or operated. Such reactors could present the appropriate solution for countries with energy needs on islands, in remotely located areas without interconnected electricity grids, or for countries with immediate needs for energy but without the full infrastructure required for stationary NPPs. Depending on the user requirements, such a plant can be operated by the supplier or by an entity from the receiving country.

For the effective and efficient implementation of safeguards at new facility types, safeguards measures need to be considered from the initial design planning stages. The IAEA has been working to support States and the nuclear industry in this area by providing ‘safeguards by design’ guidance in order to help implement safeguards effectively and efficiently. For facilities at the design stage or under construction, the IAEA has been working closely with the relevant State and/or regional authority, and facility operators, to incorporate safeguards features into the design of new facilities. For example, the IAEA has continued to cooperate closely with Finland, Sweden and the European Commission in the planning of safeguards implementation at encapsulation plants and geological repositories; with the Republic of Korea on planning for safeguards implementation at future pyroprocessing plants; with China to develop safeguards approaches for the high temperature gas-cooled pebble-bed reactor; and with Japan on the safeguards approach for the mixed oxide fuel fabrication plant at the Rokkasho site.

As new technologies and reactor types are deployed, nuclear law does not lose sight of the older models which they may replace. More than half of the reactors currently operating around the world are older than 30 years. Long term operation or lifetime extension of NPPs is a growing trend. Also, decommissioning of nuclear installations is gaining importance as an increasing number of reactors and related facilities are being permanently shut down or will be soon. Legal requirements form the basis to ensure that financial resources are sufficient and available to cover all decommissioning costs. The international legal framework contains important general principles in this regard.

The vision of decommissioning is evolving, reflecting new trends and concepts such as sustainable development and circular economy principles. Thus, the end-state definition is going beyond purely radiological criteria and more and more often covering wider environmental and even culturological context. That poses new challenges for decision making and stakeholders’ involvement processes. National legal frameworks need to evolve to adopt emerging practices such as the transfer of the site from a previous owner to a decommissioning operator. Potential implications of such approaches relate, for example, to nuclear liability issues and the adequacy of funding collected and transferred, which could affect the achievement of the decommissioning goals.

Few issues play as central a role in the public acceptance of nuclear technologies as the management and disposal of spent fuel and high level radioactive waste. At the opposite side of the scale, finding suitable endpoints is often also a concern in many States having responsibility for a comparatively small national radioactive waste inventory resulting from a more limited use of nuclear technologies, such as in medical, food or research applications.

In recent years, there has been significant progress in the development of national deep geological repositories for high level radioactive waste.[62] The most advanced programmes are nearing the formal recommendation for the disposal site, and a few are preparing approaches for the construction and operation of their deep geological disposal facility or are preparing the licence application for spent fuel emplacement in a facility under construction. Looking to the future, an increasing focus not only on the scientific and technical issues, but also on societal, political, legal and economic aspects that influence public perceptions of the safety and feasibility of implementing the geological disposal concept, will be critical.

No shared multinational, regional or international repository currently exists. However, national developments may spark a renewed interest in such repositories which could make technical and economic sense and offer safety, security and non-proliferation advantages. It can also be advantageous from an environmental viewpoint to have a small number of large repositories rather than many small ones. Further consideration of these concepts can be expected.

Remaining nimble and prepared to respond to emerging challenges in nuclear law requires us to be prepared for the advent of other game-changing technologies which lie within our grasp, such as nuclear fusion. It holds the promise of endless low-carbon energy and could be a game-changer in the fight against climate change. Fusion is now progressing from the academic ambit to a much more technological approach, and the quantities of radioactive substances generated by more advanced facilities will be much higher than those currently generated by existing experimental facilities. There are currently multiple projects in multiple countries developing multiple designs of fusion facilities. Lately, there have been some breakthroughs but fusion is not expected to contribute to power generation before 2050.

As investments and efforts expand in the area of nuclear fusion, there is a need to consider what legal frameworks are required to support the commercialization of safe fusion energy facilities, whether existing legal frameworks for fission reactors should apply or be adapted to apply to fusion technology, or whether there is a need for new fusion-specific legal frameworks and regulatory approaches.

It is generally acknowledged that the legal framework for the protection of the environment from the impact of nuclear activities has two distinct bodies of law: nuclear law, which mostly covers aspects related to radioactivity; and environmental law, which covers all types of hazard but may also include requirements for the protection of the environment against the harmful effects of ionizing radiation. Synergies between nuclear and environmental law, which share the common goal of protecting the environment, are essential for this purpose.

Some fundamental international legal principles and environmental law instruments addressing both substantive and procedural aspects are pertinent to nuclear activities. In particular, there is the 1998 Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters

[62] IAEA 2021b, paras 49–50.

(Aarhus Convention)[63] of the United Nations Economic Commission for Europe (UNECE), the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention)[64] and the 2003 Protocol on Strategic Environmental Assessment (Kiev Protocol),[65] adopted under the auspices of the UNECE.

Over the last few decades, international nuclear law has also focused more actively on protecting the environment and granting a specific status to the environment. Looking forward, a continuing focus on the protection of the environment in the nuclear sector can be expected, not least in areas such as strengthening of the IAEA Safety Standards and stakeholder access to nuclear information and participation in nuclear decision making, as well as the prevention of and compensation for environmental damage caused by nuclear incidents.

The IAEA serves as a hub for experts and representatives of Member States to share experiences and discuss topical issues in this field. In contributing to shaping nuclear law for the future, the IAEA and its Member States continue to be vigilant in assessing whether the legal frameworks for and related to the safe, secure and peaceful uses of nuclear technology and its applications are adequate to address future challenges. The IAEA works actively towards making the legal and normative framework we have today as robust as possible. There are opportunities to perform outreach to regional organizations such as the Association of Southeast Asian Nations (ASEAN), the African Commission on Nuclear Energy (AFCONE), the Forum of Nuclear Regulatory Bodies in Africa (FNRBA) and the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO), as well as to parliamentarians at the national and international levels through collaborating with organizations such as the Inter-Parliamentary Union (IPU). There are also opportunities to promote universalization with like-minded Parties to the relevant international legal instruments that wish to demonstrate leadership in supporting outreach to those States which are not yet party.

Owing to the complexity of nuclear technology, policies, laws and regulations, knowledgeable and skilled legislative drafters are required. IAEA training has traditionally focused on helping officials in Member States develop the skills needed for drafting nuclear legislation. Importantly, through the Legislative Assistance Programme we help States to adhere to all the international legal instruments and assess, review and develop nuclear legislation, to gain a better understanding of the international legal instruments, and to implement their international obligations. In addition, our legislative support includes scientific visits and fellowship opportunities in the IAEA Office of Legal Affairs and in national regulatory bodies.

Effective and comprehensive national and international legal frameworks for the safe, secure and peaceful use of nuclear science and technology underpin the lives and

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[63] Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, opened for signature 25 June 1998, entered into force 30 October 2001 (Aarhus Convention).

[64] Convention on Environmental Impact Assessment in a Transboundary Context, opened for signature 25 February 1991, entered into force 10 September 1997 (Espoo Convention).

[65] Protocol on Strategic Environmental Assessment to the Espoo Convention, opened for signature 21 May 2003, entered into force 11 July 2010 (Kiev Protocol).

livelihoods of billions of people, allowing all of us to strive to live better today and in the future. Such frameworks build the public trust necessary so that nuclear science and technology can benefit everyone. With the increasing utilization of nuclear technologies and the significant number of Member States involved in drafting or revising nuclear legislation, or planning to do so, the demand for reviewing draft and enacted legislation and for the training of drafters remains high. This demand will continue to be addressed through the annual IAEA Nuclear Law Institute (NLI) and its interactive programme, complemented where needed and requested through tailored national activities. Since the launch of the NLI in 2011, some 550 professionals from all regions of the world have graduated, nearly half of them women.

Governments are continuing to call upon the IAEA to raise the awareness of policy makers, decision makers and senior officials about the importance and benefits of the instruments and about the importance of putting in place and maintaining an adequate national nuclear legal framework. They are also increasingly calling upon us to assist in raising the awareness of parliamentarians in these areas.

In the coming years, regional training approaches on nuclear law will likely play an increasingly important role, in line with regional needs, interests and priorities. These approaches could be facilitated through collaborative arrangements with regional or national training or education centres, and some Member States have expressed interest in becoming centres for training in nuclear law at the regional level.

As the IAEA's membership grows and as Member States expand their uses of nuclear technology, the IAEA is likely to be increasingly called upon to provide legislative assistance. To further ensure that robust nuclear law frameworks are able to meet this moment, the IAEA's Secretariat remains at the ready to provide services for meetings held in conjunction with the conventions and codes of conduct. The IAEA will also maintain a spotlight on its unique function to establish safety standards and play a central role in developing comprehensive nuclear security guidance publications, according to the priorities set by Member States. Finally, the IAEA will be relied on to optimize its ability to conduct, upon request, peer reviews and advisory services as a feedback mechanism to facilitate the implementation of safety standards and nuclear security guidance. Remaining proactive in delivering such services, the IAEA will support the continued contribution of nuclear technology to human progress.

Making the global debate in nuclear law accessible is an essential prerequisite to ensure that informed decisions can be made by States. The Agency has an important role to play in this context. As with all technical conferences hosted by the IAEA, the 2022 International Conference on Nuclear Law provides a unique forum for leading global experts from governments, international and non-governmental organizations, industry and its advisers, academia and civil society to share experiences and discuss topical issues. But the discussions that take place today and the decisions arising therefrom will either directly or indirectly affect the interests of the generations to come.

The evolution of nuclear technology and its benefits has and will continue to span multiple generations. To optimally address global needs, therefore, we have a responsibility to take into account the views of not only our generation of nuclear lawyers, policy makers and scientists but also the next. It falls to each generation to re-envision the role of nuclear in improving the world. Our debate therefore needs to involve those who will be responsible for shaping nuclear law in the future.

The promise of the future well-being of humanity can be achieved through the deployment of technologies to support clean energy, clean air, clean water, resilient agriculture and the highest level of medical care. Nuclear technology can propel us forward on a sustainable path in each of these areas. Effective implementation of nuclear law frameworks is key to ensuring that we forge this path in a safe, secure and peaceful manner.

Nuclear law will continue to provide a foundation to achieve the goal of harnessing the power of nuclear technology to fulfil the dream envisioned in the Atoms for Peace speech, namely to devise methods whereby this technology would be allocated to serve the peaceful pursuits of mankind and experts are mobilized to apply it to the needs of agriculture, medicine and other peaceful activities, and provide electrical energy for sustainable development. Through this debate, we can shape the world we want to live in 50 years from now—the world we wish to leave for future generations.

The IAEA is the world's centre for cooperation in the nuclear field and will remain a pivotal force in ensuring that nuclear technology contributes to this future in partnership with our Member States and other organizations. Nuclear legal frameworks are an integral part of the global nuclear architecture and critical to its future. As the principal forum for the global debate on nuclear law issues, the IAEA, together with all those who wish to join us, will continue its efforts to shape a brighter nuclear future.

Let the Global Debate begin.

References

Eisenhower DD (1953) Speech to the United Nations General Assembly, 8 December 1953, New York

International Atomic Energy Agency (IAEA) (1961) The Agency's Safeguards, INFCIRC/26

International Atomic Energy Agency (IAEA) (1964) The Agency's Safeguards: Extension of the system to large reactor facilities, INFCIRC/26/Add.1

International Atomic Energy Agency (IAEA) (1965) The Agency's Safeguards System (1965), INFCIRC/66

International Atomic Energy Agency (IAEA) (1967) The Agency's Safeguards System (1965, as provisionally extended in 1966), INFCIRC/66/Rev.1

International Atomic Energy Agency (IAEA) (1968) The Agency's Safeguards System (1965, as provisionally extended in 1966 and 1968), INFCIRC/66/Rev.2

International Atomic Energy Agency (IAEA) (1970) Treaty on the Non-proliferation of Nuclear Weapons: Notification of the entry into force, INFCIRC/140

International Atomic Energy Agency (IAEA) (1972) The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected)

International Atomic Energy Agency (IAEA) (1973) The Text of the Agreement Between Belgium, Denmark, the Federal Republic of Germany, Ireland, Italy, Luxembourg, the Netherlands, the

European Atomic Energy Community and the Agency in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/193

International Atomic Energy Agency (IAEA) (1989) Statute. IAEA, Vienna

International Atomic Energy Agency (IAEA) (1994) Agreement of 13 December 1991 Between the Republic of Argentina, the Federative Republic of Brazil, the Brazilian–Argentine Agency for Accounting and Control of Nuclear Materials and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/435

International Atomic Energy Agency (IAEA) (1997) Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected)

International Atomic Energy Agency (IAEA) (2004) Code of Conduct on the Safety and Security of Radioactive Sources. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2006a) Code of Conduct on the Safety of Research Reactors. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2006b) The Standard Text of Safeguards Agreements in connection with the Treaty on the Non-Proliferation of Nuclear Weapons: Revision of the Standardized Text of the 'Small Quantities Protocol', GOV/INF/276/Mod.1 and Corr.1

International Atomic Energy Agency (IAEA) (2006c) Recommendations to be Considered by the Advisory Committee on Safeguards Verification within the Framework of the IAEA Statute to Further Improve the Effectiveness and Efficiency of the Safeguards System, GOV/2006/Note 45

International Atomic Energy Agency (IAEA) (2011a) Draft IAEA Action Plan on Nuclear Safety, GOV/2011/59-GC(55)/14

International Atomic Energy Agency (IAEA) (2011b) Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2011c) The International Legal Framework for Nuclear Security. International Law Series No. 4. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2012a) Guidance on the Import and Export of Radioactive Sources. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2012b) IAEA Action Plan on Nuclear Safety—Nuclear Liability. https://www.iaea.org/sites/default/files/17/11/actionplan-nuclear-liability.pdf. Accessed 8 October 2021

International Atomic Energy Agency (IAEA) (2013a) Measures to Strengthen International Cooperation in Nuclear, Radiation, Transport and Waste Safety, GC(57)/RES/9

International Atomic Energy Agency (IAEA) (2013b) The 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention—Explanatory Text. IAEA International Law Series, No. 5. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2015a) The Fukushima Daiichi Accident: Report by the Director General. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2015b) Vienna Declaration on Nuclear Safety, On principles for the implementation of the objective of the Convention on Nuclear Safety to prevent accidents and mitigate radiological consequences, CNS/DC/2015/2/Rev.1

International Atomic Energy Agency (IAEA) (2015c) Preparedness and Response for a Nuclear or Radiological Emergency. Co-sponsored by Food and Agriculture Organization of the United Nations, International Civil Aviation Organization, International Labour Organization, International Maritime Organization, International Criminal Police Organization, OECD Nuclear Energy Agency, Pan American Health Organization, Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, United Nations Environment Programme, United Nations Office for the Coordination of Humanitarian Affairs, World Health Organization, World Meteorological Organization. IAEA Safety Standards Series No. GSR Part 7. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2015d) Milestones in the Development of a National Infrastructure for Nuclear Power. IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1). IAEA, Vienna

International Atomic Energy Agency (IAEA) (2017) Joint Radiation Emergency Management Plan of the International Organizations. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2018a) IAEA Response and Assistance Network. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2018b) Guidance on the Management of Disused Radioactive Sources. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2020a) Operations Manual for IAEA Assessment and Prognosis during a Nuclear or Radiological Emergency. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2020b) Operations Manual for Incident and Emergency Communication. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2020c) The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage—Explanatory Texts. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2020d) Advances in Small Modular Reactor Technology Developments, 2020 Edition, A Supplement to: IAEA Advanced Reactors Information System (ARIS). IAEA, Vienna
International Atomic Energy Agency (IAEA) (2021a) Nuclear Security Plan 2022–2025, Report by the Director General, GC(65)/24
International Atomic Energy Agency (IAEA) (2021b) International Status and Prospects for Nuclear Power 2021, Report by the Director General, GOV/INF/2021/32-GC(65)/INF/6
United Nations (2001) Security Council Resolution 1373, S/RES/1373
United Nations (2004) Security Council Resolution 1540, S/RES/1540

Chapter 2
Nuclear Laws for Peaceful Uses of Nuclear Energy

Deng Ge

Contents

Abstract The development and utilization of nuclear energy is one of the greatest achievements of the 20th century. It has greatly enhanced the ability of humanity to understand and shape the world and had a significant impact on the development of technology and civilization. In the 21st century, the United Nations (UN) has developed the "Millennium Development Goals" and the "2030 Sustainable Development Goals" to promote a comprehensive solution to the world's social, economic and environmental issues. To this end, nuclear energy offers unique advantages, but the associated risks and challenges of its further development and utilization must be addressed. Nuclear law is a powerful tool for regulating its development and responding to those risks and challenges. The Chinese Government has always developed nuclear energy for peaceful purposes in a safe and innovative way. At the Nuclear Security Summit in 2014, President Xi Jinping proposed adhering to

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a rational, coordinated and balanced approach to nuclear security and promoting a fair, cooperative and win–win international nuclear security regime. This not only summarizes China's experience in establishing a nuclear legal framework and developing nuclear industry, but would also strengthen international nuclear governance and promote nuclear energy to better benefit humanity. The international community should fulfil international obligations strictly, implement national responsibilities effectively, and jointly maintain the UN focused international system and international legal order, contributing to the realization of the common goal of "Atoms for Peace and Development".

Keywords Nuclear energy · Nuclear technology · Legal framework · Development · Nuclear security · Nuclear governance

2.1 Establishment and Improvement of the International Nuclear Legal Framework

Nuclear energy, also known as atomic energy, refers to the energy released when the structure of the nucleus changes. Unlike other traditional industries, nuclear energy has brought revolutionary changes to human society and industrial development despite only a hundred years of development from theoretical research to industrialization. Nuclear energy is a 'double-edged sword'. The huge energy produced by nuclear fission not only benefits human life, but also brings risks and challenges. The first risk is nuclear safety. Accidents including at Chernobyl in 1986 and Fukushima Daiichi in 2011 caused serious radioactive contamination, endangered the lives and health of the public and the ecological environment of the countries and their neighbours, and also slowed down the development of the nuclear energy industry worldwide. The second is related to nuclear security. At present, the complexity of international situation, the prominent non-traditional security issues and the potential threat of nuclear terrorism all cannot be ignored. The possibility of nuclear or other radioactive materials falling into the hands of terrorists will pose a major challenge to international security. The third is related to nuclear proliferation. Nuclear technology is of dual use. If peaceful nuclear energy activities cannot be effectively controlled, the diversion of nuclear technologies and materials from peaceful uses to nuclear weapons or other nuclear explosive devices may bring devastating disaster to humanity.

The international nuclear legal framework has come into being with the development of nuclear energy worldwide. It has been continuously improved as the social, economic, scientific and technological issues associated with the development of nuclear energy are addressed, which has promoted the safe, secure and sustainable development of the peaceful uses of nuclear energy.

2.1.1 Establishment of an International Nuclear Legal Framework

In 1928, the International Commission for Radiological Protection (ICRP) was formed and began to study the development of international standards for radiation protection. The commission may be the first international organization devoted to nuclear energy utilization. At that time, there was no urgent need for nuclear law development due to the limited scope and scale of nuclear energy utilization.

In 1945, the first military use of the atomic bomb demonstrated the mass destruction and deterrence of nuclear weapons. In 1954, the connection of Obninsk nuclear power plant to the grid opened the age to use nuclear energy for peaceful purposes. In the 1960s, the nuclear power industry began to develop on a large scale. The oil crisis in 1973 brought new opportunities for the development of the nuclear power industry. In this case, the "Atomic Energy Act" of the United States of America was promulgated in 1946. In December 1953, US President Eisenhower delivered a speech on "Atoms for Peace" to the UN General Assembly.[1] On 29 July 1957, the Statute of the International Atomic Energy Agency (IAEA) came into effect, marking a milestone in the development of the international nuclear legal framework. The Statute stipulates that the mission of the IAEA is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world", and to "ensure that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."[2]

At its inception, the IAEA initiated the technical assistance programme to assist developing Member States in capacity building, introducing and developing nuclear technology, and utilizing nuclear technology safely and effectively.[3] It also developed safeguard documents "to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose."[4] In March 1970, the Treaty on the Non-Proliferation of Nuclear Weapons came into force, stipulating that non-nuclear-weapon States shall not directly or indirectly acquire or manufacture nuclear weapons or other nuclear explosive devices, and requesting non-nuclear-weapon States to negotiate and conclude a comprehensive safeguards agreement with the IAEA.[5] The Zangger Committee founded in 1971 and the Nuclear Suppliers Group founded in 1974 have established guidelines and a trigger list for nuclear transfers. An international nuclear damage liability regime has been established through the Paris Convention on Third-Party Liability in the Field of Nuclear Energy (Paris Convention) adopted by the

[1] Eisenhower 1953.

[2] IAEA 1989.

[3] https://www.iaea.org/services/technical-cooperation-programme/history. Accessed 2 November 2021.

[4] IAEA 1968.

[5] IAEA 1972; Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968, entered into force 5 March 1970 (NPT).

European Atomic Energy Community in 1960 and the Vienna Convention on Civil Liability for Nuclear Damage (Vienna Convention) under the auspices of the IAEA in 1963, to address the risks of personal injury and property loss that may be caused by transboundary nuclear accidents.[6] An international nuclear legal framework for non-proliferation of nuclear weapons and prevention of the risks of nuclear energy utilization has begun to be shaped.

2.1.2 Improvement of the International Nuclear Legal Framework

The major accidents at the Three Mile Island nuclear power plant in 1979 and the Chernobyl nuclear power plant in 1986 sounded the alarm for the safety of nuclear energy worldwide, and at the same time provided an opportunity for the international community to re-examine and improve the international nuclear legal framework. In the early 1990s, the clandestine nuclear activities of certain parties to the Treaty on the Non-Proliferation of Nuclear Weapons were discovered, prompting the international community to further strengthen the comprehensive safeguards and export control systems. In 2001, the attacks of 11 September aroused serious concerns about nuclear terrorism in the international community. In 2011, the Fukushima Daiichi nuclear accident made nuclear safety issues once again the focus of the international community. The international nuclear legal framework has been further developed and improved in response to new challenges.

2.1.2.1 Nuclear Safety

The Convention on Early Notification of a Nuclear Accident (Early Notification Convention) and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Emergency Assistance Convention), adopted in 1986, state that an international cooperation mechanism shall be established to strengthen information communication and technical assistance to mitigate the consequences of nuclear accidents or radiological emergencies.[7] The Convention on Nuclear Safety (CNS), adopted in 1994, further strengthens national responsibility for nuclear safety and international cooperation, reflecting an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful

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[6] https://www.iaea.org/topics/nuclear-liability-conventions. Accessed 2 November 2021.

[7] Convention on Early Notification of a Nuclear Accident, opened for signature 26 September 1986 (Vienna) and 6 October 1986 (New York), entered into force 27 October 1986 (Early Notification Convention); Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, opened for signature 26 September 1986 (Vienna) and 6 October 1986 (New York), entered into force 26 February 1987 (Emergency Assistance Convention).

effects of ionizing radiation.[8] The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention), adopted in 1997, clarifies the responsibilities and obligations of all countries in the safety of spent fuel and radioactive waste management throughout their lifetime.[9] The IAEA has developed and issued a series of nuclear safety standards, including Safety Fundamentals, General Safety Requirements, General Safety Guides, Specific Safety Requirements and Specific Safety Guides to assist States in effectively implementing the international obligations under the CNS and the Joint Convention. These standards have constituted a structure of safety principles for the entire process of nuclear energy utilization, and are of great significance for countries to establish effective nuclear safety regulatory systems and technical measures, and to achieve and maintain a high level of nuclear safety worldwide.

2.1.2.2 Nuclear Security

In 1979, the Convention on the Physical Protection of Nuclear Material (CPPNM) was developed under the IAEA's auspices, aiming at strengthening the security of nuclear materials during international transport.[10] The attacks of 11 September accelerated the revision process of the CPPNM. The Amendment to the CPPNM, adopted in July 2005, expands the scope of the Convention to cover physical protection of nuclear facilities and nuclear materials in domestic use, storage and transport, adding provisions to protect nuclear materials and facilities from sabotage.[11] The IAEA has also developed the Code of Conduct on the Safety and Security of Radioactive Sources and the Nuclear Security Series to provide guidance for the security efforts of Member States and the international community.[12] In addition, the International Convention on the Suppression of Acts of Nuclear Terrorism, developed under the auspices of the United Nations, was adopted in April 2005 and entered into force in July 2007.[13]

[8] Convention on Nuclear Safety, opened for signature 20 September 1994, entered into force 24 October 1996 (CNS).

[9] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, opened for signature 29 September 1997, entered into force 18 June 2001 (Joint Convention).

[10] Convention on the Physical Protection of Nuclear Material, opened for signature 3 March 1980, entered into force 8 February 1987 (CPPNM).

[11] 2005 Amendment to the Convention on the Physical Protection of Nuclear Material, entered into force 8 May 2016 (Amendment to the CPPNM).

[12] IAEA 2005.

[13] International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 September 2005, entered into force 7 July 2007 (Nuclear Terrorism Convention or ICSANT).

2.1.2.3 Nuclear Non-proliferation

In 1993, the IAEA launched the "Programme 93+2" aimed at strengthening the effectiveness and improving the efficiency of the safeguards system. The adoption of the Model Additional Protocol in 1997 strengthened the IAEA's ability to detect undeclared nuclear materials and activities.[14] In 1992, the Nuclear Suppliers Group made the conclusion of a comprehensive safeguards agreement between non-nuclear-weapon States and the IAEA as a condition for nuclear transfer, formulated the guidelines for the transfer of nuclear dual-use equipment, materials, and technology, and further improved nuclear export controls.[15]

2.1.2.4 Nuclear Liability

In 1988, under the joint auspices of the IAEA and the Organisation for Economic Co-operation and Development, the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (the Joint Protocol) was adopted; in 1997, the Convention on Supplementary Compensation for Nuclear Damage was adopted, promoting the establishment of a global nuclear damage liability system.[16]

2.1.2.5 Nuclear Cooperation

With the support of the IAEA, four regional cooperation agreements for the promotion of nuclear science and technology were signed in Asia, Africa and Latin America. As of the end of 2020, the IAEA has signed Revised Supplementary Agreements Concerning the Provision of Technical Assistance with 146 countries and regions. There are 1139 technical cooperation projects being implemented and 124 coordinated research projects involving health and nutrition, food and agriculture, water and environment, industrial application/radiation technology, safety and security, energy planning and nuclear power, and nuclear knowledge development and management, providing strong support for Member States in capacity building and human resource training in nuclear applications.[17]

[14] IAEA 1997.

[15] IAEA 2019.

[16] https://www.iaea.org/topics/nuclear-liability-conventions. Accessed 2 November 2021.

[17] IAEA 2020.

2.1.3 The Key Role of the International Atomic Energy Agency

As the most important intergovernmental organization specialized in the nuclear field, the IAEA plays a central role in promoting the establishment and improvement of the international nuclear legal framework. The IAEA also promotes the effective implementation and universal application of international nuclear laws by providing legislative assistance, peer review, expert advice, and personnel training, and assists Member States in establishing national nuclear legal frameworks. As of the end of 2020, the IAEA had issued a total of 129 nuclear safety standards and 39 nuclear security guidelines to assist Member States in developing and utilizing nuclear energy and technology in a safe and secure manner. The IAEA has also signed safeguards agreements with 184 countries, additional protocols with 136 countries, and small quantities protocols with 94 countries to verify nuclear materials, facilities and activities of the States involved.[18]

2.1.4 The International Nuclear Legal Framework for the Healthy and Orderly Development of Nuclear Energy

Since the establishment of the IAEA in 1957, dozens of multilateral international conventions related to the uses of nuclear energy, as well as a large number of bilateral or multilateral agreements on the uses of nuclear energy between countries and with international organizations, have been formed, constituting a relatively complete international nuclear legal framework, based on the principles of peace, safety, security, liability and cooperation, and providing a legal basis for the development of the peaceful uses of nuclear energy worldwide.

As of the end of 2020, there were 442 nuclear power units in operation worldwide, with a total installed capacity of more than 393 gigawatts (GW); 52 nuclear power units under construction, with a total installed capacity of more than 54.4 GW.[19] Nuclear power contributes more than a quarter of low-carbon power supply. Over the past 50 years, about 70 gigatonnes (Gt) of CO_2 emissions have been avoided thanks to the uses of nuclear power worldwide. At present, CO_2 emissions can be reduced by over 1.2 Gt annually.[20] Given all countries' policies and measures for responding to global climate change and technological innovations that have improved the safety and economy of nuclear power, nuclear energy's contribution and role in carbon emission reduction will be further expanded. According to the Energy, Electricity and Nuclear Power Estimates for the Period up to 2050 released by the IAEA in

[18] Ibid.

[19] IAEA 2021.

[20] IEA 2019.

September 2021, in the high case, by 2050, the installed nuclear power capacity worldwide will more than double the current capacity, reaching 792 GW; the share of nuclear power in the total power generation will rise to 12.3%. Many developing countries in Asia, Africa, South America and Eastern Europe will have the greatest demand for nuclear power and the fastest development in the future.[21]

2.2 China's Establishment of a Nuclear Legal Framework and Practice of Nuclear Energy Development

2.2.1 China's Establishment of a Nuclear Legal Framework

China's nuclear industry was founded in 1955. As early as the 1960s, the Chinese Government issued the "Interim Regulations on Hygiene Protection for Radiological Work", which stipulated the radiological protection issues that may arise in the development of the nuclear industry.

In the early 1980s, the Chinese Government made a major strategic deployment of reform and opening up, and decided to vigorously develop nuclear power to serve the economic development. In March 1985, the construction of the Qinshan Nuclear Power Plant was started. It was the first nuclear power plant which was independently designed, built and operated by China. In December 1991, it was successfully connected to the grid for power generation, realizing the "zero" breakthrough of nuclear power in mainland China. In order to meet the needs of nuclear power development, the Chinese Government promulgated the "Regulations on the Safety Supervision and Administration of Civil Nuclear Facilities" and the "Approval of the State Council on Compensation for Damages in Nuclear Accidents" in 1986, the "Regulations on Management and Control of Nuclear Materials" in 1987, the "Environmental Policy on the Disposal of China's Medium and Low Level Radioactive Waste" in 1992, the "Regulations on Emergency Management of Nuclear Power Plants and Nuclear Accidents" in 1993, and the "Regulations on Safety and Security of Nuclear Power Plants" in 1997. The above mentioned regulations cover nuclear safety, nuclear security, nuclear material control, nuclear liability, nuclear emergency response, radioactive waste management and other aspects, forming a legal system that regulates and promotes the development of nuclear energy.[22]

Since the beginning of the new century, China's nuclear power development strategy has gone through the stages of "moderate development", "active development", "safe and efficient development", and "proactive and well-ordered development while prioritizing safety and security". To ensure the safe, efficient and sustainable development of nuclear energy, China has further strengthened the construction of a nuclear legal framework. Since 2003, China has successively promulgated the

[21] IAEA 2021.

[22] State Council of the People's Republic of China 1986, 1987, 1993.

"Law on the Prevention and Control of Radioactive Pollution", the "Regulations on the Safety and Protection of Radioisotopes and Radiation Devices", the "Regulations on the Supervision and Administration of Civil Nuclear Safety Equipment", the "Regulations on the Supervision and Administration of the Transport of Radioactive Materials", and the "Regulations on the Safety Management of Radioactive Waste"; revised the "Regulations on Emergency Management of Nuclear Accidents in Nuclear Power Plants" and the "The State Council's Reply on Compensation for Damages in Nuclear Accidents"; promulgated, implemented and regularly updated the "National Nuclear Emergency Plan".[23] In 2018, the "Law of Nuclear Safety" was formally implemented. At present, the "Law of Atomic Energy" is about to be submitted to the Standing Committee of the National People's Congress for deliberation. A number of regulations and standard guidelines for nuclear safety, nuclear security, and nuclear import and export management have been promulgated one after another, and a nuclear legal framework including laws, administrative regulations and departmental rules has been established. As of June 2019, in the nuclear field, China had promulgated nine administrative regulations, nearly 40 departmental regulations, more than 100 safety guidelines, formulated more than 1000 relevant national and industrial standards, and 31 provinces, autonomous regions, and municipalities had formulated more than 200 local regulations, which played an important role in the safe and efficient development of China's nuclear industry.

China actively participates in international and regional cooperation in the peaceful use of nuclear energy and the non-proliferation process. In 1984, China joined the IAEA; in 1992, China joined the Treaty on the Non-Proliferation of Nuclear Weapons, and subsequently joined the Zangger Committee and Nuclear Suppliers Group and other export control framework. China has successively acceded to the Early Notification Convention, Emergency Assistance Convention, Nuclear Safety Convention, Joint Convention and other international nuclear safety conventions, as well as the International Convention for the Suppression of Acts of Nuclear Terrorism, Convention on the Physical Protection of Nuclear Material and its amendments and other international conventions on nuclear security. China strictly fulfilled its international obligations and commitments, and accordingly improved its domestic nuclear legal framework. In 1997, the Chinese Government issued the "Notice of the State Council on Issues Concerning the Strict Implementation of China's Nuclear Export Policy", clearly stipulating that nuclear exports should be safeguarded by the IAEA, and subsequently issued the "Regulations on Nuclear Export Control", "Nuclear Dual-Use Products and Related Technologies" and other administrative regulations; in 2004, relevant regulations were revised in accordance with the commitments made by joining the Nuclear Suppliers Group, and China's nuclear and dual-use nuclear export control measures were in line with international practices.[24]

[23] The Central People's Government of China 2003; State Council of the People's Republic of China 2005, 2007, 2009, 2011.

[24] State Council of the People's Republic of China 1998, 1997.

2.2.2 China's Nuclear Energy Development

With the effective nuclear legal framework, China's nuclear energy development has made great progress. So far, China has never experienced a nuclear incident of level 2 or above, and it followed the principle of 'keeping nuclear material under lock and key', which has created good conditions for the development of nuclear energy. At present, China has become the fastest growing country in the world for nuclear power. As of the end of September 2021, China has 51 nuclear power units in operation with an installed capacity of 53.3 GW; 18 nuclear power units under construction with an installed capacity of 19 GW.[25] In 2020, China's nuclear power generation capacity was 366.243 billion kW-h, with an increase of 5.02% year-on-year, accounting for approximately 4.94% of the country's cumulative power generation. Compared with coal-fired power generation, the annual nuclear power generation is equivalent to reducing the burning of 104.7 megatons (Mt) of standard coal, reducing the emission of 274.4 Mt of CO_2, 0.89 Mt of sulphur dioxide, and 0.78 Mt of nitrogen oxides, which is equivalent to afforestation of 771,400 ha.[26] The Chinese Government proposes that in 2021–2025, it will vigorously develop new energy, develop nuclear energy in a proactive and well-ordered manner while prioritizing safety and security, and continue to promote the clean and efficient use of coal, so as to reduce energy consumption per unit of GDP and carbon dioxide emissions by 13.5 and 18%.[27] In the context of carbon peaks and carbon neutrality, the transformation of China's energy and power system to a cleaner and low-carbon one will be further accelerated. As a type of clean energy with net zero emissions, nuclear energy will have a broader space for development. It is estimated that by 2025, China's nuclear power installed capacity in operation will reach more than 70 GW, and the installed capacity under construction will be about 50 GW; by 2030, China's nuclear power installed capacity in operation will exceed 100 GW, and the installed capacity under construction will exceed 50 GW; nuclear power generation will account for 8% of the country's total power generation.[28] Nuclear energy will play an indispensable role in supporting China's strategy and achieving the goal of carbon peak and carbon neutrality.

Over the past few decades, China's non-power application of the nuclear technology industry has continued to grow, forming a relatively complete industrial system in terms of material modification, non-destructive testing, irradiation breeding, irradiation processing of food and agricultural products, and nuclear medicine. Especially in recent years, the annual output value scale has achieved an increase of more than 20%, which has become a new bright spot to promote the development of the national economy. Since the outbreak of COVID-19, China has

[25] Sourced from the latest statistics of the China Atomic Energy Authority.

[26] Tingke et al. 2021.

[27] Refer to the government work report delivered by Premier Li Keqiang of the State Council of China at the Fourth Session of the Thirteenth National People's Congress on 5 March 2021, http://www.gov.cn/premier/2021-03/12/content_5592671.htm. Accessed 2 November 2021.

[28] Data taken from Tingke et al. 2021.

fully exploited its unique advantages in nuclear technology, using irradiation sterilization instead of traditional chemical sterilization, shortening the sterilization time of medical protective clothing from 7 to 10 days to one day, greatly relieving the urgent need for 100,000 sets of protective clothing daily in Wuhan and other regions. As of the end of 2020, there were 80,414 companies engaged in the production, sales and use of radioisotopes and radiation devices in China, with an increase of 22.7% over 2015; there were 149,452 radioactive sources and 205,280 radiation devices of various types in use, with an increase of 22.1 and 49.5% over 2015.[29] China will further expand its non-power application of the nuclear technology industry and cooperate with other countries in accordance with the principles of complementary advantages and mutual benefit.

2.3 Outlook

As a type of clean, low-carbon, and highly efficient base-load energy, nuclear energy is an important option for achieving the UN's 2030 Sustainable Development Goals and responding to the challenges of global climate change. The IAEA, the International Energy Agency and other organizations have issued forecasts for many years, believing that the share of nuclear energy in the total global energy will maintain a long term growth momentum in the future.[30] The international community should uphold the concept of a community with a shared future for nuclear safety, actively promote the universal application and continuous improvement of the international nuclear legal framework, and make unremitting efforts for the long term and healthy development of the global peaceful use of nuclear energy.

2.3.1 Promoting the Universal Application of the International Nuclear Legal Framework

The people of all countries live in a global village, forming a community of shared destiny. Each country should not only enjoy the right to the peaceful use of nuclear energy, but also shoulder the responsibility and obligation of preventing nuclear proliferation, maintaining nuclear safety and nuclear security. At the 2014 Nuclear Security Summit in The Hague, Chinese President Xi Jinping pointed out that "nothing can be accomplished without norms or standards".[31] All countries should earnestly fulfil their obligations under the international legal framework on nuclear safety, fully implement relevant UN Security Council resolutions, consolidate and

[29] NNSA 2020.

[30] IEA 2019.

[31] Full text can be found at http://en.qstheory.cn/2021-01/11/c_607626.htm.

develop the existing nuclear safety legal framework, and provide institutional guarantees and universally followed guidelines for the governance of the international nuclear industry.

However, the current cornerstones of international nuclear law such as the Treaty on the Non-Proliferation of Nuclear Weapons, the Convention on the Physical Protection of Nuclear Material and its Amendments, the Comprehensive Safeguards Agreement of the IAEA and its additional protocols have not yet achieved universal application, limiting the effectiveness of the international nuclear legal framework. The international community should actively promote the universal application of the international nuclear legal framework, ensure that all countries that carry out peaceful use of nuclear energy activities follow the basic principles and requirements determined by the international nuclear legal framework, strengthen the construction of non-proliferation, nuclear safety, and nuclear security systems. While benefiting human beings with nuclear energy, we should also protect our common home on the earth.

2.3.2 Assisting Countries in Establishing and Developing National Nuclear Legal Frameworks

The IAEA has presided over the formulation of a series of international conventions in the nuclear field, as well as nuclear safety and security guidelines. All relevant countries need to translate the requirements of international conventions into national legislation to ensure that international obligations and related requirements are actually implemented. At the very beginning of the development of nuclear energy, emerging nuclear energy countries need to establish a nuclear legal framework that regulates and promotes the safe development of nuclear energy.

The IAEA has extensive experience in building a nuclear legal framework, and has carried out a lot of work in assisting Member States to establish a national nuclear legal framework. For example, the IAEA compiled the Handbook on Nuclear Law and its second volume Nuclear Law Handbook: Implementing Legislation and implemented a legislative assistance programme.[32] With the development of the global peaceful use of nuclear energy, the IAEA should further increase its nuclear legislative assistance to Member States in need, raise Member States' awareness of international legal instruments in the nuclear field, support Member States in fulfilling their international obligations and commitments, and provide assistance to Member States in developing national nuclear legislation.

32 IAEA 2003; IAEA 2010.

2.3.3 Continuing to Develop and Improve the International Nuclear Legal Framework

The international nuclear legal framework is being promoted by nuclear energy, and it will surely continue to improve with the development of global nuclear energy. At present, the R&D of fourth-generation nuclear energy systems is increasing, small modular reactor (SMR) technologies are emerging one after another, and the development of nuclear fusion technology is steadily advancing, putting forward many new requirements for the development and improvement of the international nuclear legal framework. In addition, the safeguards verification of military nuclear power installations in non-nuclear-weapon States poses new challenges to the international nuclear legal framework.

Advanced SMRs adopt standardized and modular designs, with less initial investment scale and less site selection requirements, so they can be flexibly deployed. Some SMRs may be deployed in urban areas with high electricity load and high population density, and some may be deployed on the sea far away from the mainland. Dealing with safety and security issues in special application scenarios for SMRs and clarifying relevant technical and regulatory requirements are major issues that the international community must resolve as soon as possible.

Nuclear fusion energy is one of the ultimate ways to solve human energy and environmental problems. Nuclear fusion energy does not deviate from the overall scope of nuclear energy, and radiological risks cannot be eliminated 100%. The design, construction, operation and decommissioning of related facilities should be included in the scope of nuclear safety supervision and regulated by the corresponding legal and regulatory framework. Moreover, in the process of peaceful use of nuclear fusion energy, the possibility that related materials and technologies will be transferred to the manufacture of thermonuclear weapons cannot be ruled out. Therefore, the international community urgently needs to strengthen research to clarify the requirements of safety, security and peaceful use in the development and utilization of nuclear fusion energy as soon as possible, so as to lay a legal foundation for the large-scale application of nuclear fusion energy.

The peaceful use of nuclear energy is the common aspiration of all countries in the world, and it is our common responsibility to ensure the safety, security and sustainable development of nuclear energy. The international community should focus on promoting nuclear energy for the benefit of human beings, and promote the continuous improvement of the international nuclear legal framework in accordance with the principles of peace, safety, security, liability and cooperation, striving unremittingly for strengthening global nuclear governance, realizing "atoms for peace and development", and building a community with a shared future for human beings.

References

Eisenhower D D (1953) Speech to the United Nations General Assembly, 8 December 1953, New York

International Atomic Energy Agency (IAEA) (1968) The Agency's Safeguards System, INFCIRC/66/Rev.2

International Atomic Energy Agency (IAEA) (1972) The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected)

International Atomic Energy Agency (IAEA) (1989) Statute. IAEA, Vienna

International Atomic Energy Agency (IAEA) (1997) Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540

International Atomic Energy Agency (IAEA) (2003) Handbook on Nuclear Law. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2005) Code of Conduct on the Safety and Security of Radioactive Sources: Guidance on the Import and Export of Radioactive Sources. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2010) Handbook on Nuclear Law: Implementing Legislation. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2019) Communication Received from the Permanent Mission of the Republic of Kazakhstan to the International Atomic Energy Agency on Behalf of the Participating Governments of the Nuclear Suppliers Group, INFCIRC/539/Rev.7

International Atomic Energy Agency (IAEA) (2020) IAEA Annual Report 2020. https://www.iaea.org/sites/default/files/gc/gc65-5.pdf. Accessed 2 November 2021

International Atomic Energy Agency (IAEA) (2021) Energy, Electricity and Nuclear Power Estimates for the Period up to 2050, Reference Data Series. IAEA, Vienna

International Energy Agency (IEA) (2019) Nuclear Power in a Clean Energy System. https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system. Accessed 2 November 2021

National Nuclear Safety Administration (NNSA) of the People's Republic of China (2020) 2020 Annual Report. https://nnsa.mee.gov.cn/ztzl/haqnb/202106/P020210629665594621226.pdf. Accessed 2 November 2021

State Council of the People's Republic of China (1986) Regulations on the Safety Supervision and Administration of Civil Nuclear Facilities. http://www.nea.gov.cn/2017-11/03/c_136725275.htm. Accessed 2 November 2021

State Council of the People's Republic of China (1987) Regulations on the Management and Control of Nuclear Materials. http://www.nea.gov.cn/2017-11/03/c_136725276.htm. Accessed 2 November 2021

State Council of the People's Republic of China (1993) Regulations on the Emergency Management of Nuclear Power Plant Accidents. http://extwprlegs1.fao.org/docs/pdf/chn150237.pdf. Accessed 2 November 2021

State Council of the People's Republic of China (1997) Regulations on Nuclear Export Control. https://www.fmprc.gov.cn/ce/cgvienna/eng/dbtyw/fks/t127622.htm. Accessed 2 November 2021

State Council of the People's Republic of China (1998) Regulations on Export Control of Nuclear Dual-Use Products and Related Technologies. https://www.fmprc.gov.cn/ce/cgvienna/eng/dbtyw/fks/t127623.htm. Accessed 2 November 2021

State Council of the People's Republic of China (2005) Regulations on the Safety and Protection of Radioisotopes and Radiation Devices. http://extwprlegs1.fao.org/docs/pdf/chn152926.pdf. Accessed 2 November 2021

State Council of the People's Republic of China (2007) Regulations on the Supervision and Administration of Civil Nuclear Safety Equipment. http://extwprlegs1.fao.org/docs/pdf/chn149833.pdf. Accessed 2 November 2021

State Council of the People's Republic of China (2009) Regulations on Supervision and Administration of the Transport of Radioactive Materials. http://extwprlegs1.fao.org/docs/pdf/chn153827.pdf. Accessed 2 November 2021

State Council of the People's Republic of China (2011) Regulations on the Safety Management of Radioactive Waste. http://www.gov.cn/zwgk/2011-12/29/content_2033177.htm. Accessed 2 November 2021

The Central People's Government of China (2003) Law on the Prevention and Control of Radioactive Pollution (PRC Presidential Order No. 6 of 2003) https://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=en&p_isn=76093. Accessed 2 November 2021

Tingke Z, Minrong L, Qilong P (2021) China Nuclear Energy Development Report. Social Sciences Literature Press, Beijing

Chapter 3
Russian Vision of the Problems and Prospects of the International Legal Framework in the Context of Small Modular Reactors and Transportable Nuclear Power Units

Andrey Popov

Contents

Abstract Small modular reactors (SMRs) could be key to providing developing regions with clean and affordable (and cost-effective) electricity. Deployment of SMRs requires a transparent and balanced legal framework that will define the specifics and boundaries of shared responsibility between the host and supplier country, especially in the case of innovative floating SMR projects. Legal experience in nuclear-powered vessels and nuclear installations can be used in the development of regulatory approaches for floating SMRs. This chapter provides an analysis of the applicability of the existing international conventions, including the 1974 International Convention for the Safety of Life at Sea, the IAEA safeguards agreements, and civil liability instruments, to the floating SMRs. In addition, some considerations for the future development of the legal framework for floating SMRs are proposed.

Keywords Small Modular Reactors (SMR) · Floating power unit · 1974 International Convention for the Safety of Life at Sea (SOLAS) · IAEA safeguards · Civil liability · Reactor technology

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Fig. 3.1 The Akademik Lomonosov floating power unit at the site in Pevek. *Source* Rosatom 2019

3.1 Introduction

As environmental awareness grows, the challenges of decarbonizing and finding effective alternatives to meet the increasing need for energy become important. Achieving the Sustainable Development Goals (SDG) set forth by the United Nations (UN) in the 2030 Agenda for Sustainable Development[1] requires providing developing regions with clean and affordable (and cost-effective) electricity.

According to the IAEA report, Advances in Small Modular Reactor Technology Developments[2] there are more than 70 different onshore, offshore and submarine SMR projects worldwide. Among these 70 projects, 17 were developed by the Russian design companies. There is no common definition of SMR today, so for the purposes of this essay, SMR means a nuclear plant with a modular reactor of up to 300 MW(e).

Most existing SMR projects are based on mature and widely adopted PWR reactor technology. KLT-40S reactor, which relies on over 400 reactor-years of operating experience of this type of reactor on nuclear icebreakers, is no exception. KLT-40S is installed on the Akademik Lomonosov floating power unit (see Fig. 3.1), which was successfully put into commercial operation in 2020 and demonstrates high performance in the harsh conditions of the Russian North. Given the accumulated global experience in operating PWR reactors, as well as the experience of operating

[1] UNGA 2015.

[2] IAEA 2020a.

icebreakers' reactor plants in the Arctic, we can say that from a technical and safety point of view, the Russian SMRs are ready for wide commercialization (Fig. 3.1).

Addressing the issue of cost-effectiveness opened a 'window of opportunities' for international cooperation in SMR projects and, at the same time, demonstrated that, in addition to mastering the technology and proving its economic attractiveness, effective implementation requires a transparent and balanced legal framework that will define the specifics and boundaries of shared responsibility between the host and supplier country, especially in case of innovative floating SMR projects. Due to its technological sophistication and long life cycles, the nuclear power industry should not be affected by momentary changes in the political environment, and this can only be achieved through clear and consistent legal regulation of international nuclear projects.

3.2 Regulatory Control Approaches for Floating SMRs

The cross-border life cycle of floating SMRs raises cross-border issues related to the division of responsibility among project stakeholders.

The first projects, where a nuclear facility is operated by an operating organization of one State, moves by sea, and can cross boundaries of other States, were implemented back in the 1950s and 1970s. The N.S. Savannah nuclear-powered liner (United States of America), the Otto Hahn nuclear-powered merchant ship (Germany), and the Mutsu nuclear-powered merchant ship (Japan) were self-propelled vessels powered by small-sized nuclear power plants. Also, the USSR implemented several nuclear-powered icebreaker projects, such as the Lenin, Arctic and Siberia. Based on the experience of implementing these unique projects, a special regulatory framework started to form at the international level. In particular, Chapter VIII devoted to nuclear-powered self-propelled ships was added in the 1974 International Convention for the Safety of Life at Sea (SOLAS Convention),[3] and a draft of the 1962 International Convention on the Liability of Nuclear Ships' Operators was developed.

The experience of implementing these unique projects became the basis for a special international regulatory framework.

The legal and regulatory framework development stalled when nuclear-powered self-propelled vessel technology failed to achieve the required profitability indicators and was not in demand on the market. In particular, the 1962 Convention on the Liability of Operators of Nuclear Ships has not entered into force because no nuclear ship owner State has signed it.[4] Today, the fleet of civil self-propelled nuclear ships operates exclusively in the Russian Arctic, providing piloting in challenging ice conditions and solving tasks in support of the Northern Sea Route development. The

[3] International Convention for the Safety of Life at Sea, opened for signature 1 November 1974, entered into force 25 May 1980 (SOLAS Convention).

[4] Convention on the Liability of Operators of Nuclear Ships, opened for signature 25 May 1962.

nuclear-powered icebreakers and Sevmorput nuclear-powered freighter comply with the requirements of the SOLAS Convention, and the requirements of the Russian national nuclear and maritime legislation; the safety of their operation is confirmed by the corresponding licences of Rostechnadzor (the Russian Nuclear Regulator) and certificates of the Russian Maritime Register of Shipping (the Russian Maritime Regulator).

Legal experience in nuclear-powered vessels can be used in the development of regulatory approaches for floating SMRs. Of course, international documents, including the 1982 UN Convention on the Law of the Sea, were formed over half a century ago and do not contain specific rules for non-self-propelled vessels with nuclear power units, but they can be adapted for application. In particular, the 1981 Code of Safety for Nuclear Merchant Ships[5] takes into account established and recognized principles of shipbuilding, marine and nuclear technology that existed when it was developed and is limited to types of ships propelled by nuclear power units. At the same time, Chapter I of the Code of Safety for Nuclear Merchant Ships provides for the need for its revision as technology advances.[6]

The SOLAS Convention is one of the key international instruments governing the safe operation of ships. To date, the SOLAS Convention requires clarification regarding its application to floating SMRs. Compliance with the SOLAS Convention requirements is necessary to promote enhanced protection of human life at sea. In this regard, the design and construction of the Akademik Lomonosov floating power unit, as well as the design of optimized floating power units, de facto respects all existing codes and requirements for ships, both national and international. The emerging certainty of the legal status of floating SMRs will reduce the influence of political factors in the implementation of international projects and make the regulation of their life cycle more predictable and well-ordered on a global scale.

At the next stage, as experience is gained in operating floating SMRs at the national level in supplier countries, it will be necessary to form internationally agreed criteria and requirements for the safety of non-self-propelled vessels with nuclear power units, which can be combined into a separate special code similar to the Code of Safety for Nuclear Merchant Ships.[7] Such criteria will allow the developer and operating organization to form in advance the required amount of documentation to justify the operation, and stakeholders to objectively assess the safety of operation.

3.3 Licensing Specifics and Approaches of the SOLAS Convention

The specifics of the floating SMR life cycle prevent direct application of the procedures used in the conventional nuclear power industry.

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[5] IMO 1981.

[6] SOLAS Convention, above n.3.

[7] IMO 1981.

It is usually required to obtain a construction licence from the national regulator of the host country, which then issues an operating licence. Floating SMRs are designed and constructed in the supplier country and should fully comply with the regulations of the supplier country. Once construction is complete, the regulator of the supplier country issues an operating licence, with transportation to the host country being one of the stages of the unit's operation. Since floating SMRs will also be operated in the host country, the conventional approach assumes that the regulator of the host country should also assess the floating SMR's compliance with national regulations. This procedure leads to another review of the same set of documentation by two national regulators. Besides, making changes to the design based on the comments of the host country's regulator is absolutely impossible for floating SMRs, since the construction, fuel loading, first criticality of the reactor, and its commissioning take place in the supplier country in accordance with its standards.

The procedures developed for nuclear vessels and enshrined in the SOLAS Convention contain prerequisites for an optimized approach to licensing floating SMRs. In accordance with the SOLAS Convention, the design, construction, and inspection standards for the manufacture and installation of a reactor plant should meet the requirements of and be approved by the flag country of the nuclear vessel. Based on the Safety Analysis Report (SAR), the operating organization prepares and approves with the flag country a Safety Information document to confirm that the plant is free from excessive radiation or other nuclear hazard.

Safety Information is provided well in advance to the governments of the countries crossed by the nuclear vessel or hosting it.

Applying the principles set forth in the SOLAS Convention to floating nuclear power units with nuclear installations will prevent dual licensing when meeting safety requirements, where the regulator of the host country can be involved in reviewing the vessel's Safety Information to make an informed decision on whether a floating power unit can be operated in the host country. For effective implementation, this procedure can be detailed within an intergovernmental agreement between the supplier and the host country.

3.4 Legal Support for Floating SMR Transportation

The transportation stage, where the floating SMR is moved with the reactor plant loaded with fuel and in a shutdown state, is a novel stage of the floating SMR life cycle and one of the most complicated in terms of legal support. The floating SMR can be transported either by under tow or on board of a special dock ship. Akademik Lomonosov was moved from St. Petersburg to Murmansk under tow, but this method is quite sophisticated for moving over long distances, since it requires the formation of a tow order, calm weather and consideration of other variable factors.

Moving on a dock ship seems to be a more efficient way to transport over long distances, because the self-propelled dock ship is more resistant to weather changes. Transportation by dock ships is a common practice when transporting such complex engineering facilities as offshore oil rigs. There is also a vast experience in using dock ships to transport nuclear facilities.

The dock ship transportation option is close to maritime nuclear fuel transport, but the requirements applicable to nuclear fuel transport casks cannot be directly applied to floating SMRs. As a ship, a floating SMR can be categorized as a means of transport with nuclear material being an integral part of the nuclear power plant, as opposed to a nuclear material carrier ship, where a cask is cargo on the ship and easily removed by altering the vessel.

International legal regulation in force does not prohibit the maritime transport of a floating SMR loaded with nuclear fuel on board another ship, but there are no special rules for such transport. A floating SMR can be transported on a dock ship as a cargo. In accordance with the 1982 UN Convention on the Law of the Sea,[8] a ship carrying a floating SMR enjoys the right of freedom of navigation in the high seas and exclusive economic zones, as well as the right of innocent passage through the territorial sea of third countries.

However, even with regard to nuclear material transportation covered by an elaborate legal framework, there have been precedents in international practice when certain countries expressed their discontent with the transit of dangerous cargo through their exclusive economic zone.

This practice demonstrates the dependence of nuclear energy decisions on political factors and public opinion, and stresses the importance of the IAEA's awareness raising activities regarding a safe transport of nuclear materials. As the knowledge and experience of accident-free operation are accumulated, this dependence can be reduced in future.

For now, the regulatory framework is quite sufficient for the implementation of pilot projects. At the same time, individual procedures may be specified within the framework of special agreements.

3.5 IAEA Safeguards

One of the main features of floating SMRs is their transportation between different States during their life cycle. Nuclear material is subject to safeguards agreement between the supplier State and the IAEA until the liability is transferred, and not later than the arrival of the SMR in the host country. From then on, nuclear material will be subject to the host country's agreement with the IAEA and, therefore, the host country is responsible for accounting, monitoring, reporting and granting access to nuclear material to IAEA inspectors.

It should be noted that safeguards requirements are essentially different in non-nuclear weapon States with comprehensive safeguards agreements[9] and in nuclear

[8] United Nations Convention on the Law of the Sea, opened for signature 10 December 1982, entered into force 16 November 1994 (UNCLOS).

[9] IAEA 1972.

weapon States with voluntary offer safeguards agreements.[10] Unlike the non-nuclear weapon States, there is no obligation for nuclear weapon States to provide the IAEA with facility design information or to provide the IAEA inspectors access to the SMR fuel for verification prior to shipment.

Thus, the application of IAEA safeguards will require new legal and technical solutions. Under the Safeguards Member State Support Programme, the IAEA and the Russian Federation cooperate to develop approaches in implementing IAEA safeguards to floating nuclear power units designed in the Russian Federation taking into account the safeguards by design concept.

3.6 Floating SMRs and Civil Liability for Nuclear Damage

The 1963 Vienna Convention on Civil Liability for Nuclear Damage (Vienna Convention),[11] the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention),[12] and the 1997 Convention on Supplementary Compensation (CSC)[13] contain rules that exempt nuclear reactors on ships, whether the reactor is used to propel the ship or for any other purpose. According to findings of the IAEA International Expert Group on Nuclear Liability (INLEX), an advisory body to the IAEA Director General, the exemption should not apply to floating SMRs. The updated Comments on the Vienna Convention as in force in 1997 and the CSC published by the IAEA in 2020[14] note that a transported nuclear power plant in a fixed position (in particular, for a floating reactor plant, this means anchored or moored to shore and connected to shore by power cables) would be qualified as a 'nuclear facility' and thus would be subject to the civil liability for nuclear damage. In this case, the State in which the reactor is operated (including territorial waters) will be the "State responsible for the plant".

Based on INLEX's position on the shared liability for nuclear damage when moving floating SMRs, it should be taken into account that the transportation of this facility would be considered to be the transportation of nuclear material under the Vienna Convention.

Thus, the Vienna Convention currently provides the most transparent scenario in terms of the implementation of floating SMR projects. Without prejudice to the provisions of the Vienna Convention with respect to its members, issues of civil liability for nuclear damage may be settled in an intergovernmental agreement between the

[10] As an example, see IAEA 1985.

[11] Vienna Convention on Civil Liability for Nuclear Damage, opened for signature 21 May 1963, entered into force 12 November 1977 (Vienna Convention).

[12] Convention on Third Party Liability in the Field of Nuclear Energy, opened for signature 29 July 1960, entered into force 1 April 1968 (Paris Convention).

[13] Convention on Supplementary Compensation for Nuclear Damage, opened for signature 29 September 1997, entered into force 15 April 2015 (CSC).

[14] IAEA 2020b.

supplier country and the host country and, if necessary, in agreements with transit countries.

Most member countries listen to the INLEX position. Expert consensus at the international level is encouragingly positive in terms of the prospects for the implementation of pilot floating SMR projects and shows interest in such projects at the international level. Using similar approaches in respect of the Paris Convention could consolidate the established approach and facilitate the development of floating SMR projects.

3.7 IAEA Initiatives for the Study of Legal Support of Floating SMRs

Understanding the urgency of the task to form common approaches to the legal and regulatory framework of floating SMRs, the IAEA proposed the issues of floating SMR life cycle regulation for discussion by the expert community in the framework of various projects, in addition to the INLEX platform. Among other things, the IAEA, under the coordination of the Nuclear Energy Department, is implementing a pan-agency SMR project to comprehensively address issues arising from the use of this technology. Furthermore, a standing SMR group also exists to study these issues.

In particular, the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) has been analyzing the legal and institutional aspects of implementing transportable onshore, offshore and submarine SMR projects since 2011. Based on the first phase results, Legal and Institutional Issues of Transportable Nuclear Power Plants: A Preliminary Study report was issued in 2013, which provides an upper-level, multidimensional analysis of the implementation of transportable SMR projects. Currently, the second phase of this work is being completed, which involved experts from the United States of America, France, Canada, the Russian Federation, Finland, Armenia, Romania and Indonesia. The Case Study for the Deployment of a Factory Fuelled SMR report is scheduled for publication in 2022. The importance of the second project phase is that the issues of life cycle implementation are addressed systematically, not separately, with regard to their mutual influence.

In the absence of practical experience in the implementation of cross-border SMR-based projects, the work to comprehend the issues to be solved by the countries involved in the project seems relevant. At the same time, the real project may differ significantly from the theoretical one, and further development of the legal framework for SMR projects will be based on the experience gained during the implementation of pilot projects. The best practices of implemented projects and commissioning of SMRs in different designs will serve as a basis for establishing the legal and regulatory framework for SMRs, including for floating nuclear power units.

During 2021, conceptual approaches to nuclear and radiation safety requirements for transporting SMRs of various designs have been discussed at multiple IAEA sites. An ad hoc Working Group within the IAEA's Committee on Safety Standards for the Transport of Radioactive Materials is being established. The Working Group will examine the relationship between IAEA documents, in particular the Regulations for the Safe Transport of Radioactive Material,[15] and existing maritime law documents, with the involvement of the International Maritime Organization. The experts involved in this work should rely on cross-sectoral approaches to integrate maritime and nuclear law to find common ground for an effective cooperation.

3.8 Conclusion

Historically, legal frameworks are time-lagged in relation to innovative technologies, where sometimes the lag can persist for decades. For SMR deployment to be possible, the time lag between the formation of the legal framework and the development and deployment of technology should be reduced. The pace and intensity of work with the international legal and regulatory framework should be increased.

The COVID-19 situation has shown that a steady supply of electricity plays an important role to prevent diseases, from providing medical facilities with electricity and clean water to ensure the necessary hygiene to providing communications and information technology services. The development of SMR in this case had never been more relevant.

The international legal framework currently does not prohibit innovative SMR projects. At the same time, the lack of international experience in the implementation of transportable SMR projects makes it impossible to create a detailed legal and regulatory framework, which is now in place for conventional high-power NPPs. In this regard, pilot projects will require basic agreements and changes to key conventions that will extend to floating SMRs those requirements, rules and procedures that are already in place to ensure safety. Detailed elaboration is possible within the framework of intergovernmental agreements, which will take into account the specifics of unique pilot projects. The best practices will form the basis of the legal and regulatory framework for SMRs in the next stages of project development.

The IAEA's initiative of the first nuclear law conference is extremely timely. The IAEA conference can serve as a platform to share experience and opinions to identify current challenges in the development of innovative energy sources. It is important that the conference results be reflected in a practical action plan for the necessary areas of international cooperation. ROSATOM, with all of its experience in nuclear power, is ready to further work on updating international codes to ensure the stable implementation of SMR projects.

[15] IAEA 2018.

References

International Atomic Energy Agency (IAEA) (1972) The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected). https://www.iaea.org/sites/default/files/publications/documents/infcircs/1972/infcirc153.pdf. Accessed 6 September 2021

International Atomic Energy Agency (IAEA) (1985) The Text of the Agreement of 21 February 1985 Between the Union of Soviet Socialist Republics and the Agency for the Application of Safeguards in the Union of Soviet Socialist Republics, INFCIRC/327. https://www.iaea.org/sites/default/files/infcirc327.pdf. Accessed 6 September 2021

International Atomic Energy Agency (IAEA) (2018) Regulations for the Safe Transport of Radioactive Material. IAEA Safety Standards No. SSR-6 (Rev.1). IAEA, Vienna

International Atomic Energy Agency (IAEA) (2020a) Advances in Small Modular Reactor Technology Developments. A Supplement to: IAEA Advanced Reactors Information System (ARIS) 2020 Edition. https://aris.iaea.org/Publications/SMR_Book_2020.pdf. Accessed 6 September 2021

International Atomic Energy Agency (IAEA) (2020b) The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage—Explanatory Texts. International Law Series No. 3 (Rev.2). IAEA, Vienna

International Maritime Organization (IMO) (1981) Code of Safety for Nuclear Merchant Ships, Res. A.491(XII). https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.491(12).pdf. Accessed 6 September 2021

United Nations General Assembly (UNGA) (2015) Transforming Our World: The 2030 Agenda for Sustainable Development, A/RES/70/1. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Accessed 6 September 2021

Chapter 4
Milestones in Nuclear Law: A Journey in Nuclear Regulation

Stephen Burns

Contents

Abstract The development of the nuclear legal framework has been an interesting journey reflecting a commitment to addressing the key aspects of the peaceful uses of nuclear energy through a variety of approaches using both binding treaties and conventions and non-binding codes and guidance. This complex framework of hard and soft law instruments has developed in response to action forcing events. Future development of the legal regime will be aided by greater harmonization and commitment to ensuring that institutions at an international and national level are transparent and willing to engage in constructive interaction with stakeholders. Legal advisers will continue to play an important role in assisting policy makers and technical experts in crafting comprehensive and effective approaches to further development of the framework for nuclear energy and its regulation. In those deliberations a number of key elements should be highlighted. This chapter suggests that elements

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are stakeholder trust, strong institutional capacity, and integration of international instruments and standards at national levels.

Keywords Nuclear regulation · Peaceful uses of nuclear energy · Binding treaties and conventions · Non-binding codes and guidance · Legal advisers · Safety and security · Permission principle · Soft law · Hard law

4.1 Introduction

The convening by the International Atomic Energy Agency (IAEA) of the 'First International Conference on Nuclear Law: The Global Debate', in Vienna, offers an opportunity to reflect upon the development of nuclear law since President Eisenhower's 'Atoms for Peace' speech before the United Nations General Assembly in December 1953. Eisenhower's speech laid out a vision of dedicating nuclear technology towards peaceful ends and can be said to have inspired the creation of the IAEA in 1957. Since that time nuclear law has developed around the broad concepts of safety, security and safeguards, and we can say that there has been a more intentional focus on the integration of these concepts with each other in recent years. As reflected in the Handbook on Nuclear Law,[1] a number of principles can be said to characterize nuclear law as it has developed and been implemented through national and international regimes.[2]

My own journey in nuclear regulation began upon graduation from law school in 1978, shortly before the Three Mile Island accident, when I began employment as a lawyer at the US Nuclear Regulatory Commission (NRC). Over the years, I was engaged in the broad range of safety and security issues that came before this agency. My role as counsel consisted of advising and representing the NRC's technical staff in matters related to standards setting, licensing, inspection and oversight of nuclear power facilities and radioactive material. My primary engagement in the international aspects of nuclear law and regulation arose largely in the past 20 years as a senior counsel at the NRC, later as head of the Office of Legal Affairs at the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) and then as a Commissioner and Chairman at the NRC. In this Chapter I hope to address a number of characteristics of nuclear law, particularly as they have shaped the framework for regulation, to further consider the context for providing legal advice and achieving good regulation, and finally to reflect on challenges that lie ahead.

[1] Stoiber et al. 2003.

[2] The principles are: safety; security; responsibility; permission; continuous control; compensation; sustainable development; compliance; independence; transparency; and international co-operation.

4.2 Nuclear Regulation: Characteristics and Tensions

4.2.1 Nuclear Activities are Born Regulated

An interesting characteristic of nuclear activities and the nuclear industry is that they have been regulated since the very beginning. Although the discovery of X rays and radium did not give rise to more systematic regulation until well after their initial use in medical and other applications, the development of nuclear energy and access to nuclear materials was controlled by governmental authorities from the outset. This approach reflects the tension between the desire to secure such material from further weaponization and to promote the development of peaceful uses. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) embodies these principles in its objectives to curb the expansion of nuclear weapon States and to promote disarmament while allowing access to equipment, materials and information for the peaceful uses of nuclear energy.[3]

Thus, to use fissile materials and radioactive sources or to operate nuclear facilities requires some form of authorization or licence from the responsible national authority. The requirement for authorization to access radioactive materials and installations constitutes the 'permission principle' in nuclear law.[4] The current system consists of a complex network of law and guidance grounded in the core principles of safety, security and safeguards, as noted earlier, with the focal points being radiological protection, waste management and decommissioning, transport, emergency preparedness and response, environmental protection, liability and compensation, and international trade.[5]

4.2.2 A Framework Built on 'Hard' Law and 'Soft' Law

As one might expect, the framework for nuclear regulation is comprised of both international and national instruments. But equally characteristic is the foundation for regulation in both binding treaties and conventions, as well as non-binding guidance and instruments developed by the international community. The difference between binding and non-binding instruments is typically described as a distinction between 'hard' law and 'soft' law. For example, the Convention on the Physical Protection of Nuclear Material (CPPNM) and its 2005 Amendment are examples of hard law instruments that specify certain obligations with respect to security that the contracting parties agree to implement in their national programmes and legal

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[3] Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968, entered into force 5 March 1970 (NPT).

[4] Stoiber et al. 2003, p. 7.

[5] OECD/NEA 2021, Annex 1; www.iaea.org/resources/treaties/compendium-of-legal-instruments. Accessed 27 September 2021.

framework.[6] In contrast, the 2004 Code of Conduct on the Safety and Security of Radioactive Sources is a non-binding code to which States are urged to make a political commitment to achieve a high level of security in order to control radioactive sources to, among other objectives, prevent their loss, unauthorized access or illegal transfer and to mitigate the harm from potential malicious uses.[7] But even if the terms of a treaty or convention are seen as setting binding requirements and obligations, recommendations and guidelines issued by international bodies "not being formally binding, are, to the extent they are relevant, to be taken into account by the State so that the domestic rules and regulations and the measures it adopts are compatible ('con adecuación') with those guidelines and recommendations."[8]

The development of guidance and standards can bring greater precision to the means of achieving the objectives of safety and security in nuclear applications. For example, consistent with the mandate under its Statute (Article III.A.6),[9] the IAEA is empowered to establish or adopt "standards of safety for protection of health and minimization of danger to life and property". The IAEA has established safety standards, reflected in fundamental safety principles, general and specific safety requirements, and safety guides, which "reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation."[10] The Fundamental Safety Principles include the Basic Safety Standards that were initially developed in 1960 and are now sponsored by eight international organizations, including the IAEA.[11] The Basic Safety Standards continue to be informed by the recommendations of the International Commission on Radiological Protection.

It is also worth noting that a number of conventions reflect or have been shaped by such non-binding guidance and standards. For example, the CPPNM has its roots in non-binding standards focused on security and its Amendment also draws on fundamental security principles.[12] Although efforts to establish conventions on emergency notification and assistance did not achieve fruition until after the 1986 accident at the Chernobyl nuclear power plant, guidelines developed after the 1979 accident at Three Mile Island served as a basis for the negotiation of the two conventions adopted

[6] Convention on the Physical Protection of Nuclear Material, opened for signature 3 March 1980, entered into force 8 February 1987 (CPPNM); Amendment to the Convention on the Physical Protection of Nuclear Material, entered into force 8 May 2016 (Amendment to the CPPNM).

[7] IAEA 2004.

[8] International Court of Justice, *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgement, 20 April 2010, ICJ Reports 2010, p. 45.

[9] IAEA 1989.

[10] https://www.iaea.org/resources/rpop/resources/international-safety-standards/about-iaea-safety-standards. Accessed 27 September 2021.

[11] European Commission, Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Labour Organization, OECD Nuclear Energy Agency, Pan American Health Organization, United Nations Environment Programme, World Health Organization. See IAEA 2014.

[12] Lamm 2017.

in 1986.[13] The Convention on Nuclear Safety (CNS) references in its preamble "a commitment to the application of fundamental safety principles for nuclear installations rather than of detailed safety standards and that there are internationally formulated safety guidelines which are updated from time to time and so can provide guidance on contemporary means of achieving a high level of safety".[14] Similarly, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) invokes the Basic Safety Standards and the IAEA's Principles of Radioactive Waste Management in its preamble, and also draws on the Code of Practice on the International Transboundary Movement of Radioactive Waste in its provisions on that subject.[15]

Whether the instrument is characterized as hard or soft law, the obligations or commitments under the particular instrument are adopted under the national regulatory framework, consistent with the State's constitution and legislative system, and are manifested as being appropriate in the licensing regime and in regulatory standards administered by the responsible national authority. Further guidance on implementation of the licence obligations and regulatory requirements may be issued by the regulatory authority and may also be informed by industry sponsored consensus guidance. As an example, the United States of America made a political commitment to the Code of Conduct on the Safety and Security of Radioactive Sources. The US Energy Policy Act of 2005, Section 170h, 42 USC 2210h, Radiation Source Protection, adopted the central tenets of the Code and directed the NRC as the national regulator to promulgate conforming requirements applicable to its licensees and to those regulated by individual States under the NRC's Agreement State programme. The NRC issued orders to its licensees, which were eventually followed by the adoption of regulations in 10 CFR Part 37, Physical Protection of Category 1 and Category 2 Quantities of Radioactive Material, to enhance its existing security and control requirements[16] and by the issuance of further implementing guidance with respect to the regulations.[17]

[13] Convention on Early Notification of a Nuclear Accident, opened for signature 26 September 1986 (Vienna) 6 October 1986 (New York), entered into force 27 October 1986 (Early Notification Convention); Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, opened for signature 26 September 1986 (Vienna) 6 October 1986 (New York), entered into force 26 February 1987 (Convention on Assistance); IAEA 1984, 1985.

[14] Convention on Nuclear Safety, opened for signature 20 September 1994, entered into force 24 October 1996 (CNS), preambular para viii.

[15] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, opened for signature 29 September 1997, entered into force 18 June 2001 (Joint Convention), preamble para xiv and Article 27; Wetherall 2005.

[16] Nuclear Regulatory Commission 2013a.

[17] Nuclear Regulatory Commission 2013b. A second revision to the guidance document was proposed in early 2019.

4.2.3 Nuclear Law is More Often Reactive than Proactive

On the whole, nuclear law can be said to be more reactive in its development than anticipatory in the establishment of its framework. Such a characterization can be said to stem from a variety of reasons—the extent of political will and foresight in establishing the framework, technological discovery and innovation outpacing the development of legal standards, and the impact of significant events on the legal framework. Certainly, there are ways in which the frameworks at both an international and a national level have sought to anticipate and outline the parameters within which the peaceful uses of nuclear energy could grow.

The IAEA Statute, for example, provides the framework that is intended to prevent the spread of nuclear weapons while allowing for the development of peaceful uses of nuclear technology. In establishing the IAEA, the Statute provides an organizational structure through which these goals are to be achieved in the future. The nuclear liability and compensation framework emerged in anticipation of the need to ensure adequate compensation for damage suffered by persons and property as a result of a nuclear accident as well as the desire to encourage development of nuclear technology by a nascent industry.[18] The focus on establishing a liability regime in the late 1950s and early 1960s led initially to the adoption in 1960 of the Paris Convention on Third Party Liability in the Field of Nuclear Energy under OECD/NEA auspices and then in 1963 to the Vienna Convention on Civil Liability for Nuclear Damage under IAEA auspices.[19]

Obviously, at a national level, States needed at the earliest stages to establish the regulatory framework to provide for the establishment of nuclear installations and authorized uses of radioactive material. To draw on the early experience of the United States of America, the Atomic Energy Act of 1954, Public Law No. 83-703, constituted the organic legislation authorizing the civilian development of nuclear facilities. The Statute (Section 161b) established an authorization process under which regulated activities could be approved under appropriate standards and regulations as the then Atomic Energy Commission (AEC) deemed "necessary or desirable to promote the common defense and security or to protect health or to minimize danger to life or property". In its early regulations, the AEC allowed approval of construction of a nuclear plant to proceed even if additional technical evaluation and study might be needed, so long as the final determinations on safety were made before the authorization of operation of the facility. The approach garnered some opposition but ultimately survived challenge in the US Supreme Court.[20] The early

[18] Schwartz 2010.

[19] Paris Convention on Third Party Liability in the Field of Nuclear Energy, opened for signature 29 July 1960, entered into force 1 April 1968 (Paris Convention); Vienna Convention on Civil Liability for Nuclear Damage, opened for signature 21 May 1963, entered into force 12 November 1977 (Vienna Convention); additional protocols amending both conventions have come into force since their original adoption.

[20] United States Supreme Court (1961), *Power Reactor Development Corp. v. International Union*, 367 US 396, 407.

experience under the legislation and regulations illustrates the hurdles that may be faced in trying to establish requirements as new technologies develop.

But even if aspects of nuclear law have tried to apply foresight to their development and framework, much of our experience can be said to be reactive to significant events or disruptions in its environment. Both the security and safety regimes have been influenced in this way. The terrorist attacks in the United States of America on 11 September 2001 sparked a focus on the nuclear security threat and led by 2010 to the adoption of five of the seven binding legal instruments bearing on nuclear security which constitute the framework for counter-terrorism.[21] The new instruments included the Amendment to the CPPNM[22] as well as the International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT)[23] and instruments adopted under the auspices of the International Maritime Organization and the International Civil Aviation Organization.[24] The United Nations Security Council further adopted resolutions, UNSCR 1373 (2001), Threats to International Peace and Security caused by Terrorist Acts, and UNSCR 1540 (2004), Non-proliferation of Weapons of Mass Destruction, which complement the framework.

The response to the September 2001 terrorist attacks also led to a reassessment of the non-binding Code of Conduct on the Safety and Security of Radioactive Sources. The Code itself had come to fruition after focus on the safety and security of sources had garnered greater attention in the 1990s, particularly in the light of earlier accidents that caused a number of deaths, such as the accident in Goiânia, Brazil, in 1987, and a sense that the regime for control of sources was inadequate in a number of countries. An IAEA conference on the topic in Dijon in 1998 helped in developing the Code, which was ultimately approved in September 2000.[25] The events of September 2001, however, led to consideration of securing such material against diversion or use for malicious purposes, such as a radioactive dispersal device. After further review of the Code by technical and legal experts and discussion at a conference in Vienna in early 2003, the revised Code was approved in September 2003 with the objectives of providing a high degree of safety and security to "prevent unauthorised access or damage to, and loss, theft or unauthorised transfer of, radioactive sources, so as to reduce the likelihood of accidental harmful exposure to such sources or the malicious use of such sources to cause harm to individuals, society or the environment" and to "mitigate or minimize the radiological consequences of any accident or malicious act involving a radioactive source."[26]

Perhaps the most dramatic example of the reactive nature of the development of international nuclear law is the emergence of the safety framework after the accident at the Chernobyl nuclear power plant in Ukraine, then part of the Soviet Union,

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21 Wetherall 2016, p. 42.

22 Amendment to the CPPNM, above n.6.

23 International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 September 2005, entered into force 7 July 2007 (ICSANT).

24 Ibid., p. 18.

25 IAEA 1999.

26 IAEA 2003.

in 1986.[27] Chernobyl remains the most significant accident at a nuclear installation, particularly in terms of deaths resulting from the accident and transboundary effects. During a time before broad public use of the Internet and social media, its occurrence was not known or understood for several days after the accident. Prior to the accident, there were no broadly binding international treaties or conventions that addressed emergency notification and assistance or the safety of nuclear installations. Within months of the accident, the Early Notification Convention and the Assistance Convention were negotiated and entered into force, respectively, in October 1986 and February 1987. As noted earlier, the earlier development of guidance documents on notification and assistance in the years following the accident at the Three Mile Island nuclear power plant contributed to the swift negotiation of the conventions, as did the deferral of the more difficult debate over the form and scope that might be incorporated into an instrument addressing the safety of nuclear facilities.

Although work towards a safety convention languished for several years, ultimately members of the European Community proposed in 1990 the convening of a conference the following year to consider the status of nuclear safety and to recommend next steps.[28] The 1990 IAEA General Conference approved the proposal, and the special conference was held in early September 1991. Later that month, with the report of the proceedings in hand, the General Conference initiated the steps that would ultimately result in the development of a draft text of a convention. The open-ended Group of Experts on a Nuclear Safety Convention met seven times between May 1992 and February 1994 to shape the text that was submitted to the Diplomatic Conference convened in June 1994. The CNS was opened for signature in September 1994 and came into force in October 1996. Consideration was deferred on a convention on safe waste management but, as promised in Preamble (ix) of the CNS, work on such a convention resumed and eventually resulted in the adoption of the Joint Convention in 1997. Both the CNS and the Joint Convention are characterized as 'incentive' conventions, by which States are encouraged to strengthen safety within their national programmes and participate in the mechanism for peer review provided through the periodic meetings of the States Parties to the convention. In evaluating the efficacy of the conventions, debate has focused on the counterpoints between the embrace of general principles of safety versus specific norms, the emphasis on State responsibility versus a more international system, and the incentive versus a sanctions approach under the conventions.[29]

It is also worth noting the impact of the Chernobyl accident on the nuclear liability regime. Although the first nuclear liability conventions had been adopted in the early 1960s under the auspices of the OECD/NEA and the IAEA, and could be considered, as noted previously, to be proactive in terms of establishing the framework for addressing liability, the instruments had in some respects languished. At the time of the accident, the Vienna Convention could count a limited number of parties, with only two possessing operating nuclear power plants; no countries in the former Soviet

[27] Burns 2018.

[28] Jankowitsch 1994.

[29] Pelzer 2010, p. 88.

bloc were parties. Moreover, prior efforts to link the Vienna and Paris Conventions had stalled. In this context, the transboundary effects of Chernobyl spurred efforts to improve the conventions and achieve greater harmonization between the existing instruments. The Joint Protocol linking the Paris and Vienna Conventions on nuclear liability was negotiated in 1988.[30] Further negotiations led in 1997 to proposed revisions to both the Vienna Convention and to a new Convention on Supplementary Compensation (CSC); parties to the Paris Convention and its Brussels Supplementary Convention concluded negotiations to revise them in 2004.[31] Notwithstanding the impetus that the Chernobyl accident provided to examine and improve the liability regime, it has taken some time for the changes in the regimes to come to fruition, as evidenced by the CSC and the 2004 Paris/Brussels protocols not coming into force until 2015 and 2022, respectively.

4.3 Preparing for the Regulatory Challenge

4.3.1 Integrating Legal and Technical Support

The first part of this chapter has explored some characteristics and tensions reflected in the international nuclear regulatory framework. In considering the future direction of nuclear law, it is worth noting the contribution of legal advisers to the sound establishment and administration of policies and practices related to the peaceful uses of nuclear energy and materials. Legal advisers play an important role at both the international and national level. The IAEA held a meeting in 2019, in which I was pleased to participate, on the Role of the Legal Adviser in a Regulatory Body.[32] Although focused particularly on the role of the adviser in national regulatory organizations, the discussions had more general relevance to the various aspects of legal support.

Participants in the meeting included representatives with both legal and technical backgrounds from some 24 Member States and IAEA staff. The participants' home countries comprised a diverse set of Member States at different points along the spectrum of nuclear activities, ranging from States with mature programmes with operating nuclear installations, to those focused solely on radiological protection and the security of radioactive sources as well as to those embarking on a nuclear

[30] Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, opened for signature 21 September 1988, entered into force 27 April 1992 (Joint Protocol).

[31] Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage, opened for signature 29 September 1997, entered into force 4 October 2003 (1997 Vienna Protocol); Convention on Supplementary Compensation for Nuclear Damage, opened for signature 29 September 1997, entered into force 15 April 2015 (CSC); Protocol to Amend the Paris Convention on Nuclear Third Party Liability, opened for signature 12 February 2004, entered into force 1 January 2022 (2004 Paris Protocol).

[32] https://www.iaea.org/newscenter/news/providing-legal-support-to-the-regulatory-body-first-meeting-of-legal-advisers-held-in-vienna. Accessed 27 September 2021.

energy programme. Legal support was provided in diverse ways. Some legal staff members were employed within the regulatory organization itself, while other legal advisers served in the justice ministry and were assigned to provide legal counsel or representation to the specialized government agencies responsible for nuclear regulation and related activities.

Broadly stated, legal advisers contribute to the development of a State's adoption and implementation of international legal instruments as well as the national legal and regulatory framework, its reporting under its international obligations, and the carrying out of authorization, inspection, oversight and enforcement of laws and regulations as provided under the national regime.[33] More specifically, legal advisers may assist in drafting basic legislative texts and related governmental policies. With respect to the regulatory regime, the legal adviser may help develop the regulations and related guidance to ensure compatibility with governing law and effectiveness as coherent and implementable standards. Moreover, legal advisers may support the authorization process by advising on proposed decisions with respect to their consistency with applicable regulatory requirements. Legal support is also critical in assessing proposed enforcement measures. Because decision making by the responsible governmental body may be subject to judicial or administrative proceedings, legal representation is critical in such proceedings. Such proceedings typically involve authorizations of nuclear activities or enforcement matters, but can also be related to processes related to establishing standards or environmental reviews. Legal advisers may also assist in stakeholder engagement and providing information to the public.

Of particular importance is the understanding that legal advisers are not the sole contributors to international or national nuclear law and regulation. Legal advisers must work in close cooperation with policy makers and technical experts to establish an effective framework and to set out comprehensive and meaningful standards to address the primary objectives of safety, security and safeguards. At its core the framework of nuclear law reflects the synthesis of technical and legal principles and objectives. Legal and technical experts need to establish effective communication and cooperation. Accordingly, as was discussed in the 2019 workshop, focus on the following objectives should enhance the integration of legal and technical aspects of nuclear law, particularly in carrying out the regulatory regime:

(a) Ensuring that there is a common language between legal and technical experts (i.e. lawyers tend to focus on processes while technical experts focus on scientific substance) and mutual appreciation and understanding of their respective roles.
(b) Ensuring that technical experts understand the legal requirements relevant for the performance of the respective regulatory functions and vice versa.
(c) Ensuring awareness of the role of the legal adviser and related process for the provision of legal support.
(d) Ensuring that technical experts understand the legal advice and recognize its importance.

[33] IAEA 2018, paras 4.27–4.30, pp. 25–26.

(e) Ensuring that legal experts understand the technical input so that the legal advice does not lose the technical meaning.
(f) Ensuring that legal advice translates or articulates the technical input appropriately and clearly into general language.[34]

Acknowledging the importance of effective collaboration between legal and technical experts is critical to the success of institutions responsible for implementing the framework for national and international control (i.e. regulation of the peaceful uses of nuclear energy). As former NRC Chairman Nils J. Diaz said, "[n]uclear regulation is a complex techno-legal construct that requires constant examination and management, even apart from socio-political issues."[35]

4.3.2 Crafting Effective Regulation

As noted earlier in this chapter, the use of nuclear materials and nuclear installations is subject to a comprehensive system of regulation administered by responsible institutions—a reflection of the permission principle in nuclear law to ensure safety, security and accountability. The sources of such standards are reflected in international instruments, guidance and standards, national law and regulations, and even consensus industry codes and standards.

Although governmental institutions are ultimately accountable under the laws and political systems of their respective countries and the applicable international instruments, they must always strive to ensure that decision making and actions are rooted in the sound scientific and engineering judgement that the institutions were established to undertake. Moreover, the regulator must be consistently open and transparent with its stakeholders to show that undue influence does not exist. As outlined in the safety conventions, the regulator must have, in addition to technical competence, adequate and sustainable funding to demonstrate its ongoing reliability, as well as, ideally, ongoing interaction with and support from counterparts around the world.[36]

Culture and history can—and will—affect public perception and acceptance of any regulatory regime, and this can prove to be a challenge in some cases. Ultimately, however, no matter what the country, the culture, history or status of nuclear power development, the public must have trust in the regulator, and the regulator has a responsibility to nurture and maintain that trust. Trust is earned when a regulator makes its decisions in an open manner, with explanation of conclusions and after carefully considering many opinions and varied input. The regulator can further build confidence by constantly assessing the adequacy of safety and security based on experience and analysis and by undertaking an informed assessment of risk.

[34] IAEA 2020, Annex 3, p. 16.

[35] Diaz 2004.

[36] CNS, above n.14, Article 8; Joint Convention, above n.15.

Prior to beginning his service on the US Supreme Court, Justice Stephen Breyer wrote a book on the subject of risk and regulation.[37] Justice Breyer noted that regulators generally have a two part job—risk assessment (i.e. measure it) and risk management (i.e. what are we going to do about it). In the risk assessment part of the equation, decisions will be informed by the probability and consequences of an event. For the management part of it, regulators are going to use their broad discretion to exhibit predictable and stable decision making. Justice Breyer's book underscores that the public's evaluation of risk often differs radically from the experts', and he writes, "When we treat tiny, moderate and large risks too much alike we begin to resemble the boy who cried wolf."[38] Thus, the challenge is to strive for a 'sweet spot' between under-regulation and over-regulation.

The art and science of effective regulation can be described, to borrow the title from Professor Malcolm Sparrow's book on the topic, as the 'regulatory craft'.[39] In nuclear safety, for example, the regulator further builds confidence by constantly assessing 'how safe is safe enough' based on experience and analysis, and an informed assessment of risk. Regulators must neither be too lax nor too strict, nor so isolated that they are making decisions in a vacuum. Effective regulation can be pursued without imposing undue burden and stifling innovation. Boundaries must be set, but such boundaries, for example, should allow operators to undertake electricity generation effectively and to innovate within the safety and security framework. Real life and actual operating experience must be considered, as well as public and stakeholder input.

Although it is unlikely that everyone will be convinced that regulators are always dutifully practicing good regulatory craftsmanship and are being transparent in their processes, the goal is always worth striving for. Indeed, the quest itself is the most important part of the journey. Every regulatory regime—whether newly created or well established—must find its own path to this common ideal. As more established nuclear regulators assist newer regulators, as all share and learn from others' experience, as all participate in peer reviews and other opportunities through the international system, regulators are showing their respective countries and the world as a whole that they are providing credible oversight and management. Such good craftsmanship leads to good regulation and is important as we think of the challenges before us or that may emerge in the future.

4.4 Looking Forward

In trying to anticipate the future in the nuclear sector, we can attempt to identify trends and developments and assess their impact on nuclear law and regulation. At a high level the challenges ahead remain the same in terms of achieving the overarching

[37] Breyer 1993.

[38] Ibid., p. 28.

[39] Sparrow 2000.

goals of safety, safeguards and security. For civilian uses of nuclear energy, this means a continued focus on the safe operation of existing nuclear installations, particularly as they may enter long term operation beyond their initial licence term, as well as a focus on the construction of new plants and assessment of emerging technologies. The management of radioactive waste and its disposal remains an area of focus. Adequate control of radioactive sources to ensure radiological safety and to prevent their misuse will continue to be a challenge. Although this is by no means a comprehensive list of the challenges that those engaged in nuclear law and regulation may face, it does prompt consideration of the context in and the means by which we go forward. In my view we are unlikely to see any new binding treaties or conventions absent some significant event or 'near miss'. But in this context, the system can continue to improve even on a soft law basis if due attention is given to cooperation and collaboration in the international community, to greater harmonization of standards, and to transparency and stakeholder engagement.

4.4.1 Soft Law as the Primary Platform

The likelihood seems remote that new binding international legal instruments will be negotiated in the nuclear field in the foreseeable future. Although strong arguments can be made, for example, to elevate the Code of Conduct on the Safety and Security of Radioactive Sources to a binding convention,[40] or to improve the nuclear security framework,[41] coalescence around such objectives has yet to occur. In the wake of the accident at the Fukushima Daiichi nuclear power plant, proposals emerged to amend both the Early Notification Convention and the CNS, but none of the proposals ultimately garnered the support to adopt such amendments.

In the case of the Early Notification Convention, work on improving the guidance on emergency response and reporting likely contributed to the absence of sufficient support to bring the Russian Federation's proposal to a diplomatic conference.[42] In terms of the CNS, several proposals to amend the CNS were offered, but only one offered by Switzerland continued to a diplomatic conference in 2015. In lieu of adopting the proposed amendment, contracting parties to the CNS agreed to a non-binding statement—the Vienna Declaration on Nuclear Safety—that commits to focusing on prevention and mitigation of accidents in new plant designs, periodic consideration of the safety of existing installations and implementation of 'reasonably practicable' safety improvements, and commitment to the IAEA Safety Standards and good practices identified during the CNS review meetings.[43]

[40] Gonzalez 2014.

[41] Wetherall 2016, pp. 22–37.

[42] Johnson 2014, pp. 18–19.

[43] Vienna Declaration on Nuclear Safety, adopted 9 February 2015 (Vienna Declaration).

Experts in the nuclear and other fields have elaborated on the difficulties in achieving binding international instruments as well as the advantages soft law instruments may provide in a particular context.[44] Among other things, such norms can elaborate more fully the means of achieving the goals that are addressed, establish the 'good behaviour' expected of States, provide a basis for legislation and regulation at a national level, and may sow the seeds for moving towards more formal obligations.

4.4.2 International Cooperation and Collaboration

Continued attention to cooperation and collaboration among States is critical to maintaining and enhancing the institutional capacity and legal framework for nuclear regulation. Such attention is critical not only for States with long experience with nuclear energy, but also to the capacity building of States new to the development and institution of nuclear energy programmes. As noted earlier, the CNS and the Joint Convention provide as part of their 'incentive' nature provisions for periodic review meetings of the contracting parties to consider the reports addressing their measures to implement their obligations under the conventions.

Apart from the obligations under these conventions, other opportunities for assessment and improvement of institutional capacity exist. Both the IAEA and the OECD/NEA have developed guidance on approaches to establishing effective organizations.[45] Periodic IAEA conferences on topics related to various aspects of safety and security provide opportunities for exchange among States. Moreover, the IAEA has developed a number of peer review services; a virtual technical meeting was held in 2020 on the peer review and advisory services related to nuclear safety and security.[46] These services can help States achieve excellence in their approaches to oversight of nuclear activities and conformance to international norms, and the results can be a good barometer of an effective and improving organization, or can identify gaps or weaknesses. Participation should be encouraged in these vehicles for self-assessment and peer review. And we should not dismiss the contribution that bilateral engagements or regional cooperation, such as undertaken in the European Union in the context of its directives related in the nuclear field, can also achieve. As an example of bilateral cooperation, the NRC hosted staff from Japan's Nuclear Regulatory Authority (NRA) to provide them with greater insight into the NRC's inspection approach to help the NRA update its own inspection regime. Cooperation is essential for effective nuclear law and regulation in the coming years.

[44] Wetherall 2005; Dupuy 1991.

[45] IAEA 2016; https://www.oecd.org/publications/the-characteristics-of-an-effective-nuclear-regulator-9789264218741-en.htm. Accessed 27 September 2021.

[46] https://gnssn.iaea.org/main/Pages/PRASC-Technical-Meeting_2020.aspx. Accessed 27 September 2021; https://www.iaea.org/services/review-missions. Accessed 27 September 2021.

4.4.3 Greater Harmonization

Focus on greater harmonization of standards applied in the nuclear sector is an important objective in the future, particularly in the light of the prospects for development and installation of small modular reactors (SMRs) using either well established light water technology or advanced technologies. Each State is responsible for establishing its own regulatory requirements; as a result the regulatory regimes are essentially specific to each country, though informed by international guidance and standards as provided in the CNS. At a high level, steps towards harmonization gradually evolved over the years, spurred for example by the broad acceptance of the IAEA Safety Standards. Nonetheless, greater harmonization of regulatory criteria and standardization of designs can avoid the need to reengineer or customize a design for every country seeking to deploy a facility and may aid newcomer countries in establishing a nuclear energy programme. For SMRs, which may rely on modular assembly in factories, greater harmonization can be key to international deployment.

A number of initiatives over the past few decades have focused on the objective of greater harmonization. The Generation IV International Forum was established in 2001 to consider advanced designs, and the Multinational Design Evaluation Programme (MDEP)[47] was established in 2006 as a forum for cooperation among regulators undertaking the licensing of new reactors, particularly Generation III+ designs.[48] Within the nuclear industry, the Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL) in the World Nuclear Association (WNA) was formed in 2007 to promote harmonization and international convergence of safety standards for reactor designs.[49]

In the context of the growing interest in SMRs, the IAEA and the OECD/NEA have provided opportunities to explore ways of ensuring safety in a context that allows technological innovation. In this regard, one sees the potential for further harmonization of regulatory requirements and cooperation among regulators.[50] For example, the US and Canadian nuclear regulatory authorities agreed on a joint Memorandum of Cooperation in August 2019 to enhance their longstanding regulatory interaction, with a specific emphasis on the assessment of new reactor technologies. The initiative includes sharing of regulatory insights from SMR design reviews and anticipates development of common guidance between the two organizations for the eventual review of licence applications using the designs. In sum, we appear to be poised for greater cooperation and harmonization in establishing regulatory acceptance criteria, a worthy objective in the years ahead.

[47] https://www.oecd-nea.org/mdep/. Accessed 27 September 2021.

[48] https://www.gen-4.org/gif/. Accessed 27 September 2021.

[49] WNA 2019.

[50] https://www.iaea.org/topics/small-modular-reactors/smr-regulators-forum. Accessed 27 September 2021; www.oecd-nea.org/jcms/pl_46728/multi-sector-workshop-on-innovative-regulation-challenges-and-benefits-of-harmonising-the-licensing-process-for-emerging-technologies. Accessed 27 September 2021.

4.4.4 Transparency and Stakeholder Engagement

Finally, a continued focus on enhancing transparency and engaging stakeholders is important to sustaining and further developing an effective legal and regulatory framework for nuclear activities. These principles have been more specifically acknowledged in the environmental conventions that also intersect with nuclear law.[51] Although transparency is considered a core principle in nuclear law,[52] the nuclear sector has grown to embrace greater transparency over the years. With its origins in the military area and the desire to deter the proliferation of nuclear weapons, the sector was more secretive at its beginning. To be sure, there remain significant aspects of the regulation of nuclear installations and materials that require confidentiality to safeguard information or material that can be otherwise used for unlawful or malicious purposes, to maintain security or even to protect interests in intellectual property. Nonetheless, credibility and trust in the responsible institutions necessitates a commitment to providing information in the public domain, even if it reveals shortcomings and need for improvement. As an example of how the international system has moved towards greater transparency, broader public dissemination of reports has evolved in the CNS review process. For the first time, after the seventh review meeting of the CNS held in 2017, all national reports were made publicly available.

Paired with the principle of transparency is a commitment to meaningful stakeholder engagement. Stakeholders constitute a broad and diverse set of persons and organizations: vendors and operators; those living near or working in nuclear facilities; government bodies and representatives at a local or national level; international counterparts and organizations; those who might be adversely affected by the regulated operations; the media; and non-governmental organizations. Stakeholders are not only those who may support the regulatory organization and its objectives, but also those who are deeply sceptical, and even those who are largely indifferent, except when the regulator or the regulated draws media attention. Engagement with stakeholders should be meaningful and maximize opportunities to build trust, to enhance participation and obtain feedback. Both the IAEA and the OECD/NEA have examined the issue as it relates to the nuclear sector,[53] and continued focus is needed to ensure the proper evolution and effectiveness of nuclear law and regulation.

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[51] Convention on Environmental Impact Assessment in a Transboundary Context, opened for signature 25 February 1991, entered into force 10 September 1997 (Espoo Convention); Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, opened for signature 25 June 1998, entered into force 30 October 2001(Aarhus Convention); Protocol on Strategic Environmental Assessment to the Espoo Convention, opened for signature 21 May 2003, entered into force 11 July 2010 (Kiev Protocol).

[52] Stoiber et al. 2003, p. 10.

[53] IAEA 2017; OECD/NEA 2015.

4.5 Conclusion

Law is a means not an end in nuclear regulation. The development of the legal framework has been an interesting journey reflecting a commitment to addressing the key aspects of the peaceful uses of nuclear energy through a variety of approaches using both binding treaties and conventions as well as non-binding codes and guidance. The state of this complex set of relevant instruments can at times make one feel pessimistic when considering what it took to reach the point where we are today and the gaps that may still exist. Yet, one can also be optimistic that we will continue to progress, even if that requires a focus on pragmatic steps that may be more incremental than revolutionary.

Our progress requires an intentional focus and dedication to international cooperation and a willingness to share experience and to be open to continuous improvement. Future improvement in the legal regime will be aided by seeking greater harmonization across the system. And it requires a commitment to ensuring that institutions at an international and national level are transparent and willing to engage in constructive interaction with stakeholders. Legal advisers will continue to play an important role in assisting policy makers and technical experts in crafting comprehensive and effective approaches to further development of the framework for nuclear energy and its regulation. In those deliberations, we can continue to ask ourselves a number of questions. Are we credibly engaging the important issues in a manner worthy of our stakeholders' trust? Have we ensured a strong institutional capacity at both an international and a national level? Have we ensured applicable international instruments and standards have been integrated into national regimes? Does the framework comprehensively address the primary objectives of safety and security and where should we focus for possible improvement?

The journey continues.

References

Breyer S (1993) Breaking the Vicious Circle: Toward Effective Risk Regulation. Harvard University, Cambridge, MA

Burns S (2018) The Impact of the Major Nuclear Power Plant Accidents on the International Legal Framework for Nuclear Power. Nuclear Law Bull 101:14

Diaz N (2004) Leadership Toward a Progressive, Integrated Nuclear Community: Going Forward Together. www.nrc.gov/docs/ML0432/ML043270636.pdf. Accessed 27 September 2021

Dupuy P (1991) Soft Law and the International Law of the Environment. Michigan Journal of International Law 12:420-435

Gonzalez A J (2014) Towards a Convention on Radiation Safety and Security. In: Mariano Manóvil R (ed) Nuclear Law in Progress, Legis S.A. Argentina, Buenos Aires, pp 423–436

International Atomic Energy Agency (IAEA) (1984) Guidelines for Mutual Emergency Assistance Arrangements in Connection with a Nuclear Accident or Radiological Emergency, INFCIRC/310. IAEA, Vienna

International Atomic Energy Agency (IAEA) (1985) Guidelines on Reportable Events, Integrated Planning and Information Exchange in a Transboundary Release of Radioactive Materials, INFCIRC/321. IAEA, Vienna

International Atomic Energy Agency (IAEA) (1989) Statute. IAEA, Vienna

International Atomic Energy Agency (IAEA) (1999) Safety of Radiation Sources and Security of Radioactive Materials. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2003) Security of Radioactive Sources. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2004) Code of Conduct on the Safety and Security of Radioactive Sources. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2014) Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. Co-sponsored by European Commission, Food and Agriculture Organization of the United Nations, International Labour Organization, OECD Nuclear Energy Agency, Pan American Health Organization, United Nations Environment Programme, World Health Organization. IAEA Safety Standards Series No. GSR Part 3. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2016) Governmental, Legal and Regulatory Framework for Safety. IAEA Safety Standards Series No. GSR Part 1 (Rev. 1). IAEA, Vienna

International Atomic Energy Agency (IAEA) (2017) Communication and Consultation with Interested Parties by the Regulatory Body. IAEA Safety Standards Series No. GSG-6. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2018) Organization, Management and Staffing of the Regulatory Body for Safety. IAEA Safety Standards Series No. GSG-12. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2020) Report of the Meeting on the Role of the Legal Adviser in a Regulatory Body, 30 July–2 August 2019

Jankowitsch O (1994) The Convention on Nuclear Safety. Nuclear Law Bulletin 54:9-22

Johnson P L (2014) Opening Address: Developments in Nuclear Law. In: Mariano Manóvil R (ed) Nuclear Law in Progress, Legis S.A. Argentina, Buenos Aires, pp 13–28

Lamm V (2017) Reflections on the Development of Nuclear Law. Nuclear Law Bulletin 99:41–42

Nuclear Regulatory Commission (2013a) Physical Protection of Byproduct Material; Rule 78 Fed. Reg. 17007. https://www.federalregister.gov/documents/2013/03/19/2013-05895/physical-protection-of-byproduct-material. Accessed 27 September 2021

Nuclear Regulatory Commission (2013b) Implementation Guidance for 10 CFR Part 37, Physical Protection of Category 1 and Category 2 Quantities of Radioactive Material, NRC Doc. NUREG-2155 and Rev. 1 (2015). https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2155/index.html. Accessed 27 September 2021

OECD Nuclear Energy Agency (2015) Stakeholder Involvement in Decision Making: A Short Guide to Issues, Approaches and Resources. OECD Publishing, Paris

OECD Nuclear Energy Agency (2021 forthcoming) Principles and Practices of International Nuclear Law. OECD Publishing, Paris

Pelzer N (2010) Learning the Hard Way: Did the Lessons Taught by the Chernobyl Accident Contribute to Improving Nuclear Law? In: OECD/NEA (ed) International Nuclear Law: History Evolution and Outlook. OECD, Paris, pp 73–118

Schwartz J (2010) Liability and Compensation for Third Party Damage Resulting from a Nuclear Incident. In: OECD/NEA (ed) International Nuclear Law: History Evolution and Outlook. OECD, Paris, pp 307–354

Sparrow M (2000) The Regulatory Craft: Controlling Risks, Solving Problems, and Managing Compliance. Brookings Institution Press, Washington, DC

Stoiber C, Baer A, Pelzer N, Tornhauser W (2003) Handbook on Nuclear Law. IAEA, Vienna

Wetherall A (2005) Normative Rulemaking at the IAEA: Codes of Conduct. Nuclear Law Bulletin 75:77

Wetherall A (2016) Strengthening the International Framework for Nuclear Security: Better Sooner than Later. Nuclear Law Bulletin 98:42

World Nuclear Association (WNA) (2019) CORDEL Strategic Plan 2019–2023. https://www.world-nuclear.org/getattachment/c3d5b873-95aa-4c88-aa71-80a274b0453b/CORDEL-Strategic-Plan-2019.pdf.aspxa. Accessed 27 September 2021

Chapter 5
Strengthening the Global Nuclear Safety Regime

Richard Meserve

Contents

Abstract Nuclear power is an important component of the global response to climate change. Nuclear power provides continuous electricity and can overcome the intermittency of the renewable energy sources dependent on wind and sun. Assurance of nuclear safety is essential for further expanding nuclear power as a part of the global response to climate change. The commitment to safety must be a universal priority, as the prospects for nuclear power everywhere would be adversely influenced by the public outcry following a serious nuclear event anywhere. The importance of the global nuclear safety regime was revealed by the accident at the Fukushima Daiichi NPP. The accident reinforced that in addition to the need to have a competent *national* nuclear safety system in place, it is ultimately important to have an *international* system that ensures that the relevant national institutions diligently and effectively fulfil their roles. This chapter examines the current global nuclear safety regime and suggests improvements, including through safety inspection, greater transparency measures, increased harmonization of standards, and others.

Keywords Nuclear safety · Nuclear power · IAEA fundamental safety principles · Global nuclear safety regime · Advanced reactors · Regulator (regulatory body) · Harmonization of standards · Safety inspections · Safety and security integration

The world must urgently confront the need to move to carbon-free sources of energy if it is to overcome the devastating effects of increasing greenhouse gas concentrations in the atmosphere. Nuclear power should be an important component of its response. Today nuclear power provides about 10% of the world's electricity generation and

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nearly a third of carbon-free power generation.[1] But its role could become much greater. Although renewables will no doubt be deployed at a much larger scale than today, there will be a continuing need for carbon-free dispatchable power to overcome the intermittency of renewables. Nuclear power plants (NPPs) can fill that need and join renewables in responding to the existential challenge that climate change presents.

To pave the way for the expansion of nuclear power, the assurance of nuclear safety is essential. The commitment to safety must be a universal priority, as the prospects for nuclear power everywhere would be adversely influenced by the public outcry following a serious nuclear event anywhere. It is therefore particularly appropriate to examine the nuclear safety system that is in place and to assess whether improvements should be made.

As emphasized in the IAEA's Fundamental Safety Principles, the operator must assume the primary obligation for safety.[2] The operator controls the plant and is in the best position to assure continuing safety performance. The operator must have the engineering, financial and management capability to ensure that the plant operates with safety as the highest priority. The national regulator, in turn, undertakes the reinforcement of the operator's obligation to ensure safety by defining the operator's responsibilities and policing the operator's actions to ensure that those responsibilities are fulfilled.[3] The regulator must be independent, capable and sufficiently staffed and funded to perform its functions. Every regulator should be tough and thorough (while also fair) in assuring that every operator meets its responsibilities.

Although the operator and the regulator play essential roles, they benefit from an important backstop: the global nuclear safety regime.[4] The regime is a collective international web of stakeholders and relationships that sets a level of performance expected of all operators and regulators and that seeks to build competence and capability among them. The global nuclear safety regime is made up of several components:

- Intergovernmental organizations. The principal participants are the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). The IAEA sets safety standards and, at the request of a Member State, conducts inspections in a variety of areas and provides advice on nuclear activities. The NEA is involved in international cooperative safety research and the study of safety and regulatory issues.
- Multinational networks among regulators. Examples include the International Nuclear Regulators Association and the European Nuclear Safety Regulators Group. These networks enable regulators to exchange views and information and coordinate activities.

[1] https://www.iaea.org/newscenter/news/nuclear-power-proves-its-vital-role-as-an-adaptable-reliable-supplier-of-electricity-during-covid-19. Accessed 11 July 2021.

[2] IAEA 2006.

[3] Ibid., p. 7.

[4] The nature and importance of the global nuclear regime was described by the International Nuclear Safety Group (INSAG). INSAG-21 provides the backdrop for this paper. See INSAG 2006.

- Multinational networks among operators. The most important of these networks on the international stage is the World Association of Nuclear Operators (WANO). Among other activities, WANO provides peer reviews of operator activities and serves as a clearinghouse for the exchange of information. Owner groups, comprised of operators who share a particular design, provide a similar information sharing role. The World Institute for Nuclear Security (WINS) serves the same function on security related matters.
- The international nuclear industry. This includes vendors who design and sell NPPs, international equipment suppliers and service organizations, and the architect/engineering firms and contractors that build plants around the world. These firms transfer knowledge relating to NPPs and have strong incentives to encourage safe operations.
- Multinational networks of scientists and engineers. Scientific and engineering societies encourage and enable communication among experts in many nations.
- Standards development organizations. These include the American Society of Mechanical Engineering (ASME), the Institute of Electrical and Electronics Engineers (IEEE), the American Nuclear Society (ANS) and counterparts around the world. Compliance with detailed standards is an important component of the strong quality assurance requirements demanded of nuclear installations.
- Other stakeholders. Nuclear activities understandably attract attention. Non-governmental organizations and the press play a significant role in monitoring activities and can provide an important stimulus for ensuring safe operations.

The various components of the global nuclear safety regime and the web of arrangements that link them to each other are depicted in Fig. 5.1.

The importance of the global nuclear safety regime was revealed by the accident at the Fukushima Daiichi NPP. Japan had a sophisticated operator and an experienced regulator, but the accident could not be prevented. Deficiencies in the design basis for the plant, in the national institutional arrangements and in emergency preparedness (at operator and government levels) were overlooked because of a prevailing belief in Japan that the plant was adequately safe.[5] The fundamental lesson learned was that, in addition to the need to have a competent *national* nuclear safety system in place, it is ultimately important to have an *international* system that ensures that the relevant national institutions diligently and effectively fulfil their roles.[6]

In addition to the need to ensure exemplary safety performance that will enable nuclear power to contribute significantly to the response to climate change, there are other considerations that reinforce the importance of re-examining and strengthening the global nuclear safety regime. There are reports that 30 countries that currently do not rely on nuclear power are considering, planning or starting a nuclear power

[5] IAEA 2015, p. 67.

[6] INSAG has discussed the importance of an interlocking web of open relationships among operators, regulators and stakeholders in order to ensure that the overall system serves to provide "strength in depth". See INSAG 2017.

Fig. 5.1 The various components of the global nuclear safety regime. *Source* International Nuclear Safety Group 2006

programme, and another 20 have expressed an interest.[7] Many of these countries are in the developing world and their interest in exploiting carbon-free sources of electrical power is a welcome development from a climate change perspective. However, their efforts to use NPPs to address energy needs present a challenge because many of the countries do not have nuclear experience and must build a capability that does not exist today.[8] The global nuclear safety regime should play an important role in enabling these nuclear programmes to be successful in meeting safety and security obligations.

At the same time, the systems that ensure safety now face a new challenge. Although there will no doubt be continuing reliance on existing and new light water

[7] https://world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx. Accessed 11 July 2021.

[8] INSAG 2012, pp. 1–4.

reactors (LWRs) in the coming years, there has been a resurgence of recent interest in advanced reactors. Many advanced reactors use different coolants (gas, liquid metal or molten salt) and different moderators. The vendors are hopeful that the new designs will offer electrical output at lower cost per kWh, thereby making nuclear power more competitive with alternative power sources. Moreover, the new designs promise significantly improved safety through, for example, the use of simplified, passive, or other means to achieve essential safety functions. Many vendors are contemplating NPP designs that produce a much smaller output than most existing LWRs, with the result that the unit capital cost may be more manageable for some owners. Furthermore, the smaller size may be particularly attractive to countries with small grids,[9] which likely will include many newcomers. Unlike for many current LWRs, for which security and non-proliferation related elements were largely an add-on to existing plants, security and safeguards can be enhanced for contemplated plants by accommodating them in the basic design.

Although there is great promise from advanced reactors, they present particular safety challenges. Careful analyses will be required to establish that the innovative safety systems are effective in the variety of circumstances in which there is dependence on them. It will be important to maintain adequate defence in depth and to ensure a balance between accident prevention and mitigation. At the same time, sodium-cooled fast reactors, for example, will require consideration of sodium–water and sodium–air chemical reactions, while molten salt reactors will require careful examination of corrosion issues and the freezing of molten salt in piping. In short, the participants in the safety system will have to confront significant challenges in establishing and analysing the safety case for an advanced reactor and in adjusting regulatory requirements, which currently focus on issues arising in LWRs, to very different technologies.[10] The global nuclear safety regime can promote cooperation among the countries that are deploying advanced reactors and facilitate sound decision making.

Moreover, many NPPs that are currently operating were built many years ago and are close to or past the end of their originally anticipated 40-year lifetime. The plants have benefitted from detailed surveillance, maintenance and replacement of components over the years and many are running reliably. As a result, operators in several countries are contemplating an extension of operations well beyond 40 years. Indeed, in the United States of America, some NPPs have had their licences extended to 80 years.[11] However, ageing plants present unique safety challenges: systems, structures and components can deteriorate over time through mechanisms that may not be fully understood; spare parts may be difficult to find; and certain safety features found in more modern plants may not be available. Continuing the

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[9] As a rule of thumb, no power plant should constitute more than about 10% of the capacity on a grid so as to enable the plant to shut down for refuelling or for safety reasons without seriously disrupting power availability.

[10] The many challenges that must be overcome to enable the deployment of innovative advanced reactors are discussed in the Letter from R. A. Meserve to R. M. Grossi. See INSAG 2021.

[11] https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html. Accessed 11 July 2021.

operation of older plants therefore requires attention to ageing mechanisms, with heightened focus over time on surveillance, maintenance and the replacement and upgrading of systems, structures and components. The global system should provide guidance to countries that must deal with ageing plants so as to ensure that safety margins are maintained.

These considerations are sufficient to justify the careful scrutiny of the global nuclear safety regime. But what should change?

As noted above, the existing safety regime is premised on the obligation of operators to ensure safety, subject to rigorous oversight by a national regulatory entity. One might imagine a different regime in which an international regulator with sweeping transnational authority ensures the adequacy of the safety performance of every operator. Such an approach might be seen as a way to ensure that all nuclear activities, regardless of location, conform to high safety standards. The approach might facilitate the harnessing of safety capabilities from around the globe in an efficient and effective manner for the benefit of all.

It is unlikely, however, that such a regime can arise in a form in which an international regulator would displace national regulators. Populations living in the vicinity of a nuclear facility will no doubt demand that its safety is pursued by a politically responsive body, rather than by a distant international regulator. Moreover, it is doubtful that any nation would willingly surrender its sovereign authority over critical energy infrastructure. As the safety system must operate within each nation's legal, economic and social culture, adaptations of the regulatory system to fit local conditions are probably necessary in any event.[12]

As a result, a global nuclear safety regime premised on a single and strong international regulator is likely to be unachievable and and may not be desirable. Nonetheless, there are a number of things that should be considered to augment the existing global nuclear safety regime and to strengthen the capacity of operators and national regulators to fulfil their essential safety roles.

- Safety inspections. The IAEA offers an extensive array of inspection services that are available to Member States.[13] However, the IAEA does not have the power to undertake safety inspections without the invitation of the Member State, and many States do not request inspections. Moreover, the IAEA has no enforcement authority to deal with deficiencies that it uncovers. Given the importance of nuclear safety, the IAEA should be given the powers to undertake inspections wherever and whenever it finds inspections to be appropriate. Furthermore, it should have the capacity to seek compliance with any deficiencies that are uncovered. The aim should be to provide the IAEA with powers in the safety arena that are analogous to its powers on safeguards matters under the Additional Protocol. An

[12] See Meserve 2009, pp. 105–106.

[13] https://www.iaea.org/services/review-missions. Accessed 11 July 2021.

amendment of the Convention of Nuclear Safety would be the logical vehicle for the establishment of these powers.[14]

- Transparency. The results of the inspections undertaken by the IAEA are made public only with the consent of the Member State. However, if the report remains hidden, serious deficiencies can remain uncorrected. The results of the IAEA inspections should be made public—albeit perhaps after review by the affected Member States to address errors—allowing other elements of the safety regime to learn of the deficiency and to press for correction. The International Nuclear Safety Group (INSAG) has emphasized the "strength in depth" that can arise from open interaction with regard to safety issues among operators, regulators and affected stakeholders.[15]
- Harmonization of standards. Many of the vendors of advanced reactors are hopeful of international sales. In the light of the anticipated efficiencies that may result from serial factory production, substantial foreign sales may be an essential part of their business plans. Given that licensing is (and will remain) the responsibility of each national regulator, there is a danger that adaptations or modifications may need to be made to obtain licensing in each country in which a plant is sold. This is obviously likely to increase costs and diminish prospects for international deployment. On account of the need for extensive use of NPPs to respond to climate change, efforts should be intensified to harmonize regulatory requirements so that inappropriate or needless modifications can be avoided. Indeed, there are strong benefits in ensuring that each regulator profits from the knowledge of others and that needless regulatory differences in approach are eliminated.

  Efforts are under way to encourage harmonization. The IAEA process for setting standards, which involves the development of international consensus, nurtures common approaches. The IAEA is now also working on the establishment of a technology neutral framework for safety, security and safeguards, which should similarly facilitate the development of harmonized safety understandings. The NEA's Multinational Design Evaluation Programme focuses on harmonizing the licensing process for new reactors; it enables regulators to leverage the resources and knowledge of the national regulatory authorities that are tasked with the review of a new design for a nuclear power reactor, while preserving the sovereign authority of national regulators for all licensing and regulatory decisions. The programme encourages convergence and harmonization of codes, standards and regulatory approaches.[16]

  There is one aspect of the current efforts that could productively change. Each national regulator now makes its own decisions as to the application of IAEA standards. The system might benefit if full compliance with IAEA standards were the norm (subject to IAEA inspections), while respecting the authority of the national

[14] The establishment of such strengthened inspection and enforcement authority would likely take years of difficult negotiation, followed by a time-consuming process to bring an amendment of the Convention into force. In the meantime, the other changes outlined below should be considered.

[15] INSAG 2017.

[16] https://www.oecd-nea.org/mdep/index.html#2. Accessed 11 July 2021.

regulator. The aviation industry could provide a model in this regard. Binding international minimum standards are established by the International Civil Aviation Organization, thereby facilitating international air travel using standardized aircraft designs. Each nation sets its own airworthiness codes, but the differences from State to State have not proven to be significant. Perhaps the role of the IAEA standards could be strengthened, enabling the IAEA to perform a function similar to that of the ICAO by supporting the harmonization of nuclear requirements, while allowing individual nations to maintain sovereignty.[17]

- Integrating safety and security. Safety and security are clearly linked and steps taken to improve one can benefit the other. For example, the massive structures of reinforced concrete and steel of an NPP serve both safety and security objectives. However, some plant features and operational practices that serve one purpose can on occasion conflict with another. For example, access controls that are imposed for security reasons might limit emergency safety response or obstruct entrances and exits in the event of a fire or an explosion. In short, there can be synergy and antagonism simultaneously between safety and security. This suggests that safety and security responsibilities on the site of an NPP should be vested in a single body so that objectives can be balanced appropriately.[18] Moreover, continuing efforts are appropriate within the IAEA to integrate the safety and security guidance provided by it.[19]
- Operating experience. The communication of operating experience has served over time to improve the performance of NPPs. Communications concerning accidents and near misses, design or equipment deficiencies, and other operational experiences enable operators and regulators to learn from each other and to strengthen safety performance. In addition to national systems for the sharing of such information, operators and regulators also report safety related information through existing global systems. The IAEA and the NEA jointly operate an incident reporting system (IRS)[20] that is available to participating countries; WANO provides access to operating information on a private and confidential basis to its member operating companies. However, not all relevant events are reported, particularly to IRS, and not all those who have access to these repositories of information make full and effective use of the data. This may in part be because there are inadequate mechanisms to sort and analyse the information, distil and prioritize the lessons that should be learned, and propagate the information in a user-friendly fashion. The system should be upgraded to facilitate the exchange of accumulated knowledge from operating experience to further the common interest in avoiding accidents. Access to such information is particularly important for newcomer countries so that they do not need to relive the hard-learned lessons of their predecessors in the nuclear enterprise.

[17] See World Nuclear Association 2013 and 2020.

[18] INSAG 2010.

[19] A forthcoming report being jointly prepared by INSAG and AdSec (the Advisory Committee on Nuclear Security) will reinforce the importance of coordination between safety and security.

[20] https://www.iaea.org/resources/databases/irsni. Accessed 11 July 2021.

- International research and development. Cooperation takes place today in research and development on nuclear matters. For example, the NEA facilitates international cooperation in the research into nuclear matters from which all benefit. However, these efforts could be expanded. As noted above, many NPPs are operating beyond their design lifetime and a further shared understanding of ageing phenomena can help to ensure that safety is preserved over time. Modern digital instrumentation and control are being applied to both old and new plants, raising different safety issues from the analogue systems that are being replaced. These issues have even more prominence with the growing challenge of assuring cybersecurity. Moreover, advanced reactors present many new safety issues, and a deep understanding of them will be necessary to ensure that the promised safety enhancements are in fact realized.[21] Coordinated research programmes to increase knowledge of advanced designs will help to ensure that the necessary data are in place to facilitate licensing decisions.

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The global nuclear safety regime provides an important means to ensure the safety of existing and future NPPs. The opportunities to improve the regime should be pursued in order to ensure that nuclear technology can be harnessed safely for the benefit of all humankind.

References

International Atomic Energy Agency (IAEA) (2006) Fundamental Safety Principles. Co-sponsored by European Atomic Energy Community, Food and Agriculture Organization of the United Nations, International Labour Organization, International Maritime Organization, OECD Nuclear Energy Agency, Pan American Health Organization, United Nations Environment Programme, World Health Organization. IAEA Safety Standards Series No. SF-1. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2015) The Fukushima Daiichi Accident. IAEA, Vienna

International Nuclear Safety Group (INSAG) (2006) Strengthening the Global Nuclear Safety Regime (INSAG-21). IAEA, Vienna

International Nuclear Safety Group (INSAG) (2010) The Interface Between Safety and Security at Nuclear Plants (INSAG-24). IAEA, Vienna

International Nuclear Safety Group (INSAG) (2012) Licensing the First Nuclear Power Plant (INSAG-26). IAEA, Vienna

International Nuclear Safety Group (INSAG) (2017) Ensuring Robust National Nuclear Safety Systems—Institutional Strength in Depth (INSAG-27). IAEA, Vienna

International Nuclear Safety Group (INSAG) (2021) INSAG Annual Letter. https://www.iaea.org/topics/nuclear-safety-and-security/committees/insag/annual-letter-of-assessment. Accessed 11 July 2021

Meserve R (2009) The Global Nuclear Safety Regime. Daedalus 138(4):100–111 https://doi.org/10.1162/daed.2009.138.4.100

[21] There is a full discussion of these issues in the letter from R. A. Meserve to R. M. Grossi. See INSAG 2021.

World Nuclear Association (2013) Aviation Licensing and Lifetime Management—What Can Nuclear Learn? https://world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/CORDELAviationReport.pdf. Accessed 11 July 2021

World Nuclear Association (2020) Harmonization of Reactor Design Evaluation and Licensing: Lessons Learned from Transport. https://www.world-nuclear.org/getmedia/cb928ee3-dea9-41ed-a324-552c499f4375/Harmonization-of-Reactor-Design-(Transport)-Final.pdf.aspx. Accessed 11 July 2021

Chapter 6
The Challenge of Climate Change—Complete Energy Systems Transformation: No Nuclear, No Net Zero

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Contents

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Abstract To achieve Net Zero, natural gas, gasoline, diesel, and fuel oils must be replaced with another source. However, most of the current low-carbon energy sources will also need to be replaced as almost none have more than about 25 years remaining of useful life. The pace and scale of the needed change is unprecedented: almost the whole of the world's primary energy supply must be replaced. The (re)development of the entire energy system is inherently a sovereign risk and it can only be governments who set national energy policy. There is no doubt that markets will continue to play a part in future energy systems, but at the top level, the pace and scale of change to achieve Net Zero is simply far too fast for markets to adapt properly. This chapter is a call to action to the national policy makers and presents this challenge as an opportunity for creating higher-quality jobs and potentially highly attractive and long-dated investment options. The chapter also outlines some risks, including political indecisiveness and policy volatility as potential impediments to making the most of this opportunity and achieving the Net Zero.

Keywords Net zero · Low-carbon energy sources · Climate change · Primary energy consumption · Wind energy · Solar energy · Fossil fuels · Hydropower · Nuclear energy · Energy market · Clean power · Modular reactors · Energy transition

6.1 The Challenge of Climate Change and Transformation of Primary Energy

To achieve Net Zero, on any timescale, almost the whole of the world's primary energy supply must be replaced. Virtually all of it. Clearly, all the fossil fuels must be replaced. That is a simple and obvious statement and not only must natural gas, gasoline, diesel, fuel oils be replaced with another source or vector of primary energy, but most of the current low-carbon energy sources will also need to be replaced. The sheer pace and scale of what's needed is unprecedented with even war-time efforts being the closest the world has seen before. That said, it also represents the most powerful opportunity for employment in higher-quality jobs as well as potentially highly attractive and long-dated investment opportunities but where the biggest risks may well be from political indecisiveness and policy volatility. In other words, the trust and confidence in governments—or lack of it.

To go with this is the reality that this pace and scale of change cannot be achieved by markets alone. In Sect. 6.11 the basis of energy markets is examined in more detail, but the fundamental conclusion is simple. In its totality, energy is one of the largest cases of nationally significant infrastructure. The (re)development of the entire energy system is inherently a sovereign risk. To put it another way, any government 'owns failure' in nationally significant infrastructure. It can only be governments who set national energy policy. The history of the last 40 years with markets adapting—relatively slowly in terms of the current challenge—to engineering developments has been highly effective and there is no doubt that markets will continue to play a part in future energy systems. But at the top level, the pace and scale of change to achieve Net Zero is simply far too fast for markets to adapt properly.

The other top-level constraint is, of course, that of physical deliverability. This is not simply about the length of time to build large primary energy sources such as hydropower and GW-scale nuclear reactors. It is about how to develop and grow entire supply chains to support the installation (note, not just construction) at a national level of many GWs of capacity each year. And for supply chains, it is not just about pumps, valves, gearboxes and other components. The supply chain for people will be just as important.

6.2 Primary Energy

Meanwhile, in a low-carbon world, there are only four sources of primary energy. Sources of primary energy must be distinguished from energy vectors or ways of transporting energy from its source to a user. In no particular order these sources of primary energy are:

- Wind and solar electricity;
- Nuclear energy—currently only from fission but ultimately from fusion as well;
- Hydropower—including tidal and wave energy;
- Energy from fossil sources with effective carbon capture and sequestration.

Gases such as hydrogen and ammonia are not themselves sources of primary energy but merely ways of transporting the energy—energy vectors.

With the complete rebuilding of national energy systems, one fundamental aspect of global economies is changing. The 21st century is increasingly reliant on energy for day to day living and the cost of that energy is becoming an increasing determinant of economic competitiveness. The new energy systems will have a profound impact on national economic competitiveness and well-being for many generations to come—for our grandchildren and beyond. Meanwhile, it is essential to recognize that current energy systems were designed for a different era. As an example, the United Kingdom's (UK) energy system was largely designed after the Second World War and initially designed to move energy from coal fields to manufacturing centres, as well as for domestic use. Neither of those major design points apply now. Energy today comes from gas fired power stations, large nuclear power stations situated around the coasts and increasingly from renewable sources with an ever greater move into deep waters offshore. The population distribution has changed significantly from the 1950s to now, manufacturing centres are smaller and often in different locations, and energy transmission infrastructure has been regulated based on reducing the cost to consumers over five year periods.

The biggest challenge of all is the need for a proper systems approach given that the Darwinian market models simply cannot conceivably react quickly enough. Newer technologies have been heavily promoted over the past decade to drive their adoption—but that drive has been about cost reduction, not based on any sense of what a reasonable outcome—or alternative outcomes—might be. There has been no thorough analysis of what a new system could look like or how to get there.

Darwinian evolution at the heart of good markets is about a generate, test, selection and failure mechanism, and the high-tech, start-up approach of 'fail fast' does not work in the primary energy sphere. The evolution of primary energy creation systems and different approaches to the underpinning infrastructure is simply too slow. In a UK context, by the date of the 2021 United Nations Climate Change Conference (COP26), the UK will have lost almost 7.5% of the time between the original announcement by the Prime Minister, Theresa May, of the legally binding requirement for the UK to achieve Net Zero by 2050—with virtually nothing to show for it.

There is now no time to waste—if, indeed, there is even enough time to achieve Net Zero by 2050.

6.3 Current Energy Consumption

Global energy consumption, on a substitution basis[1] is shown in Fig. 6.1. The sheer scale of the decarbonization challenge is best shown on this substitution basis. Comparison of the scale of the four traditional energy sources—biomass, coal, oil and gas—with the remaining lower-carbon primary energy sources shows that daunting scale of the challenge.

Similar charts for the United States of America (USA), Japan, China, the UK, Germany and Sweden are included in this chapter. It is also instructive to consider the carbon intensity maps produced regularly by Grant Chalmers[2]—see Figs. 6.2 and 6.3.

It is clear from the plots in Figs. 6.2 and 6.3 that countries such as Sweden, blessed with natural resources of hydropower and/or those who have also historically built significant nuclear capacity, will have a far, far easier route to Net Zero than others.

[1] The 'substitution method'—in comparison to the 'direct method'—attempts to correct for the inefficiencies (energy wasted as heat during combustion) in fossil fuel and biomass conversion. It does this by correcting nuclear and modern renewable technologies to their 'primary input equivalents' if the same quantity of energy were to be produced from fossil fuels.

[2] See @GrantChalmers on Twitter. Graphs such as Figs. 6.2 and 6.3 are published regularly. These images, along with others in this document from the same author which are appropriately identified, have been provided by Grant Chalmers to whom the author is indebted.

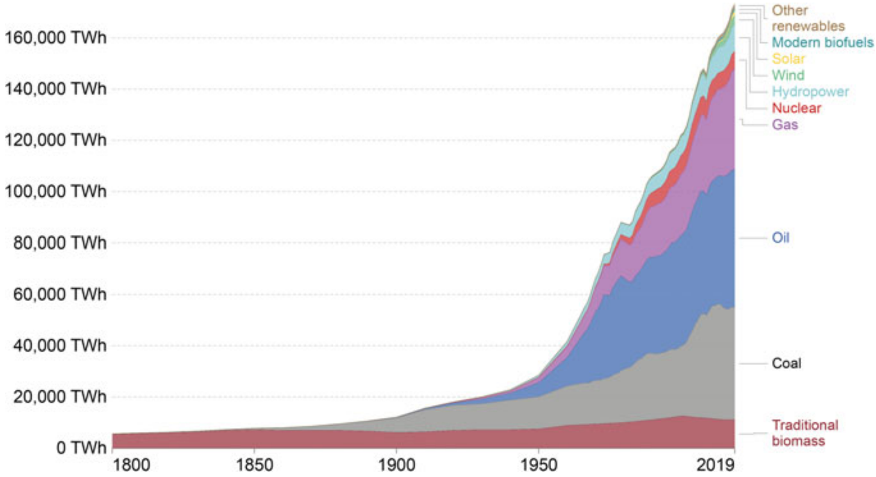

Fig. 6.1 Global primary energy consumption by source. *Note* Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels. *Source* https://ourworldindata.org/energy-production-consumption (Accessed 14 July 2021)

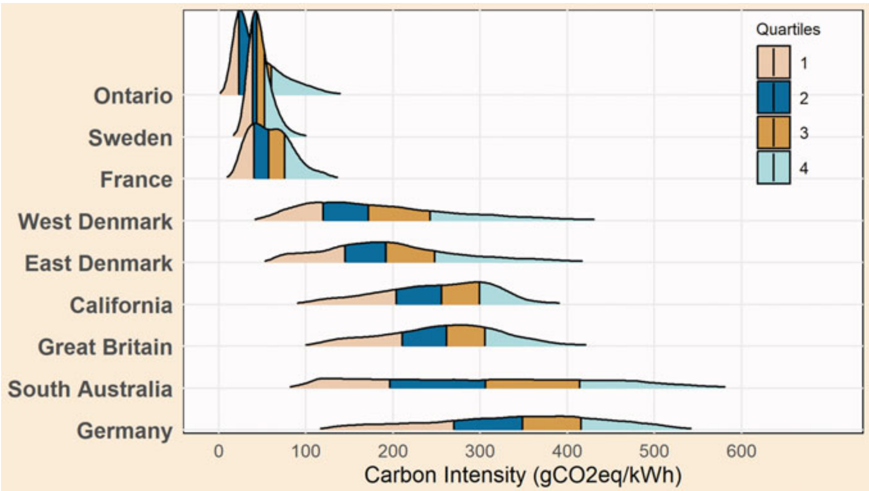

Fig. 6.2 Carbon intensity of electricity consumption 2017–2021. *Source* @GrantChalmers

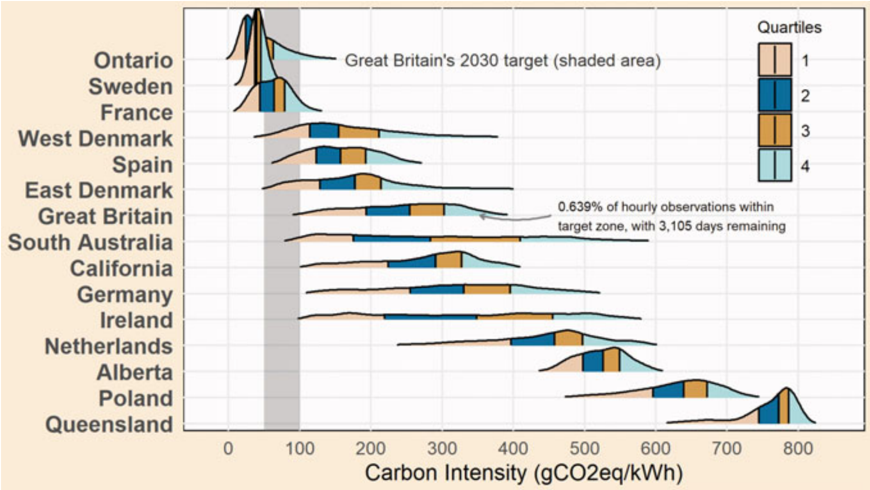

Fig. 6.3 Carbon intensity of electricity consumption 2020–2021. *Source* @GrantChalmers

France, the Province of Ontario and Iceland[3] all fall into that category. It is equally clear that despite the heavy focus on renewables in countries such as Germany, the dependence on fossil energy remains and even in countries such as Denmark there is an inescapable reliance on imported energy from other countries such as via the Nordic Grid or from fossil power. Queensland appears here at the more extreme end of fossil dependency and will appear elsewhere (Fig. 6.19) as an example of a badly (at least *weirdly*) performing energy market.

Interestingly, in terms of CO_2 emissions, in the UK, the overall carbon saving since the opening of Calder Hall in 1957 is 2.3 billion tonnes CO_2 eq (which is equivalent to *all* UK emissions from 2015 through to 2020).

The continuous theme for the graphs in Figs. 6.4, 6.5, 6.6, 6.7, 6.8 and 6.9 is the huge amount of primary energy from fossil fuels which must be entirely replaced.

The UK story is largely now one of driving out coal as a source of primary energy coupled with a very large series of investments in wind and solar energy supported by the very favourable electricity market reform of the early 2010s which 'socialized' the costs and consequences of intermittency and had the effect of paying for renewable energy whether it was needed or not. The same period included the approval of one new nuclear power station despite the foundation legislation for low-carbon energy in the UK including a strong signal that fleets of more than one design of GW-scale nuclear plants were intended. That intention became weaker with the 2010 coalition government in which the Liberal Democrats, historically an anti-nuclear political party, were given ministerial control of the Department of Energy and Climate Change. The relative power of the renewables teams of civil

[3] Iceland, with a major geothermal resource, regularly has carbon emissions around 50 gCO_2 eq/kWh. See as an example https://twitter.com/GrantChalmers/status/1404713459091066880?s=20. Accessed 14 July 2021.

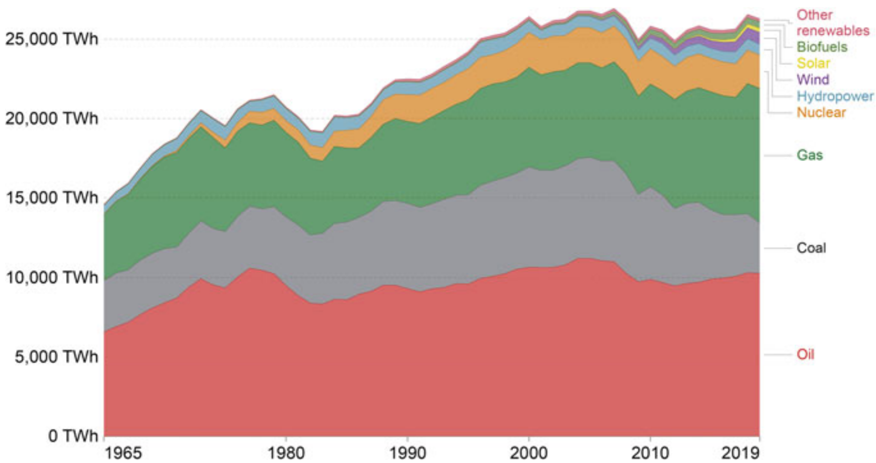

Fig. 6.4 Energy consumption by source—USA. 'Other renewables' includes geothermal, biomass and waste energy. *Note* Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption. *Source* https://ourworldindata.org/energy-mix?country= (Accessed 14 July 2021)

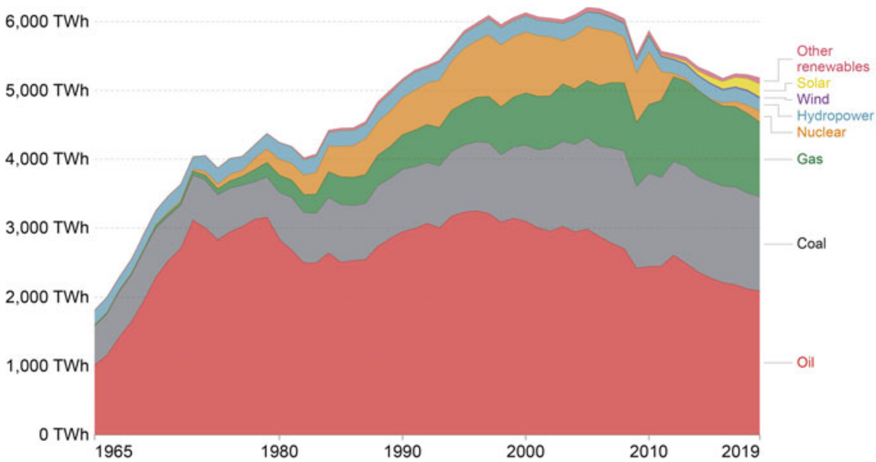

Fig. 6.5 Energy consumption by source—Japan. 'Other renewables' includes geothermal, biomass and waste energy. *Note* Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption. *Source* https://ourworldindata.org/energy-mix?country= (Accessed 14 July 2021)

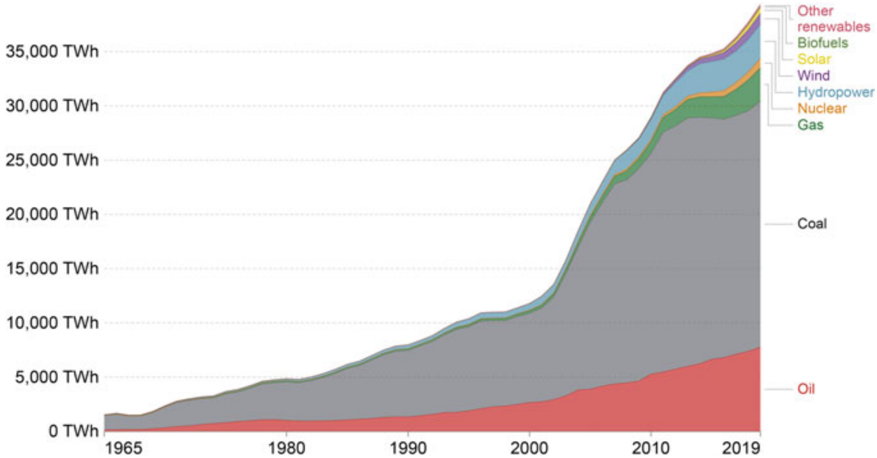

Fig. 6.6 Energy consumption by source—China. 'Other renewables' includes geothermal, biomass and waste energy. *Note* Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption. *Source* https://ourworldindata.org/energy-mix?country= (Accessed 14 July 2021)

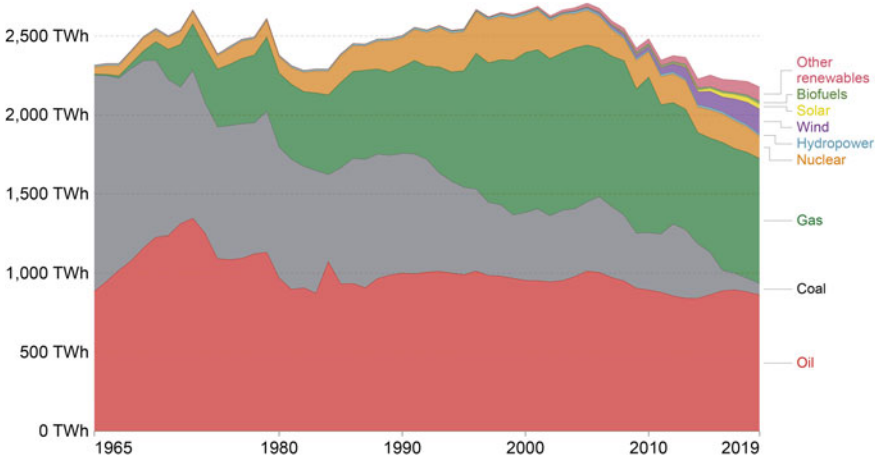

Fig. 6.7 Energy consumption by source—UK. 'Other renewables' includes geothermal, biomass and waste energy. *Note* Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption. *Source* https://ourworldindata.org/energy-mix?country= (Accessed 14 July 2021)

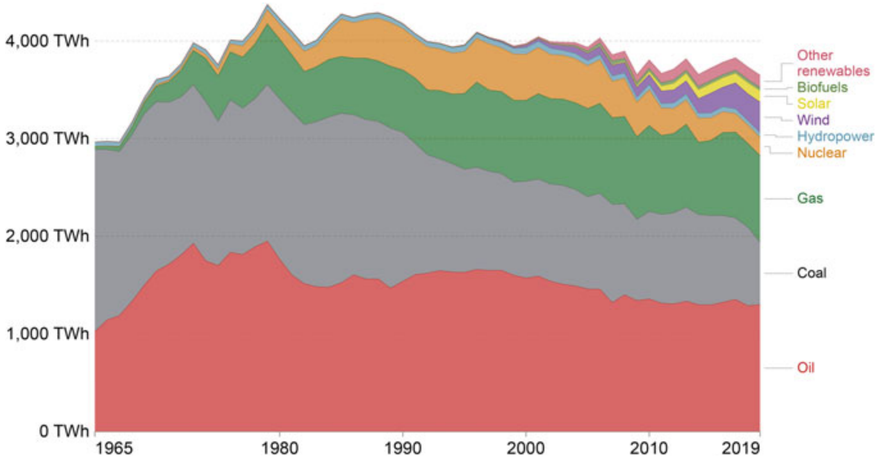

Fig. 6.8 Energy consumption by source—Germany. 'Other renewables' includes geothermal, biomass and waste energy. *Note* Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption. *Source* https://ourworldindata.org/energy-mix?country= (Accessed 14 July 2021)

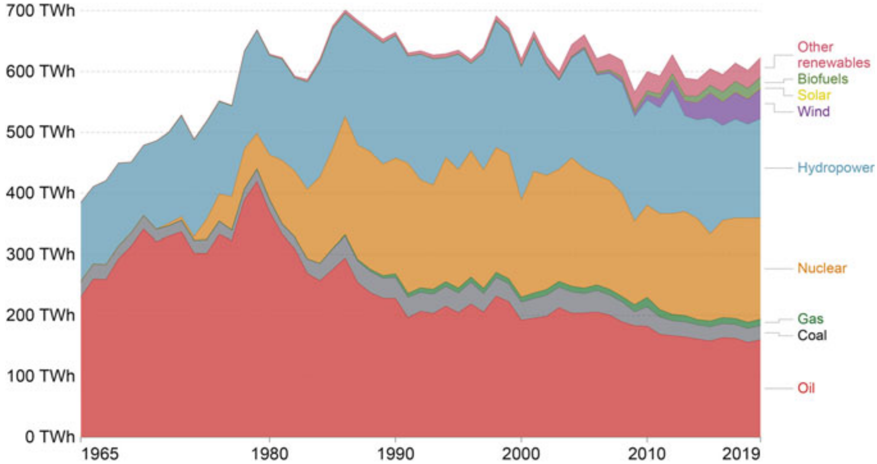

Fig. 6.9 Energy consumption by source—Sweden. 'Other renewables' includes geothermal, biomass and waste energy. *Note* Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption. *Source* https://ourworldindata.org/energy-mix?country= (Accessed 14 July 2021)

servants increased significantly over that period while the Office for Nuclear Development became less influential from 2014 onwards. The UK has gone from leading the 'nuclear renaissance' in the 2008–2014 period to, at best, playing catchup. While the Prime Minister produced a visionary 10 Point Plan for a Green Industrial Revolution[4] in 2020, the subsequent White Paper was relatively weak in terms of practical ambitions for nuclear.

The politics of Germany, particularly driven by the prominence of Green, anti-nuclear politics in the state elections in Baden-Württemberg in the immediate aftermath of the Fukushima tragedy at the Daiichi nuclear power plant, is famous. The subsequent energy policy 'Energiewende' has failed to reduce CO_2 emissions significantly. A study found that if Germany had postponed the nuclear phase out and phased out coal first it could have saved 1100 lives and US $12 billion in social costs per year. An article by Environmental Progress[5] claims that Germany could have already phased out fossil fuels if it had chosen to invest in nuclear instead of renewable energy.[6] The deep antipathy to nuclear power in Germany can, it has been suggested, be traced back to the original investments in nuclear power in Germany in the 1970s.[7] According to Marx,[8] much of the original support for nuclear power in Germany came from industry—notably BASF and Hoechst—and was not the primary result of Federal or State Government Policy. In the 1960s there had been majority societal support for nuclear power, but neither Federal nor State governments made any significant attempt to sell the policy to the German people. Social licence for nuclear power in Germany became progressively diluted as the larger corporates promoted nuclear power, with added emphasis following the 1973 oil crisis. Ultimately, a large part of the country's electric utilities' expansion was based on nuclear energy but the industrial companies that originally championed nuclear ultimately moved to support coal, coal-to-liquid and lignite industries.

The graphs speak volumes about the scale of the build challenge. It has been clear since the drive to install wind and solar energy generation that the useful life of each is significantly less than other conventional sources of primary energy.[9] That alone should galvanize energy policy makers and governments. There has been a wonderful development of renewable energy over the last decade and a half but, as is so often the case in nationally significant infrastructure, the lifetimes and investment cycles are generally ignored until a relevant crisis appears. The UK may have experienced an 'appropriate' crisis in September 2021 as this is being written. Weather conditions reducing renewables generation to very low proportions (2.78% right now) with very high gas prices have forced the restart of the one operable coal plant and energy

[4] HM Government 2020 (Nuclear power is the third section after offshore wind and low-carbon hydrogen).

[5] https://grist.org/energy/the-cost-of-germany-going-off-nuclear-power-thousands-of-lives. Accessed 14 July 2021; https://www.nber.org/papers/w26598. Accessed 14 July 2021; https://www.welt.de/wirtschaft/plus204786230/Atomausstieg-Was-die-Energiewende-wirklich-kostet.html. Accessed 14 July 2021.

[6] https://environmentalprogress.org/big-news/2018/9/11/california-and-germany-decarbonization-with-alternative-energy-investments. Accessed 14 July 2021.

[7] https://www.dw.com/en/nuclear-power-in-germany-a-chronology/a-2306337 (A brief history of nuclear power in Germany). Accessed 14 July 2021.

[8] Marx 2014.

[9] See as an example Fuchs et al. 2021.

prices have escalated dramatically, causing a large number of retail organizations to fail. The vital takeaway is that virtually none of the currently operating renewable sources of primary energy will still be operating by 2050. In addition to the massive decarbonization system plans yet to be developed, there must be an ongoing replacement and re-powering plan to keep renewable energy production online and durable.

One important message is that in rebuilding a nation's energy system, there is unlikely to be a silver bullet. A modern, resilient energy system with a robust level of energy security will be one with a balance of energy creation sources, one that has sufficient capacity in its constituent parts to cope with even very low probability scenarios. The optimal solution must factor in possible rates of construction, likely all-powerful (read strongly binding from an optimization perspective) constraints of a physical nature (how much land/sea area is needed? Can you create a large enough workforce? Where will the steel come from? reducing embedded carbon, etc.) to minimize the cost of the system at the level of the national economy.

6.4 Attributes/Superlatives of Nuclear Energy

Before delving into further detail of some of the practical issues, it is worth revisiting the reasons why nuclear power can, and in many cases should, be a powerful and critical component of a 21st century energy system.

6.4.1 Most 'Energy Dense'—Most of the Virtues Flow from This

Energy density data are quite revealing:

- Uranium enriched to 3.5% used in a light water reactor has about 3900 GJ/kg;
- Uranium as fuel in a fast neutron reactor has about 28,000 GJ/kg;
- Hard black coal has about 24–25 MJ/kg (note MJ not GJ);
- Hydrogen has about 120–142 MJ/kg;
- Natural gas has about 42–55 MJ/kg.

Hence uranium has about 156,000 times the energy of coal in a conventional light water reactor, but if burnt in a fast neutron reactor (see Sect. 6.9.2) that figure rises to about 1.12 million times the energy of coal.

Because of the exceptionally large energy density of nuclear fuel, nuclear power has the least land requirement of any. Table 6.1 sets out a recent analysis of lifecycle land use.[10]

[10] Chivers et al. 2017.

Table 6.1 Lifecycle spatial requirements of different energy sources

Energy system	Spatial footprint—km^2/TWh		
	Gagnon et al.[a]	EWG[b]	Cheng and Hammond[c]
Coal	4	3.63	–
Natural gas (unabated)		0.09	
Nuclear	0.50	0.48	0.30
Wind	72	2.33–116.66	1.15–44.17
PV	45	13.50–27.00	16.17–20.47
Biomass	533–2200	1320–2200	470

[a]Gagnon et al. 2002
[b]EWG: https://www.ewg.org/research/green-energy-guide. Accessed 14 July 2021
[c]Cheng and Hammond 2017

In terms of land area used for actual generation, the figures are a little different and could be a very different basis of selection (although nuclear is always the most effective use of land mass by far, however the analysis is performed).

To pick a simple example from the UK, take Torness, a 1988 power plant of 1.36 GW output that would generate four times the power of East Anglia One, UK's largest windfarm, which is currently being built: it has 102 turbines and needs 300 km^2. Torness occupies, in total, about 130 ha (about 1.3 km^2)—the nuclear island itself very considerably less than that.

To replace Torness you would need 400 wind turbines, taking about 1200 km^2. The entire *global* nuclear fleet could easily fit within that several times over.

6.4.2 Creates the Most Skilled Jobs

Fig. 6.10 shows the earnings map across the UK with the example of the Copeland constituency. This includes the Sellafield and related nuclear industrial sites.

In general, the nuclear industry provides better paid jobs than in most other areas with large numbers of professional services jobs. Other than the Copeland area (which is dominated by the nuclear industry), the red areas on the map are in and around London. The figures for all the red patches on the map are set out in Table 6.2.

There are some other helpful statistics to add here too. At the Hartlepool power station, the average wage is over £50,000, more than twice town average. In the UK, 90% of nuclear jobs are outside London and the Southeast. Nuclear contributes around £12.4 billion to the national economy (when taken with multipliers). Overall, in the UK there is a £2.8 billion Exchequer tax receipt from nuclear jobs and industries.

And it helps keep the lights on reliably.

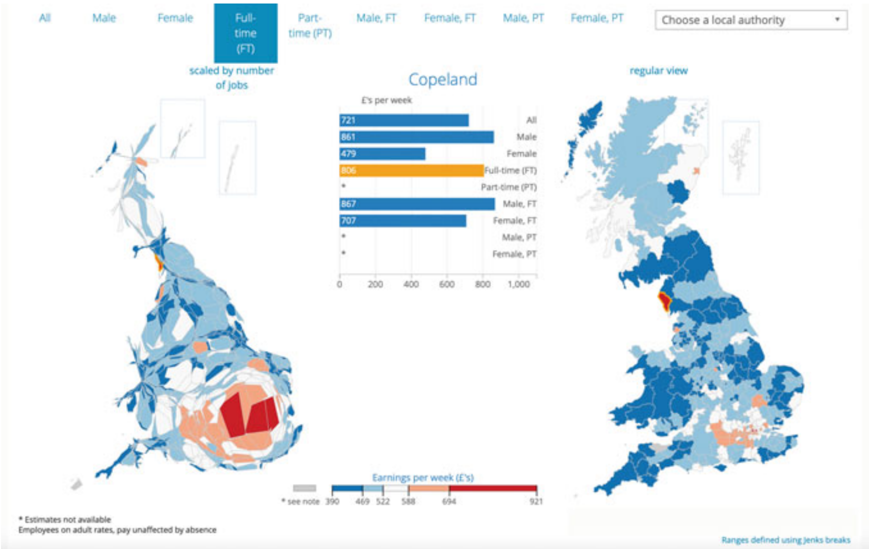

Fig. 6.10 Average earnings map for the UK. *Source* https://www.ons.gov.uk/visualisations/nesscontent/dvc126. (Accessed 14 July 2021)

Table 6.2 Average weekly earnings for red zones

Area	Average weekly earnings (£)
Westminster	635
Copeland	721
Tower Hamlets	768
City of London	870

6.4.3 *Only Technology Can Produce Clean Heat and Clean Power*

Nuclear energy stems from the production of low-carbon heat. It is, with wind, solar and hydropower, one of the few sources of primary energy. Wind and solar convert energy from the climate to electrical energy and hydropower converts climate driven rainfall and gravity into electrical energy. Nuclear power comes from a fundamental physical process which releases energy contained within any element in the periodic table with a larger atomic number than iron.[11] The energy released by any nuclear reaction—fission or fusion—is captured as heat and all the subsequent energy use is from that low-carbon heat. Conventionally, the heat is used to boil water and use the steam to spin turbines and generators. Increasingly though, heat is now a major issue for both industry and other methods of electricity generation such as high temperature

[11] See as an example Ling et al. 2016.

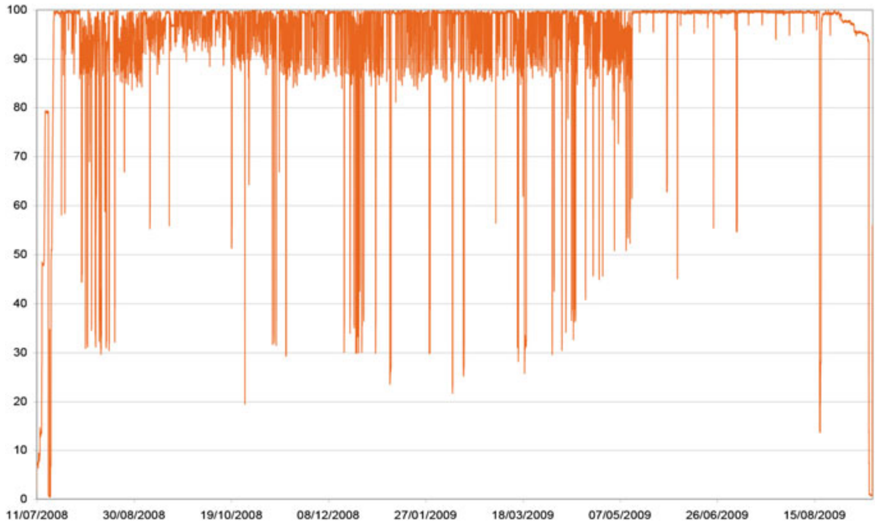

Fig. 6.11 Example of nuclear power station load following. *Source* OECD/NEA 2011, image courtesy of Électricité de France

electrolysis (see Sect. 6.6.1.1) but also for the production of hydrogen—likely to be a critical part of any future energy system in many countries—by thermochemical (catalytic) systems.

Conventional nuclear power is also a Flexible Base Power, i.e. large scale reactors turning out electricity, and capable of load following to balance with much less flexible and intermittent renewables. Figure 6.11, taken from the OECD/NEA document entitled 'Technical and economic aspects of load following with nuclear power plants'[12] shows an example of that load following in action in the EDF French fleet where around three quarters of their electricity came from nuclear power.

The economics of load following for a nuclear reactor are interesting and complex—while the cost of fuel saved is small, incremental costs (such as the additional use of ion-exchange resins in pressurized water reactors (PWRs)) can more than outweigh those savings. But load following by nuclear power stations can and does happen regularly.

6.5 Nuclear Off the Assembly Line—Modular Reactors

Conventionally, most nuclear power stations have been built entirely on-site with little prefabrication or major manufacturing off-site. This is not the case for the some of the earliest regular uses of nuclear power in submarines but until the second decade of the 21st century, so-called 'stick build' was the normal approach. In the first years

[12] OECD/NEA 2011.

of this century interest began to increase in the potential for swapping stick build for a manufacturing process where parallelism of manufacture could reduce the time taken for the whole project (which is part of the reason why nuclear electricity prices are so sensitive to the weighted average cost of capital (WACC) as discussed in Sect. 6.10.1). A manufacturing process within factory conditions should also give rise to higher and more consistent quality of all the elements of the build process and elimination of rework on a construction site.

6.5.1 AP1000 Style and Passive Safety

Nuclear power has a history dominated by engineering always seeking to tweak and change, no real attempt to design for manufacture, no real focus on the delivery of new projects in terms of GW/year and too little on the fundamental reliability of cost and schedule on construction.

Nuclear industry has had a major drawback that there was no clear product. The industry has been selling components to utilities that would historically integrate them in a relatively bespoke process—other than in the Republic of Korea and China where a more industrial process has been historically the case. There has been no design for manufacture, no focus on GW/year and too little focus on the reliability of cost and schedule. The second generation of reactors in the UK—advanced gas cooled reactors (AGRs)—are all different despite the intent that they would be a fleet of a common design. There was a clear attempt to drive fleet build in the UK 2008 White Paper and the Generic Design Assessment was created at the time as part of the "Facilitative Actions" intended to do as much as possible for a new fleet of reactors up front, once and to make it hard to change en-route other than on a fleet basis. Despite the vision and aspiration of the time, at the time of writing, the UK has only approved one new nuclear power project and the Sunday Times newspaper recently described nuclear policy in the UK after 2010 as having been "ossified".[13]

In the UK, following the Magnox reactor build programme, the successor programme to build AGRs was originally intended to be a fleet build with all the consequential learning and efficiency gains. In practice, the AGRs are all different with different construction groups and too little focus on consistency with the first of a kind having been thoroughly and completely designed. Similarly, in the USA there had been a common PWR reactor design, the Standardized Nuclear Unit Power Plant System (SNUPPS) design produced by Westinghouse in the 1970s. The design was developed for four US utilities, and plants were built at Callaway and Wolf Creek. The UK plant at Sizewell B was also based on SNUPPS—but as is too often the case, with significant modifications.

In the 1990s, a number of reactor vendors decided to produce new designs as part of a drive for ever greater safety levels. Westinghouse first produced the AP600

[13] https://www.thetimes.co.uk/article/were-pivoting-to-nuclear-but-are-ministers-too-late-vjrmhltb2. Accessed 17 October 2021.

Table 6.3 Sizewell B/AP1000 construction comparison

Unit	Concrete	Rebar
Sizewell B	520,000 m^3 (438 m^3/MWe)	65,000 t (55 t/MWe)
AP1000	<100,000 m^3 (90 m^3/MWe)	<12,000 t (11 t/MWe)

design, which received NRC certification in 1999, as their first attempt at a simpler, safer modern reactor design with a core damage frequency around 1000 times better than the regulatory requirement. This design, ultimately upgraded to the AP1000, was first built in Sanmen in China with following construction at Vogtle for the Southern Company of the USA.

A single unit of the AP1000 has 149 structural modules of five types and 198 mechanical modules of four types: equipment, piping and valve, commodity, and standard service modules. These comprise one-third of all construction and can be built off-site in parallel with the on-site construction. It is interesting to compare the AP1000 with the previous Westinghouse unit built in the UK at Sizewell B, as set out in Table 6.3.

The history of these plants as a first-of-a-kind construction is mixed with problems and delays. The Wall Street Journal in December 2016[14] reported that "construction at Sanmen was moving ahead faster than the company was completing its engineering work, a decision Westinghouse now concedes was a mistake. Several times, Westinghouse had to rip out equipment that had already been installed and start again or undertake lengthy re-examinations of engineering work." The build at Vogtle was eventually rescued when the company brought in Bechtel to take over the project management and complete the project which, not unlike the experience in Sanmen, was slipping. The Sanmen project went online on 28 June 2018 and as of July 2021, the Vogtle unit 3 construction was approximately 98% complete, with the total Vogtle 3 and 4 expansion project approximately 92% complete.[15] It is now expected that the lessons learned on the AP1000 completion at Vogtle will provide the basis for a much faster, more predictable build of future AP1000 reactors at costs which should be economically attractive compared to renewable electricity. At the time of writing, Bechtel, Westinghouse and Southern Company (the owners of the Vogtle plants) are discussing building AP1000 reactors on the Wylfa site on which Hitachi had been developing their own Horizon project, until it finally ceased development on 31 March 2021. The Bechtel/Westinghouse/Southern Company proposal, should the UK Government decide to take it forward, is planned to be available well before the end of the highly challenging Sixth Carbon Budget for the UK, which was published by the Climate Change Committee in December 2020.[16]

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[14] https://www.wsj.com/articles/troubled-chinese-nuclear-project-illustrates-toshibas-challenges-1483051382. Accessed 14 July 2021.

[15] https://www.southerncompany.com/innovation/vogtle-3-and-4.html. Accessed 14 July 2021.

[16] UK Climate Change Committee 2020.

In parallel, Hitachi and Toshiba in Japan had designed boiling water reactors (known as ABWR) which were heavily modular in design with novel approaches to construction on-site. The first four of these units have been reportedly[17] built in 39–43 months on a single shift basis—that may in part reflect the highly disciplined approach to construction in Japan as a professional discipline backed up by strong cultural reinforcement.

6.5.2 The Nuclear Product—A Modular Power Station

The challenges of GW-scale reactor projects (the scale of capital cost which puts the projects firmly into the 'sovereign risk' territory), the challenges in many countries with delivering very large projects to time and cost (irrespective of technology, power or transport, for example) and the logical conclusion of the modularization approach for GW-scale reactors was to contemplate smaller, highly modular designs.

A number of these are now well into development with the NuScale project for Utah Associated Municipal Power Systems (UAMPS) the furthest along at the time of writing. The project is based on a design for up to 12 NuScale Power Modules, each of which is designed to be entirely factory built and capable of being shipped to site by river or road. Other component systems will be similarly handled in modular fashion. Turbine-generators, chemical control processes and other modular systems will be assembled off-site, skid mounted, and shipped to the plant site. The current cost estimate of US $6.1 billion includes the NuScale overnight capital cost, owners' costs, escalation, contingency, fees, warranty and capitalized interest, with a planned power output of 77 MW per module giving a potential total of 924 MW.

The project is currently stated to be on track for the first module to go online in 2029 and in their 2019 article, which examined the cost structure of the NuScale power module, Black et al.[18] suggested that, overall, "the substantially lower estimated expenditures for direct and indirect capital costs will likely lead to LCOE measures that are significantly lower than conventional nuclear plants and more in line with other energy technologies."

Following the progress shown by NuScale, others have approached small modular reactor designs increasingly, attracting capital investment in the designs and significant interest from countries around the world—the USA, Canada and many European countries now expressing clear interest in the technologies. World Nuclear News lists the following designs, set out in Table 6.4, as being well advanced and ready for near-term deployment.[19]

[17] World Nuclear Association 2021a.

[18] Black et al. 2019.

[19] World Nuclear Association 2021b.

Table 6.4 Some SMR designs

Name	Capacity	Type	Developer
VBER-300	300 MWe	PWR	OKBM, Russian Federation
NuScale	77 MWe	Integral PWR	NuScale Power + Fluor, USA
SMR-160	160 MWe	PWR	Holtec, USA + SNC-Lavalin, Canada
SMART	100 MWe	Integral PWR	KAERI, Republic of Korea
BWRX-300	300 MWe	BWR	GE Hitachi, USA
PRISM	311 MWe	Sodium FNR	GE Hitachi, USA
Natrium	345 MWe	Sodium FNR	TerraPower + GE Hitachi, USA
ARC-100	100 MWe	Sodium FNR	ARC with GE Hitachi, USA
Integral MSR	192 MWe	MSR	Terrestrial Energy, Canada
Seaborg CMSR	100 MWe	MSR	Seaborg, Denmark
Hermes prototype	<50 MWt	MSR-Triso	Kairos, USA
RITM-200M	50 MWe	Integral PWR	OKBM, Russian Federation
BANDI-60S	60 MWe	PWR	Kepco, Republic of Korea
Xe-100	80 MWe	HTR	X-energy, USA
ACPR50S	60 MWe	PWR	CGN, China
Moltex SSR-W	300 MWe	MSR	Moltex, UK

6.5.2.1 What Is the Fastest Way to Build?

If Japan and the Republic of Korea can achieve construction times apparently so very low (as shown in Sect. 6.12.2), the question is now being asked about just what could be done with massively parallel factory build of the whole power station. Then how rapidly could, say, a 300 MW unit be assembled on-site from the point that a standard base—such as Arup have proposed for UKSMR—has been installed? Why could the assembly of modularly build units not be brought down to less than two years with smart inter-module interfaces?

This is the challenge for the nuclear industry in 2021.

6.5.2.2 UKSMR Approach

The UKSMR consortium, founded by the Rolls-Royce defence and aerospace company, building on their extensive experience of building all of the UK's nuclear submarine reactors, has developed their SMR design to the point where it is now expected to enter the UK's Generic Design Assessment in Autumn 2021. Over the last few years, the concept of modularization of the reactor manufacturing which Rolls-Royce had been developing for a number of years, has now moved towards a bigger vision of a modular power station.[20] This, of course, reflects the reality that no

[20] Personal communication.

operator or investor will be interested in a reactor on its own—it is an entire power station which is the source of practical energy and revenue stream and the more that can be done to streamline, de-risk and reduce the costs of the power stations are all potentially valuable additions to the case for SMRs. With the challenge now in attempting to achieve Net Zero, the critical issue for new build is GW/year within an electricity price cap/constraint. The more that SMRs can be created as rapid delivery products, the more attractive they will become on top of the much lower capital cost and thus have only a very short term need for any governmental support. Of course, the challenge will remain to ensure that SMR designs are actually implemented on a fleet build basis and that the lessons from the AGRs are never repeated.

In Rolls-Royce's view, the current, outdated model of nuclear new build as a major, one-off infrastructure project is not fit for purpose in a world that needs new nuclear power stations delivered quickly and affordably to a wide variety of global locations.

They say that their approach means that approximately 90% of the plant will be factory fabricated and delivered by road or rail as modules alongside the remaining components to the prepared site where the plant will be assembled and commissioned by the Rolls-Royce SMR team under a turnkey Engineering, Manufacture, Assembly (EMA) contract.

They have a clear view that offering a nuclear power station as a manufactured product should deliver the cost and risk reductions and quality improvements associated with factory fabrication whilst simultaneously removing the expense, lead-time and risk associated with developing a new, inexperienced supply chain and EPC contractor team for each new plant constructed.

According to the project team, the Rolls-Royce SMR has been designed from the outset with end user requirement at the heart of the design focusing on:

(a) Lower capital cost per MW-installed by design to:

- Maximize power for small physical size;
- Make use of a commercially available suite of products—simplified and standardized equipment that is used in other applications and avoidance of 'one-off' components;
- Avoid high and heavy parts with only a few global manufacturers;
- Radically reduce construction-based activities: modularization of whole plant, not just nuclear island;
- Focus modularization on standardization, commoditization, factory repeatability and a production line approach;
- Avoid very large one-off modules that must be disassembled for transport and/or require expensive facilities to build;
- Avoid redesign for each site with an aseismic bearing to prevent the need for site-to-site redesign.

(b) Reduced build time through:

- Modules factory fabricated and functionally tested off-site;

- Road transportable modules removes requirement for new transportation infrastructure (e.g. ports);
- Expedited module assembly on-site using site factory;
- Simultaneous module lift and assembly using site factory;
- Utilizing in-built knowledge transfer across units through repeatable factory product.

(c) Lower risk/increased certainty:

- Low licensing risk: proven PWR technology and standard uranium fuel;
- Lower environmental impact: reduced site footprint, lower site disruption and boron free design;
- Site canopy provides controlled site environment for assembly;
- Aseismic bearing removes need for site-to-site redesign and eases licensing between sites.

The Rolls-Royce team believe that their approach will deliver:

- £1.8 billion capital price underpinned by existing equipment pricing and extensive manufacturing experience;
- Repeatable cost driven by 90% factory product;
- Clean electricity at scale at a price competitive with intermittent renewables;
- Fast deployment—four year construction for a fleet unit;
- No need for complex EPC contractual interfaces—lower risk single entity delivery model using an Engineering, Manufacture, Assembly (EMA) turnkey delivery contract;
- Minimized site disruption during construction (average of 500 people on-site negates needs for extensive worker infrastructure);
- Highly scalable through innovative production methodology;
- Can fit within existing infrastructure (grid, transport);
- Compact footprint increases site flexibility and maximizes potential plant locations (including replacement for existing coal or gas fired plants);
- Indirect cooling option increases siting flexibility;
- Long term job creation, sustainable in factories and supply chain avoiding the boom and bust cycle associated with large one-off infrastructure projects;
- Multi-use electricity and/or heat output adaptable to on- and off-grid applications;
- Lower capital, risk, build time enables investment by commercial entities on a standard debt and equity basis;
- Repeatable low cost, factory product rather than large one-off infrastructure project;
- Low completion risk given standardized manufactured nature of product and repeatable EMA turnkey plant delivery.

At the time of writing, it is rumoured that Rolls-Royce has raised over £200 million of private capital to match the funding from the UK Government announced in November 2020.[21] An announcement is expected around the time of COP26.

6.5.2.3 GE BWRX-300 Approach

GE have also taken their ESBWR design, which was licensed by the NRC in 2014—although never built—and developed a 300 MW boiling water reactor (BWRX300). GE have developed this design in partnership with Dominion Power[22] and others. GE are currently working with Ontario Power Generation[23] to progress options for the potential deployment of small modular reactors in Ontario. There is a well supported SMR roadmap for Canada[24] which could be argued to be the nation currently at the forefront of SMR enthusiasm. Senior government officials, most notably federal Natural Resources Minister Seamus O'Regan, regard SMRs as indispensable tools for meeting Canada's greenhouse gas emissions targets, by replacing coal fired plants and by electrifying mining and oil and gas facilities.

Like the UKSMR design, the BWRX300 is taking a modular approach to the whole power station where GE has an advantage through having its own turbine designs. Because of the ancestry of the GE SMR and that many of the components in it have already been licensed, there is a clear argument that as a well understood type of design with the licensing date from the ESBWR, the licensing process for the GE SMR could be relatively quick. It will be interesting to see how this turns out in practice.

The BWRX-300 builds on the success and lessons learned from over 60 years of BWR operating history. The top-level features of the BWRX-300 include:

- Tenth generation Boiling Water Reactor;
- Evolved design from US NRC licensed ESBWR;
- Design-to-cost approach;
- Significant capital cost reduction per MW;
- World class safety;
- Capable of load following;
- Being ideal for electricity generation and industrial applications, including hydrogen production;
- Constructability integrated into design;
- Reduced on-site staff and security;
- Licensing initiated in the USA and Canada;

[21] https://www.ukri.org/news/uk-government-invests-215-million-into-small-nuclear-reactors. Accessed 14 July 2021.

[22] https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300. Accessed 14 July 2021.

[23] https://www.ge.com/news/press-releases/ge-hitachi-working-ontario-power-generation-smr-technology-options-ontario. Accessed 14 July 2021.

[24] https://smrroadmap.ca. Accessed 14 July 2021.

- Operational by 2028.

The BWRX-300 optimizes innovation with technology readiness. It relies on proven fuel, material and manufacturing techniques while incorporating breakthrough passive and simple design concepts. The result is a cost effective, advanced reactor design with world-class safety and economic performance that can be licensed and constructed in the near term. It offers low risk in comparison to historical large light-water reactor (LWR) projects in the USA and promises to be highly competitive in the worldwide energy market.

The key simplifications of the BWRX-300 are the use of RPV isolation valves that mitigate the impacts of loss of coolant accidents and large capacity isolation condensers that provide over pressure protection without the need for safety relieve valves. A cutaway drawing of the design is shown in Fig. 6.12 (reproduced here by kind permission of, and copyright GE Hitachi Nuclear Energy).

6.5.3 Or Shipyard Building?

Meanwhile, there is a school of thought that taking small modular designs one stage further and use modern shipyard manufacturing techniques could make a significant difference again in the speed and quality of manufacturing of SMRs. The experience of modular construction in, for example, the research ship, Sir David Attenborough and the new UK aircraft carriers have raised the profile of what can be achieved.[25] There are now increasing numbers of shipbuilding projects in defence, such as the Babcock Group's recent proposal for new warships for the Greek navy using a modular build approach based on the UK's successful Type 31 frigate.

In the nuclear powered shipping world, while nuclear powered submarines were the first, with the Mark 1 prototype reactor first starting up in Idaho in 1953, the USS Nautilus was launched in 1954 after the keel was laid in June 1952. More recent work in Russian icebreaker construction has not been anything like as rapid, with the Arktika beginning construction in November 2013 and ready for sea trials under nuclear power in June 2020, missing the original completion date of December 2017. The Ukraine crisis undoubtedly played a material part in the delay.

Another interesting development was the construction and operation of the nuclear power barge, Akademik Lomonosov. The keel was laid in April 2007 with a planned completion date of May 2010. However, after a second keel laying at a different shipyard, the vessel was launched at the end of June 2010, the reactors were installed in October 2013 and nuclear fuel loaded in April 2018, with operation starting in December 2019 supplying both electricity and heat to Pevek, a Russian town inside the Arctic Circle.

Much work has been done to see how modern shipbuilding in countries such as the Republic of Korea and Singapore could be used to build not just power barges

[25] https://www.clbh.co.uk/project-news/modular-construction-expertise-put-cammell-laird-premier-league-shipbuilding. Accessed 14 July 2021.

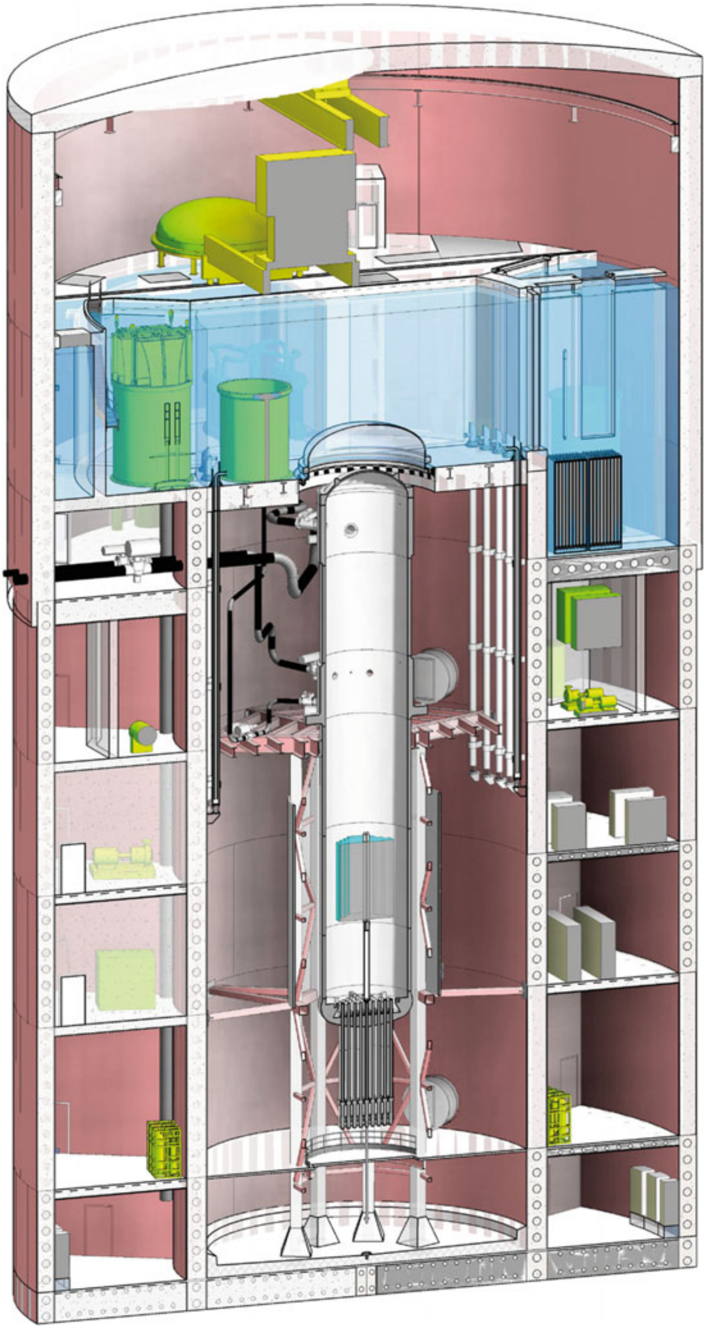

Fig. 6.12 GE BWRX-300 cutaway reactor and containment design. *Source* GE Hitachi Nuclear Energy Americas LLC

Fig. 6.13 LucidCatalyst's Hydrogen Gigafactory Concept. *Source* LucidCatalyst 2020

but nuclear powered ships and floating hydrogen factories. CorePower[26] is one such organization led by experienced shipping professionals which has built sufficient confidence in its approach that it is entirely privately funded from investors in the shipping and finance industries.

Similarly, the Gigafactory proposed by LucidCatalyst, shown in Fig. 6.13, in which there would be a dedicated manufacturing facility where the high temperature heat sources, and associated equipment, are fabricated and installed on-site. Hydrogen production facilities would also be manufactured, installed, commissioned, and operated on-site. The whole approach they take is building on modern shipyard practices.

LucidCatalyst states that "[t]he main advantage of shipyard manufacturing comes from high productivity, which leads to lower costs and faster projects. Shipyard productivity is among the highest in the world. Labor costs constitute only 10–15% of the final assembly and delivery cost. By contrast, labor constitutes up to 35% of the costs in best-in-class conventional construction. The most productive shipyards in the Republic of Korea and Japan have been able to sustain 10–15% per year improvements in productivity over multiple years."[27]

The Gigafactory proposed by LucidCatalyst would use multiple heat sources (600 MWt) connected to a heat exchanger unit that transfers the heat to a molten salt heat supply network for a thermochemical hydrogen plant. Manufacturing facilities would be built with rail and port access, allowing the manufacturing plant to ship high value components that are not necessarily used at the facility when the construction of the plant is complete.

[26] https://corepower.energy. Accessed 14 July 2021.

[27] LucidCatalyst 2020.

LucidCatalyst believe that Hydrogen Gigafactories can be sited on refinery-scale brownfield sites, such as large existing coastal oil and gas refineries, with large scale interconnection points to the gas grid. This avoids the need to interconnect multiple scattered hydrogen projects to the main gas grid. It may also be favourable to co-locate ammonia production facilities or other synthetic fuel conversion plants using hydrogen as a feedstock, which benefit from low cost electricity and hydrogen.

Other organizations such as Thorcon[28] and Seaborg[29] are currently examining the possibility of shipyard manufacture of power barges and hydrogen production.

The Core Power team are currently working on designs for nuclear powered ships which, if the designs prove workable, would revolutionize large shipping and remove one of the largest single sources of CO_2 emissions in 2050—estimated[30] by then to be around 17% of global emissions. The Cape Class ships being designed to be nuclear powered would have roughly 2.5 million miles of operation at full cruising speed between refuelling, with a cruising speed in excess of 30 knots that would transform not only the Trans-Pacific trade opportunities but also avoid the need to use the Suez Canal. Following the severe logistical problems caused by the Evergiven incident in the Suez Canal in 2021, the ability to avoid the need to use the canal could be transformative for Asia/Europe trade as well.

6.6 Nuclear as an Alternate Fuel Provider

Students of high school science are very familiar with the creation of hydrogen and oxygen from water by the application of electricity. Conventional electrolysis is not a particularly economical method of production of hydrogen and most hydrogen used in the chemistry industry is produced by Steam Reforming of Methane where the reaction ultimately produces four molecules of hydrogen and one molecule of CO_2 from one molecule of methane and two molecules of water (as steam). This process is currently extensively promoted for the creation of a near term hydrogen economy. Modern electrolysis uses more sophisticated techniques such as Polymer Electrolyte Membrane (PEM) cells which work at high current densities and can produce large volumes of hydrogen.

However, like most chemical reactions, at progressively higher temperatures, the efficiency increases and high temperature electrolysis using solid oxide cells can work at temperatures from 100 to 850 °C. The efficiency rises from around 41% at 100 °C to around 64% at 850 °C.

[28] https://thorconpower.com. Accessed 14 July 2021.

[29] https://www.neimagazine.com/news/newsamerican-bureau-of-shipping-assesses-seaborgs-compact-molten-salt-reactor-8421245. Accessed 14 July 2021.

[30] https://www.transportenvironment.org/discover/shipping-emissions-17-global-co2-making-it-elephant-climate-negotiations-room. Accessed 14 July 2021.

At high temperatures, it is also possible to convert CO_2 and steam to a hydrogen/carbon monoxide mix—syngas. That can further be reacted to create hydrocarbon fuels and other chemicals.[31]

6.6.1 *Hydrogen: Thermochemical Processes (AMRs/Gen IV)*

Two routes exist here: direct thermochemical catalytic processes and high temperature steam electrolysis. Both need temperatures above 500 °C and at higher temperatures nearer 1000 °C potentially more powerful techniques could come into play.

6.6.1.1 High Temperature Steam Electrolysis

These processes typically use solid oxide fuel cells (SOFCs) operating in reverse.[32] Ceres Power, a developer of SOFCs, is now examining the use of its cells to make hydrogen[33] which are likely to operate at higher temperatures nearer 1000 °C. Recent work at the USA's Idaho National Labs reports progress with a modern SOFC at the lower temperatures of around 600 °C.[34] Given the likely demand for hydrogen to replace natural gas in heating and as an alternative fuel for transport, high efficiencies of production are rapidly becoming important. Lucid Catalyst suggest that the economics of hydrogen production ultimately favour high temperature nuclear (see Fig. 6.14). One issue will be relative efficiencies of the thermochemical processes, which avoids the inefficiencies of creating electricity versus the complexities of the catalytic processes which use heat alone.

In their analysis, LucidCatalyst believe that light water reactors built with shipyard efficiencies should be the cheapest method of creating hydrogen in the long run. Either way, their work suggests it is a close run between that and hydrogen created by a high temperature gas reactor (HTGR), of which the Japanese HTGR is arguably the most mature design although the Chinese HTR-PM[35] was due to be loading fuel in early 2021.[36]

[31] Elder et al. 2015.

[32] SOFCs were originally designed to generate electricity from hydrogen and oxygen but can be reversed to produce the elements by high temperature electrolysis of steam; Keçebaşa et al. 2019.

[33] https://www.proactiveinvestors.co.uk/companies/news/941528/ceres-power-revenues-ahead-of-target-as-fuel-cell-production-scales-up-941528.html. Accessed 14 July 2021.

[34] https://inl.gov/article/new-technology-improves-hydrogen-manufacturing. Accessed 14 July 2021.

[35] The CNNC HTR-PM is a pebble-bed type reactor which has been under development since about 2012 and uses spherical, accident-tolerant fuels. Its initial use is for electricity production.

[36] https://www.neimagazine.com/news/newsfirst-fuel-shipped-to-chinas-htr-pm-project-8453226. Accessed 14 July 2021.

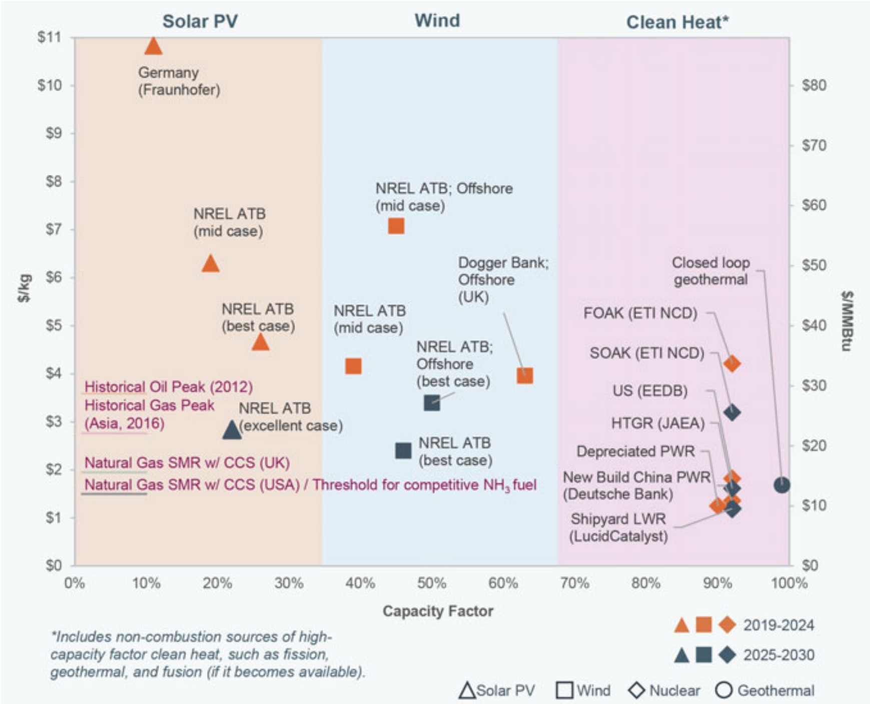

Fig. 6.14 Cost of hydrogen production from different energy technologies in the real world now and in 2030. *Source* LucidCatalyst 2020

6.6.1.2 Thermochemical Catalysis

With the availability of high temperature heat from advanced reactor designs, there are two (amongst many) thermochemical catalytic processes which become potentially very interesting. These are the copper-chlorine (Cu-Cl) cycle and the sulphur-iodine (S-I) cycle. Both these cycles are described in a comprehensive review by Funk.[37] Both of these operate at around 45–50% overall efficiency so may compete well with conventional electrolysis using the SOFCs. The Cu-Cl cycle could be well suited to the range of temperatures produced by the high temperature reactor designed by Urenco, the uBattery[38], which is designed to produce heat up to 710 °C. The S-I cycle would fit better with high temperature designs such as the JAEA HTGR because of need for higher temperatures for one particular step in the cycle. The Japanese HTGR[39], which first went critical in 1998 and has many years of development behind it, recently restarted operations following the blanket shutdown of all nuclear facilities in Japan following the Fukushima tragedy.

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[37] Funk 2001.

[38] https://www.u-battery.com. Accessed 14 July 2021.

[39] Nishihara et al. 2018 (Description of the Japanese HTGR).

The chemistry of the two catalytic cycles is shown below. First, the copper-chlorine cycle:

$$
\begin{array}{ll}
2CuCl_2(s) + H_2O(g) \rightarrow CuO * CuCl_2(s) + 2HCl(g) & T = 400\,^\circ C \\
CuO * CuCl_2(s) \rightarrow 2CuCl(l) + 0.5O_2 & T = 500\,^\circ C \\
4CuCl(s) + H_2O \rightarrow 2CuCl_2(aq) + 2Cu(s) & T = 25 - 80\,^\circ C \\
CuCl_2(aq) \rightarrow CuCl_2(g) & T = 100\,^\circ C \\
2Cu(s) + 2HCl(g) \rightarrow 2CuCl(l) + H_2(g) & T = 430 - 475\,^\circ C
\end{array}
$$

Secondly the sulphur(sic)-iodine cycle:

$$
\begin{array}{ll}
H_2SO_4 \rightarrow SO_2 + H_2O + 1/2O_2 & T = 850\,^\circ C \\
I_2 + SO_2 + 2H_2O \rightarrow H_2SO_4 + 2HI & T = 120\,^\circ C \\
2HI \rightarrow I_2 + H_2 & T = 450\,^\circ C
\end{array}
$$

Overall:

$$H_2O \rightarrow H_2 + 1/2O_2$$

6.7 Nuclear as a Battery

6.7.1 Natrium

Nuclear power has been traditionally lauded for its 24/7 baseload operations with high capacity factors. However, in an era when the inherent intermittency of other low-carbon electricity sources creates significant problems of despatching and load following, that always-on, firm power aspect of nuclear is sometimes criticized by proponents of renewable (as opposed to the real outcome needed, low-carbon) power. One recent design could change that perception and, at the same time, produce economically priced electricity, especially when financed at appropriately low cost of capital. The Natrium design, from TerraPower, which is the nuclear technology company founded by Bill Gates (a strong proponent of nuclear power to address Net Zero and climate change), takes a different approach to the problems of despatching and load following. The design couples a sodium cooled fast reactor (see also Sect. 6.9.2) with a sizeable storage capacity using molten salts. It is the molten salt store which provides heat for steam production for the turbines. When demand is low, the reactor's heat is stored in the molten salt; when demand is high, the heat in the molten salt is used while the reactor continues to provide heat. The designers refer to the approach as a reactor and integrated energy storage device. At the time of writing, four Wyoming communities are in the running to play host to a new nuclear reactor coming to the state. The next generation plant will replace an existing coal fired plant. It is clear from the project's backers that the design has attracted serious interest. Backers include PacifiCorp (a subsidiary of Berkshire Hathaway, for whom the plant will be built), Bechtel Corporation, GE Hitachi Nuclear Energy Americas, Energy Northwest, Duke Energy Carolinas (another experienced nuclear operating utility) and several US National Laboratories (Argonne, Idaho, Los Alamos, Oak Ridge and Pacific Northwest). Aspects of the design are shown in the single site layout graphic in Fig. 6.15 (reproduced here by kind permission of TerraPower LLC).

The ability to ramp up and down the electrical output is shown diagrammatically in Fig. 6.16.

It is clear that the Natrium approach offers a potentially powerful solution, at a scale which does not test a nation state's risk tolerance, to a world where nuclear and intermittent renewables will need to coexist efficiently. Solving the intermittency problems with endless batteries is beyond sledgehammer and nut analogies. Any rational system design, with access to technologies such as Natrium, is highly unlikely to prefer a battery solution unless utterly unavoidable. Clearly, with hydrogen production will come the desire for vast capacities of storage unless the hydrogen can, within a day or two, be created entirely to demand. The transitional technology of steam reformed methane will clearly help but with a primary energy system that is inherently controllable and predictable by combining technologies such as Natrium with

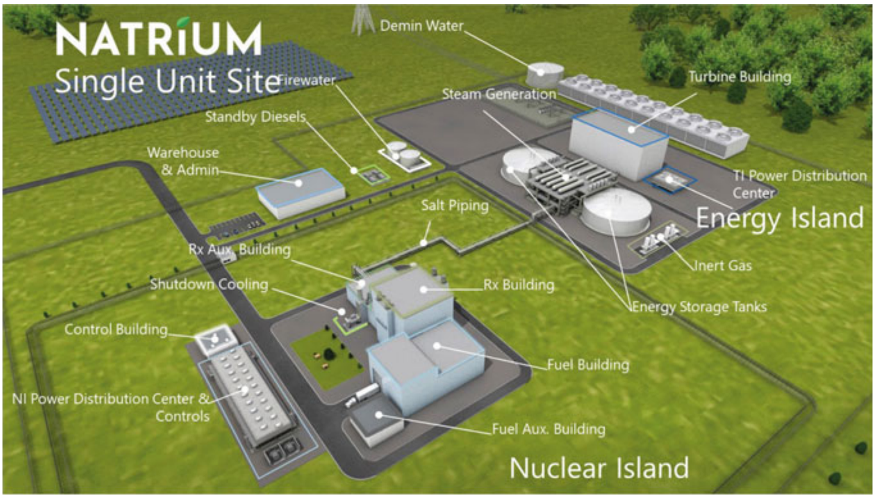

Fig. 6.15 Natrium single unit site layout. *Source* TerraPower LLC

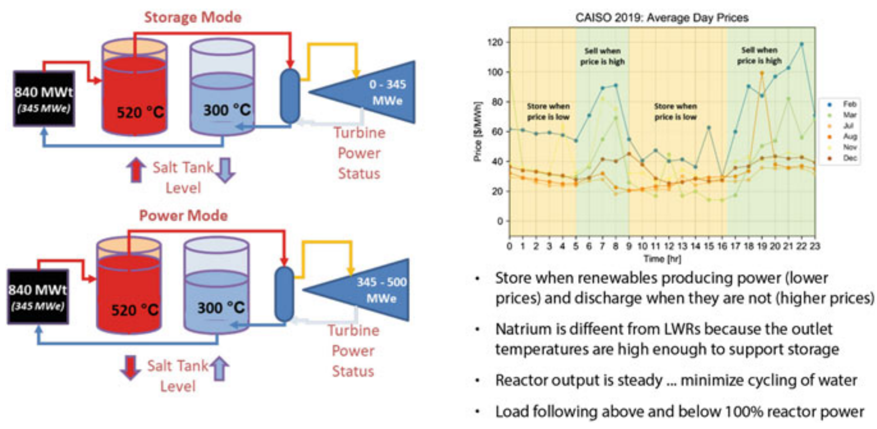

Fig. 6.16 Natrium flexible power output diagram. Storage moves nuclear out of a solely baseload role, allowing greater utilization of renewables. *Source* TerraPower

renewables could well turn out to be the lowest cost solution. The developments in Wyoming deserve very careful observation both because of the ingenious technology but also the strong backing of Bill Gates and a hand-picked, professional team.

6.8 Nuclear as an Industrial Decarboniser

6.8.1 SMRs and Process Heat

In the race to decarbonize industry, private businesses in Poland are starting to set an example. There, three billionaires are working together to build nuclear reactors to provide process heat and power for their industrial processes. Sebastian Kulczyk's company, Ciech, signed a letter of intent with Michał Sołowow's company, Synthos. Recently, Zygmunt Solorz-Żak has also joined forces with Sołowow. Ciech and Synthos are cooperating in the development of small and micro-modular reactors. The cooperation of Ciech, a representative of energy intensive business of great importance for the Polish economy, with Synthos Green Energy may result both in accelerating the process of decarbonizing the domestic industry, but also in strengthening its position on the global market. Synthos has become a strategic and exclusive partner of GE-Hitachi Nuclear Energy Americas LLC in the implementation of SMR technology in the form of the BWRX-300 reactor. There will be many more in practice and there are a large number of discussions underway at the time of writing.

6.8.2 AMRs and Off-Grid Use (Mining, Other Remote Industrial Use)

The best examples here come from Canada where remote energy needs are a major challenge. There are many comminates where the energy is provided by diesel generation and in the worst cases, the diesel is flown in. There has been an impressive policy drive by Federal and Provincial governments to build trust and confidence in the nuclear prospects in Canada which not only includes exploiting the country's national laboratory in an impressive and creative way but also the drive by Ontario Power Group who are currently down-selecting from three SMR opportunities—GE's BWRX300, Terrestrial's IMSR and the X-Energy reactor.

But for off-grid use, reactors such as uBattery are ideally placed either for community use or industrial/mining power. The Canadian Government has produced a number of clear policy documents, against which they continue to deliver. The Canadian Nuclear Association's 2018 Roadmap[40] is a clear reference point and strongly supported by the government. Following that, the Federal Government launched an action plan in December 2020[41] and the momentum continues.

6.8.3 AMRs and Marine Decarbonization

As noted elsewhere (see Sects. 6.2 and 6.11), there is interest in ammonia as a fuel for shipping. However, this would come with major infrastructure requirements at all ports and dealing with a much nastier and riskier substance than conventional marine fuel. A group of Scandinavian shipping experts have created an organization by the name of Core Power[42] with operations in London and Singapore and they are working on designs for nuclear powered ships working together with TerraPower and others. One of the fundamental differences between conventionally powered large container ships and nuclear powered ones is that fuel consumption is largely irrelevant (by comparison) and nuclear powered ships could be fuelled for 15–20 years. It is also possible, given the large amount of power available from nuclear sources, that large container ships can be designed to cruise at 30+ knots. Should that turn out to be practical, it will transform bulk shipping—the trans-Pacific trade will be very different and far more practical, and the Suez Canal will be less necessary as at 30 knots, travelling round Southern Africa will be entirely within clients' timescales.

This is one of the intriguing developments happening largely under the radar.

[40] https://smrroadmap.ca. Accessed 14 July 2021.

[41] https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-uranium/canadas-small-nuclear-reactor-action-plan/21183. Accessed 14 July 2021.

[42] https://corepower.energy. Accessed 14 July 2021.

6.9 Burning Our Legacy: New Reactor Design to Use up Waste

6.9.1 Closed Fuel Cycle

The nuclear power industry has forever had an Achilles heel in the minds of the public rising from the issue of nuclear waste. Waste is almost always the first or second question or objection raised when nuclear power is discussed publicly. A huge amount of work has been done on deep geological disposal in Finland (Onkalo—started construction in May 2021), the USA (Yucca Mountain and the operational site at WIPP in New Mexico) and in the UK where the work of the Radioactive Waste Management organization inherited decades of work by NIREX. In the UK, communities are now vying for the opportunity to have the deep geological disposal facility with Allerdale and Copeland (both near Sellafield) already in discussions. There are suggestions that other communities may come forward in due course.

The topic is sufficiently sensitive that in the UK's 2008 White Paper, the policies were based on the assumption of a once-through fuel cycle (i.e. no more reprocessing) and a requirement that before permitting any nuclear build project, the Secretary of State had to be satisfied that "the Government will need to be satisfied that effective arrangements exist or will exist to manage and dispose of the waste they will produce".

Deep geological disposal is not, however, the only option. In China and the Russian Federation there is continuing interest in a 'closed fuel cycle'. When uranium is burnt in conventional reactors, only a small amount of the uranium is consumed (the ^{235}U). The vast bulk of the uranium (typically 97%) remains unburned. However, any element with a higher atomic number than 56 (iron) can, in theory, be split in a fission reaction to release energy. Broadly speaking, the higher the atomic number, the greater the amount of energy that can be released from the fission of each atom. The physics behind this can be found in many textbooks, the key concept being the 'binding energy per nucleon' (see Fig. 6.17)—that is, how much energy binds each proton and neutron together in the nucleus of the atom.

In principle, every atom of uranium could be split to release energy with the right sort of technology. Conventional nuclear reactors are designed to enable a fission chain reaction using slow neutrons—the function of the moderator in each reactor is to slow down the neutrons emitted in the nuclear chain reaction so that they, crudely, have more time to react with another uranium atom as the neutron travels around the reactor core. These slow neutrons are often referred to as 'thermal neutrons' as their speed is about the same as would be expected from molecules at normal operating temperatures whereas when the neutron is emitted from the fission process, its initial speed is much nearer to the speed of light. This can be observed in practice in the fuel ponds of nuclear reactors where spent fuel is stored and glows with a blue light. This is known as Cherenkov radiation and is produced when beta-particles (electrons) are

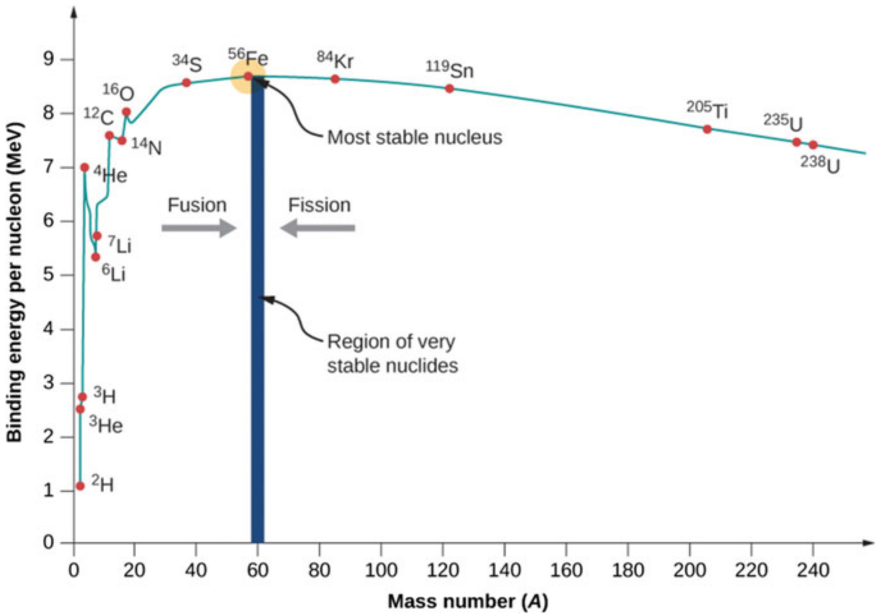

Fig. 6.17 Binding energy per nucleon. *Source* Ling et al. 2016

slowed down from the (almost) speed of light in the uranium fuel to the (lower) speed of light in the water.[43]

6.9.2 Fast Neutron Reactor

A different type of reactor can be designed which will use the fast neutrons directly without the need to slow them down. These are referred to as fast reactors and have been known since the earliest days of nuclear power—the reactors EBR-1 and its successor EBR-2, which first operated in December 1951 and July 1964, respectively. Crudely, fast reactors can be thought of as the neutrons hitting uranium atoms extremely hard and forcing the neutrons to split apart where to do so would release energy. On this basis, if uranium fuel were to be run for a long time (60 years is often cited as the sort of timescale necessary) the only elements that would be left would be much smaller (i.e. lower atomic numbers) and, again in general, radioactive mid-periodic table elements have much shorter half-lives than the high atomic number elements which are produced on the decay of uranium atoms in light water and other thermal neutron type reactors.

[43] https://www.radioactivity.eu.com/site/pages/Cherenkov_Effect.htm. Accessed 14 July 2021.

Hence the idea of a closed fuel cycle[44] is to start with uranium ores, enrich (or not), process in a sequence of reactors—slow and fast—and cause fission to happen for as long as possible. Then take the resultant waste with a relatively short half-life, store it as safely as possibly for a few hundred years and then take the remaining waste with, by then, a low level of radioactivity and return it to the mines from which the uranium was originally mined. China, India and the Russian Federation[45] have investigated these processes, as has France and the UK. In the 1970s, there was a clear view within the CEGB that a closed fuel cycle could work well in the UK given the experience in reprocessing (a necessary part of the fuel recycling process) and the work on the sodium cooled fast reactors at Dounreay that was part of the early work in that direction. Two fast power reactors have been built at Dounreay. First the Dounreay Fast Reactor (DFR) with an electric power of 15 MW, which began operation in 1960 and in 1962 became the first fast reactor power plant to supply electricity to a national grid. The DFR was closed in 1977. In 1975 the second fast reactor, the Prototype Fast Reactor (PFR) was connected to the grid. It had an electric power of 250 MW. It was closed in 1994. Like so much of the forward thinking from the CEGB, once State support for future energy development became unfashionable and entirely devolved to 'markets', the UK has lost leadership in many aspects of nuclear technology to other countries.

Work on a closed fuel cycle continues in a number of countries and 'spent' nuclear fuel is often referred to be some in the nuclear industry as 'once-used' fuel.

6.10 Nuclear as Low Cost Primary Energy

6.10.1 Powerful Impact of Cost of Capital

Nuclear power has a material advantage in that the operational lives of reactors built in the 21st century are now often 60 years as the initial design life but the designs themselves are such that 20 or maybe even 40 year life extensions are very likely. This, when taken with a sensible, low cost of capital, enables nuclear power to be competitive with renewables, even before the system costs of intermittency are considered. The current forecast by EdF Energy for the electricity price for the Sizewell C project, as shown in the work by David Newbery at the University of Cambridge,[46] along with nuclear costs more widely, demonstrate this clearly as shown in Fig. 6.18 (reproduced here by kind permission of the original author). Newbery concludes that "Nuclear power, whose costs are not predicted to fall over the next 30 years, is still cheaper than renewables (when including intermittency costs) over a wide range of WACCs when using the NIC (2020b) data, and even with Sizewell C cost assumptions, would

[44] IAEA 2011.

[45] https://www.world-nuclear-news.org/Articles/Russia-proposes-new-closed-fuel-cycle. Accessed 14 July 2021.

[46] Newbery 2020.

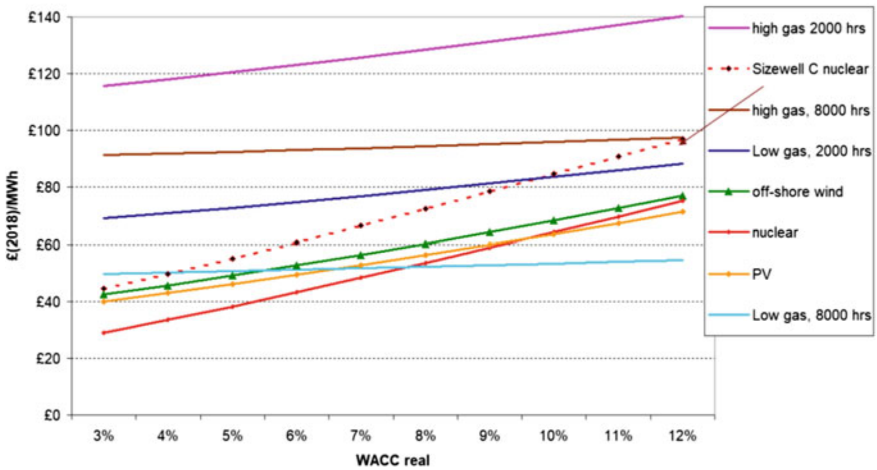

Fig. 6.18 Electricity cost sensitivity to WACC. Average costs per running hour in £/MWh. *Note* Low and high gas costs include low and high CO_2 price projections from FES 2020. *Source* Newbery 2020

be cheaper at WACCs below 4%." There are many in the nuclear industry who would, at the time of writing, take a different view to Newbery on the future costs of nuclear and in the report being finalized at the time of writing from the UK's Nuclear Industry Council—Nuclear 2050[47]—the industry has set out that it can and will reduce costs by at least 30% with continuing new build and next of a kind (NOAK) learning. This NOAK learning has been seen in the fleet roll-out of wind and solar and is reputedly true in the Chinese fleet deployment of nuclear power.

As yet, there is too little recognition of the impact of the WACC on the electricity price of different forms of primary energy production. For a GW-scale project in the UK, the approximate sensitivities are about £8/MWh change for every £1 billion change in the capital cost of the plant. However, the figure is around £13/MWh change for each one percentage *point* change in the cost of capital. Reducing the cost of capital for a project financed plant from 9% WACC to 8% WACC reduces the electricity price by around £13 for every MWh generated. The figure for wind, according to Carbon Brief[48] is around £2.50/MWh for each percentage point change in WACC. It is important when considering economic models to be clear-eyed about the variations in sensitivity to WACC when (as many models do) making standard assumptions about WACC in a model.

It is worth considering the moral consequences of differences in cost of capital. First, the definition of WACC is simply the blended financing cost of a project or business considering all the sources of capital it employs and making adjustment for

[47] Report in progress at time of writing and to be made available at: https://www.niauk.org (forthcoming).

[48] https://www.carbonbrief.org/wind-and-solar-are-30-50-cheaper-than-thought-admits-uk-government. Accessed 14 July 2021.

the different tax consequences of each form of finance—particularly that debt interest is tax deductible. For more details, see the Corporate Finance Institute's resources.[49] In its simple form, the formula for WACC is

$$WACC = \left(\frac{E}{V}\right)R_e + \left(\frac{D}{V}\right)R_d(1 - T)$$

Where:

E = market value of the firm's equity (market cap)[50]

D = market value of the firm's debt

V = total value of capital (equity plus debt)

E/V = percentage of capital that is equity

D/V = percentage of capital that is debt

R_e = cost of equity (required rate of return)[51]

R_d = cost of debt (yield to maturity on existing debt)

T = tax rate

6.10.2 Financing Should Not Be Harder Than Physics

It is well understood that in any country, the lowest cost of capital comes from simple borrowing by the government. This is in part because there is no real recognition of 'equity' in government financing—for conventional government financed projects there is no equity to perish in the event of major cost overruns, only the government debt appears to suffer. In practice, there is no penalty to the project and any losses are made up in practice either by cuts elsewhere in government expenditure or by budget increases (tax rises).

6.10.2.1 Project Finance—Limitations

In the approach used to finance conventional projects, a mixture of equity and debt is used. The cost of the debt and equity depends on the perceived risk of the projects but

[49] See as an example https://corporatefinanceinstitute.com/resources/knowledge/finance/what-is-wacc-formula. Accessed 14 July 2021.

[50] https://corporatefinanceinstitute.com/resources/knowledge/finance/what-is-market-capitalization. Accessed 14 July 2021.

[51] https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/required-rate-of-return. Accessed 14 July 2021.

the cost of both is significantly higher than government borrowing. Until the second decade of the 21st century it was normal to see projects financed with WACCs in the high single digit percentages (not much under 10%) up into double digits—some of the early renewable projects were privately said to attract equity returns over 30% and WACCs nearer to 20%.[52]

In the many, many PFI/PPP projects around the world, private capital was employed and in the good PFI/PPP deals there was a trade-off for the use of the more expensive private capital when compared to cheaper government debt. The trade-off was apparent when considering the whole life cost of a project. For certain types of project, roads, hospitals, certain types of defence contract, the propensity for optimism bias and bad project management within the public sector was believed to lead to higher than necessary whole life costs. In the PFI/PPP deals, the whole life cost was reduced with a trade-off between a higher cost of capital against the ability of the private sector to design, manage and operate the projects more efficiently, resulting in lower whole-life costs. This trade-off flows from the construct where the private owner and operator takes on many of the risks of the project which it then manages better than the public sector could or would; the traditional mantra being that *risks are allocated to the party best able to manage and control each risk*. In some cases, there is no doubt this approach has worked well but in reality, much depends on the quality of the design of the commercial arrangements and, as ever, the inherent wisdom of both those creating the deals and those operating them.

However, in larger nuclear projects, where the capital cost is in the £13 billion–>£20 billion range this sort of trade-off is not possible at least for the early projects in a fleet delivery. At this scale of project, the scale of potential risk is so large that no rational company would take it on. This has been proved, very painfully, by Hitachi's purchase of the Horizon nuclear power project from E.ON and RWE in 2012 for which they reportedly paid close to £800 million. In 2019, after extended struggles to raise the finance for the project failed, despite both the British and Japanese governments being intimately involved, Hitachi wrote off US $2.75 billion from the equity in the project. In normal circumstances, the management and often the board of a firm reporting such a large write-off would be ignominiously sacked. However, on the leak of the announcement in the Japanese press, Hitachi's share price rose.[53] In a private communication to the author, there was a suggestion that the actual share price recovery on the back of the announcement that Hitachi were stopping further work on the project actually created more value in the Hitachi enterprise than the value of the write-off, such was the deep concern by investors in the future of the project.

The reality is that for nationally significant projects such as high-speed rail, major underground tunnelling projects and large scale energy projects (whether the creation of primary energy or a large scale rebuilding of transmission or distribution systems),

[52] Private communication to the author from the manager of a major investor in early renewable projects.

[53] https://www.reuters.com/article/us-hitachi-nuclear/hitachi-shares-rise-after-report-it-is-considering-scrapping-britain-nuclear-project-idUKKBN1O90KI. Accessed 14 July 2021.

there is no escaping the fact that 'governments own failure'. The early, first of a kind (FOAK) GW-scale nuclear projects (and perhaps even SMR projects) are ultimately sovereign risks. This is simply demonstrated by the fact that no private company will ever again take on a FOAK nuclear project in the UK on a traditional project finance basis. The L in PLC contains some of the logic—PLC stands for Public Limited Company and the risks the company can absorb are limited by its equity capital.

So, with the absence of a trade-off for higher costs of capital in conventional project finance, coupled with the great sensitivity of the electricity price to the cost of capital seen in Fig. 6.18, it is immediately obvious that nuclear power, probably irrespective of the scale of the project, ought to be financed by the lowest cost of capital possible. Not to do so simply creates an artificial tax on the cost of energy to a national economy where the proceeds of that 'tax'—needlessly high interest rates or equity returns—flows not to a national exchequer but to investors who may well not be domiciled in the country of the project.

6.10.2.2 Regulated Asset Base Financing

The focus in the UK in 2021 is now around the use of regulated asset base (RAB) finance in financing new nuclear—and potentially other energy—projects. Following earlier consultations[54] in the UK's Energy White Paper[55] published in December 2020, there is now a recognition that the form of finance used since early privatizations in the UK could be applied to large new energy projects. To see the difference, the UK Regulators' Network publication in September 2019[56] is instructive. There, the progress of the WACC used in regulated energy, telecoms and water is shown. After the appeals to the Competition and Markets Authority in 2020, the final WACC determinations for the water companies are around 2.3% real on a conventional RPI basis or 3.3% real on a CPI basis. If nuclear were to achieve something in the 4–4.5% region, the impact on nuclear electricity prices would be extremely significant, as Newbery has shown.

Given that the need to achieve Net Zero means the replacement of virtually all the primary energy production in most countries, the consequences of the way the new energy projects are financed will ultimately drive the energy competitiveness of the nation and through that, national economic competitiveness itself. Decisions taken in the earliest decades of the 21st century on the future energy systems and their financing will define national economic competitiveness in the 2050s and beyond. There will be material winners and losers here at a national level and it appears at the time of writing that few countries have yet fully understood the long term legacy nature of their energy policies, let alone the physical challenges referred to in Sect. 6.11.6.

[54] Department for Business, Energy and Industrial Strategy 2020a.

[55] Secretary of State for Business, Energy and Industrial Strategy 2020.

[56] UKRN 2019.

6.11 Energy Markets

6.11.1 Markets in a Low-Carbon Era

Much of the logic and structure of electricity markets globally flows from the era of the privatization of largely complete electricity systems and the break-up of the monopolistic State structures that created them. Later we will look at some physical aspects of this but to start out with a background thought, consider this: in electricity markets, almost all the sources of low-carbon electricity are from sources with zero or virtually zero marginal costs. Wind, solar, nuclear and hydropower all have that one common attribute. Should there ever be a world in which hydrogen were to be the fuel for gas turbines then that condition could be broken.

But a market where marginal costs are near enough zero is clearly weird. Imagine that in any other real world market in operation.

For now, it is important to stand back and consider if any of the current—highly sophisticated—market models and mechanisms are fit for a low-carbon electricity world where the entire system is being rebuilt. Certainly, with a large enough hammer, existing markets can be forced to deal with such a world,

But now is the time for wise people to think about electricity markets in a low-carbon world from the very beginning. With this pace and scale of change, and the physical constraints which are obvious and referred to in Sect. 6.11.6, a re-examination of what a market is for, what society wants a market to deliver and how best to deliver that needs a complete review. Continuing with current market models, endlessly bending them into new and exotic shapes neatly fits the phrase “just because you can, doesn’t mean you should”.

6.11.2 When Do Markets Work Well?

There are two contexts within which to consider whether markets may, or may not, be applicable. First, the applicability of markets to the construction of nationally significant infrastructure or large scale infrastructure systems. This has been a well recognized issue in the context of PFI and PPP. Table 6.5 sets out conditions for an effective market and whether each condition applies to the construction of nationally significant infrastructure or large scale infrastructure systems. It is clear from this analysis that simple markets do not and cannot work well for such projects and enterprises.

But the other context in which markets are the standard mode of operation is for energy pricing and here the story is a little more mixed. Much of the creativity around energy markets arose post-privatization in the UK when economic theory became the servant of tough efficiency drives. A valuable resource to examine electricity markets globally is Harris’s book, ‘Electricity Markets—Pricing, Structures

Table 6.5 Market attributes—do they apply to infrastructure construction?

Condition	Infra?
A large number of buyers and sellers ⟹ A large number of consumers with the willingness and ability to buy the product at a certain price, and a large number of producers with the willingness and ability to supply the product at a certain price	×
Perfect information ⟹ All consumers and producers know all prices of products and utilities each person would get from owning each product	×
Homogeneous product ⟹ The products are perfect substitutes for each other (i.e. the qualities and characteristics of a market good or service do not vary between different suppliers)	×
Well defined property rights ⟹ These determine what may be sold, as well as what rights are conferred on the buyer	✓
No barriers to entry or exit	×
Every participant is a price taker ⟹ No participant with market power to set prices	×
Perfect factor mobility ⟹ In the long run factors of production are perfectly mobile, allowing free long term adjustments to changing market conditions	? ?
Profit maximization of sellers ⟹ Firms sell where the most profit is generated, where marginal costs meet marginal revenue	✓ ? ?
Rational buyers ⟹ Buyers make all trades that increase their economic utility and make no trades that do not increase their utility	×
No externalities ⟹ Costs or benefits of an activity do not affect third parties. These criteria also exclude any government intervention	× ×
Zero transaction costs ⟹ Buyers and sellers do not incur costs in making an exchange of goods in a perfectly competitive market	× × ×
Non-increasing returns to scale and no network effects ⟹ The lack of economies of scale or network effects ensures that there will always be enough firms in the industry	×

and Economics'.[57] Chapter 4 of the book covers the history of the liberalization of electricity markets. Rather than repeat the history here, suffice it to say that the story is long, complex and of almost filigree construction. The origins of much of the UK's adoption of a market approach to energy goes back to the then Energy Minister, Nigel Lawson. Lawson stated at a BIEE conference in 1982: "I do not see the government's task as being to try and plan the future shape of energy production and consumption. It is not even primarily to try to balance UK demand and supply for energy. Our task is rather to set a framework which will ensure that the market operates in the energy sector with a minimum of distortion and energy is produced and consumed efficiently."[58]

What is clear, is that there have been some significant problems in the almost experimental way liberalization was implemented, resulting in some unhelpful enduring

[57] Harris 2006.

[58] This was subsequently quoted in UK parliamentary report on The Price of Power: Reforming the Electricity: Market Contents: https://publications.parliament.uk/pa/ld201617/ldselect/ldeconaf/113/11305.htm. Accessed 14 July 2021.

problems in the 21st century and the energy system which now operates in different parts of the world. Some examples of those problems include:

- A regulatory system in the UK focused on reducing the cost to consumers over a five year period, while the entire system is being designed with multi-generational consequences.
- That regulatory system penalizing resilience and driving down capacity margins to the point where system balancing has become a major trading opportunity.
- Major market price excursions in the independent grid[59] in Texas in February 2021 resulting from problems caused by extreme weather. Real-time wholesale market prices on the power grid operated by the Electric Reliability Council of Texas (ERCOT) were more than $9000/MWh late Monday morning, compared with pre-storm prices of less than $50/MWh, according to ERCOT data.[60]
- The electricity market in Australia: Problems have been compounded by many individual issues but a good example of system design flaws has been the successful introduction of large volumes of rooftop solar to a system where the distribution charges are simply based on kWh usage as opposed to buying the ultimate capacity needed by a user; as the usage falls, the very long wires in Australia become uneconomic without significant change in the pricing mechanism; Simshauser[61] states that "missing policies relating to climate change, natural gas and plant exit has recently produced results that have tested political tolerances."
- Negative pricing in both the UK and Australian markets are increasingly a consequence of the growth of intermittent generation and examples can be seen in Fig. 6.19. In early December 2019, Storm Atiyah hit the UK with wind speeds post-landfall of around 70 mph. The resulting electricity prices went to £-88/MWh, which was described by a renewables commentator as a "great early Christmas present" (see Fig. 6.20).

These examples of distortionary elements of what are increasingly looking like inherently unstable energy systems flow from the UK's electricity reforms of the early part of the second decade of this century. These reforms introduced Contracts for Difference (CfDs) to protect renewable generators from wholesale market price volatility by providing a guaranteed price relative to the day-ahead market price. This was part of the incentives for the renewable sector to continue to build apace and to socialize the inherent and inevitably rising costs of intermittency such that the wider market pays for those costs. Payments under the CfD regime are only available if the generator has sold its output into the day-ahead market, which of course then becomes rational and standard behaviour. If in practice on the day, the generator produces more than it had contracted for—a windfarm might generate more than expected if the weather is windier than forecast—the generator would then be

[59] Texas, Hawaii, and Alaska have independent grids.

[60] https://www.reuters.com/article/us-electricity-texas-prices-idUSKBN2AF19A. Accessed 14 July 2021.

[61] Simshauser 2019.

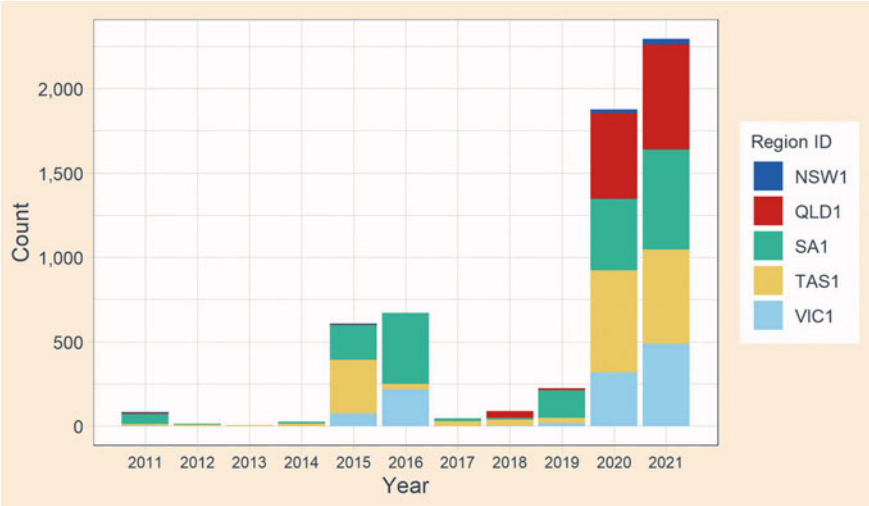

Fig. 6.19 Zero or negative five-minute dispatch prices for May, Australian NEM 2011–2021. *Source* @GrantChalmers

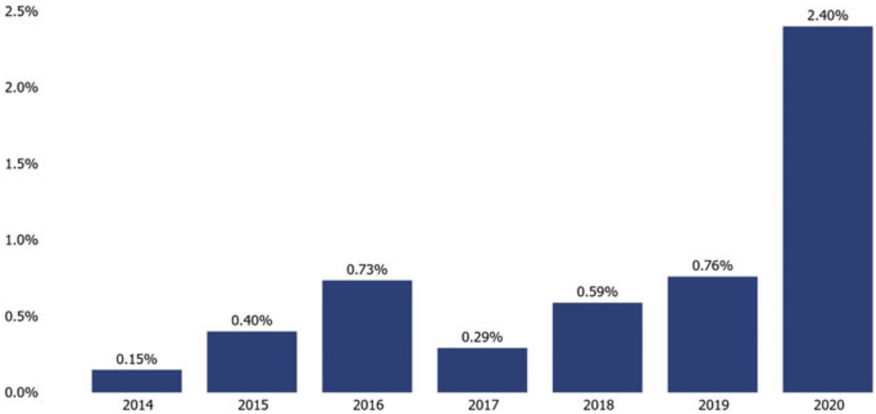

Fig. 6.20 Percentage of settlement periods with a negative system price in the UK since 2014. *Note* Low and high gas costs include low and high CO_2 price projections from FES 2020 2020 is not a full year—includes 1 January 2010 to 31 May 2020. *Source* Elexon, see https://www.elexon.co.uk/article/elexon-insight-negative-system-prices-during-covid-19 (Accessed 14 July 2021) Elexon is to be recognized as the source of this material

subject to imbalanced costs. From the cost of balancing, there is no disincentive to over-produce since if the system operator requires the generator to reduce output, it will receive a curtailment payment—the generator is actually rewarded by adding unexpected problems onto the electricity market. This creates a material market distortion and the increase in zero-marginal cost sources of production will depress wholesale power prices, lowering returns for non-renewable generators and zero-marginal cost generation that has been built either without a subsidy, or with one of the other subsidy schemes.

As the inexorable rise of system balancing problems and opportunities continue, one engineering group with a systems level view of the problem has described "demand side response is the other side of supply side failure".[62]

6.11.3 What Is the Purpose of a Market?

Historically, markets have been powerful mechanisms in support of a Darwinian approach to evolutionary changes in energy production. They have worked well to provide signals to potential investors about which technologies turn out to be more efficient (read, produce greater or more stable financial returns). That has allowed evolution in gas turbine generation, for example, where the cost of a generating unit and the relative predictability of energy prices was within the risk appetite of normal commercial organizations.

Fundamentally, the market mechanisms have responded well to relatively slow and small pace and scale of change at any time from a technological perspective. However, disruptions in the regulatory systems such as the introduction of New Electricity Trading Arrangements (NETA) in the UK have caused some dramatic financial failures such as:

- The bankruptcy of British Energy.
- Driving out "excess" capacity to the point of seriously damaging resilience.
- The announcement, in October 2002, from PowerGen, the German-owned group once seen in the city as a paragon, indicating a shutdown of a quarter of its generating capacity and bluntly telling ministers that the sector as a whole was "bust".
- TXU Europe, with more than 5 million customers in the UK, heading for insolvency, cut adrift by its struggling American parent which refused to invest £450 million to help it meet long term contracts with other producers and has put it up for sale. TXU said it had decided to take "dramatic action" to protect its US financial position and credit rating. Its shares had dropped sharply on Wall Street in early October 2002. They then fell another 39% in early trading to $11.50. "There were only two options: to protect TXU Europe or TXU Corporation," a spokesperson said. "That's not a difficult choice." An inevitable market reaction—the question of whether it was right for UK citizens in the long run—is a different matter.

This whole section (Sect. 6.11) on energy markets makes clear the scale of the challenge in redesigning energy markets as a whole given the pace and scale of

[62] Private communication triggered by articles predicting that IoT creativity 'behind the meter' could solve many of the problems of intermittency in a renewables-heavy electricity grid.

change necessary to replace virtually all the sources of primary energy in most countries over merely 30 years. The complexities of the electricity market in the UK post-privatization cannot be repeated as market solutions will not deliver the necessary primary energy production in time. There is too little trust and confidence, at the time of writing, for that even to be a pipe dream.

6.11.4 Markets as Darwinian Evolution

Before completing this section, it is worth considering markets as a Darwinian process.[63] For markets to be successful, the process is essentially a 'generate and test' approach to finding progressively better solutions to a problem. Biologically, this happens naturally through genetic mutations which can potentially occur with each cell division and each reproductive cycle. Industrially too, small product tweaks can happen on the production line.

Another way of considering evolution, is one approach to finding a minimum in a multi-dimensional surface such as the simple one in Fig. 6.21.

The real world solution to a systems design will have to cope with a multi-dimensional surface of far greater complexity with many local minima, and even if a global minimum exists, the process to move around the surface in search of the truly optimal minimum will take many iterations.

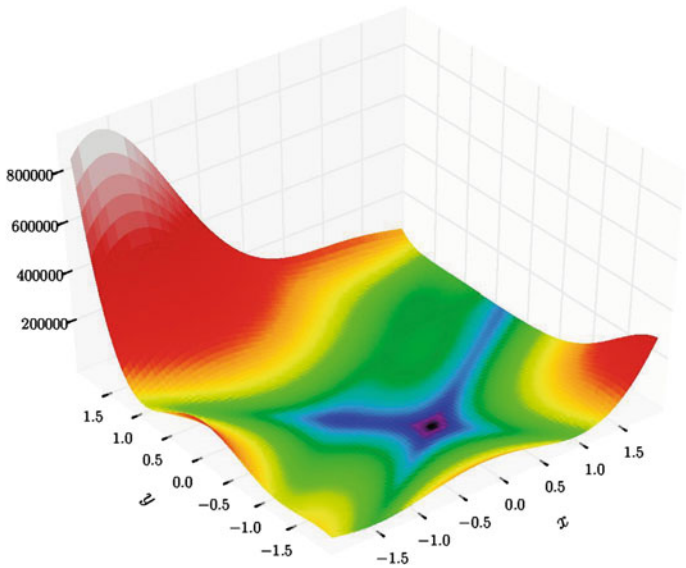

Fig. 6.21 Simple optimization surface. *Source* Gaortizg 2012

[63] See as an example Rajagopal 2015.

The process must create examples to test and a testing process which can weed out failures rapidly. Again, biologically this enables viruses such as the flu and common cold viruses to evolve continually and require rapid adaptation of any potential treatment regimen. For something as vast as the energy system where single elements such as a transmission or distribution system take many years to build, market driven evolution cannot work. At the margins, the practical operation of a system design can be finely tuned within the local minimum in which it inevitably sits. But any evolutionary approach to a good (let alone perfect!) energy system will fail without a very, very accurate guide in the form of a systems design which can point the way to small evolutionary refinements to a carefully thought-out plan.

6.11.5 An Example of a Systems Approach

One of the earliest attempts at a systems model was within the original DECC2050 calculator[64] devised by the late Sir David MacKay who at the time was the Chief Scientific Adviser to DECC and the author of arguably the best book on low-carbon energy, Sustainable Energy—Without The Hot Air.[65] The calculator was the first device to enable policy makers to examine the potential impacts of policy ideas in the round and produced some very surprising results. It is worth examining the examples in that model to see the complexity of interaction of various carbon-reduction pathways. It is particularly interesting, and was a very unwelcome example at the time, to see exactly what the 'Low Cost' pathway suggested. The reader is encouraged to experiment with that model to gain some sense of just how complex and unintuitive the world of carbon reduction can be. The model itself was rapidly copied (the code itself was made freely available) by other countries and more than 25 similar models were created in other countries.[66]

One of the latest attempts at a whole systems approach to modelling the sources of primary energy in a 2050 world was undertaken by the UK's National Nuclear Laboratory together with the technology-neutral Energy Systems Catapult.[67] The work, published in June 2021[68] used a systems model developed by the Energy Systems Catapult known as "ESME".[69] This is in distinct contrast to the work undertaken by the UK's Department of Business, Energy and Industrial Strategy in the 2020 Energy

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64 http://classic.2050.org.uk. Accessed 14 July 2021.

65 MacKay 2009. In the author's opinion this should be mandatory reading for anyone interested in the achievement of Net Zero.

66 https://www.gov.uk/guidance/international-outreach-work-of-the-2050-calculator. Accessed 14 July 2021.

67 https://es.catapult.org.uk. Accessed 14 July 2021.

68 UK National Nuclear Laboratory 2021.

69 https://es.catapult.org.uk/capabilities/modelling/national-energy-system-modelling. Accessed 14 July 2021.

White Paper[70] which was based on a dynamic dispatch model originally created for the Department by Lane, Clark and Peacock in 2012.[71] Nonetheless, while a whole systems approach is the only rational way to consider the redesign of the entire energy system for a nation, far too little of that sort of work has been completed to date and is not yet widely used in policy determination. There are other models of course—University College London has a wide range of modelling approaches[72]—but there is yet to be a consistent approach to systems modelling at the national level, importantly with assumptions which are currently valid. As an example, at the time of writing, none of the modelling considers the potential impact of lower costs of capital from a RAB regime which would dramatically alter all the economic analyses.

6.11.6 Physical Challenges as Constraints in the Systems Approach

One of the biggest challenges in modelling a future systems approach is not just a reasonable assessment of the economics of the whole system, but the physical constraints and practicalities of replacing many GW/year of primary energy production from now to 2050. Two different types of constraint are particularly important—the actual construction constraints and the mechanisms by which energy is finally delivered to end users, domestic or commercial and industrial.

6.11.6.1 Primary Energy Creation—Physical Construction

An example of physical constraints around the choices of how primary energy might be produced is to consider the scenarios in the UK's 2020 Energy White Paper modelling referred to in Sect. 6.11.5. In this report, Fig. 6.22 provides scenarios which include 5–40 GW of nuclear, 65–180 GW of wind and 15–120 GW of solar power.

First, consider the wind generation figures. There is, in 2021, about 24.5 GW of installed wind capacity, onshore and offshore. Incremental wind capacity is likely to be largely offshore given both the politics of the UK and where the big wind resource exists. At the time of writing, the largest wind turbine available is a 14 MW unit from GE (the Haliade-X). A marvel of engineering, this turbine is as tall as the Eiffel Tower in operation. The modelling suggests that the UK would need to build about 40–155 GW of new deployed wind capacity by 2050. Assuming this would all be supplied by turbines of 20 MW each, to allow for technological advances, that would imply building around 2000–7500 floating platforms on which to base these turbines, in deeper waters. Over the period from 2025 to 2050 that is a

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[70] Department for Business, Energy and Industrial Strategy 2020b.

[71] Department of Energy and Climate Change 2011.

[72] https://www.ucl.ac.uk/energy-models/models. Accessed 14 July 2021.

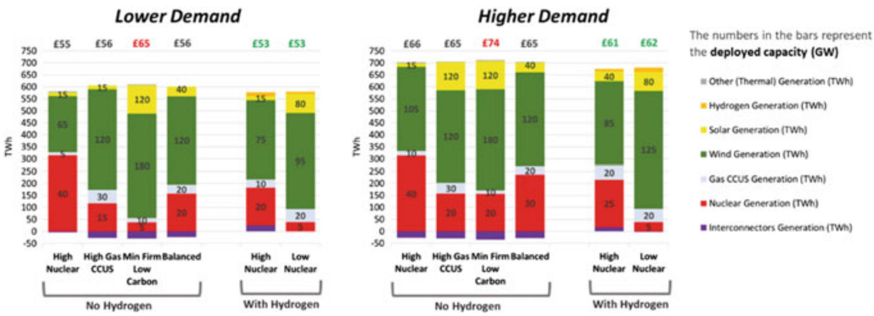

Fig. 6.22 Low-cost energy scenarios. *Source* Department for Business, Energy and Industrial Strategy 2020b

construction rate of between 80 and 300 floating platforms a year, every single year. Even achieving 80 per year will be very challenging. Separately, the area may also be an issue. The Dogger Bank wind project is currently expected to use 190 turbines each of 13 MW. The project will occupy two separate plots, one of 199 mi^2, the other of about 231 mi^2. On that basis, 2000 turbines would need about 4500 mi^2, and 7500 turbines would need almost 17,000 mi^2.

For solar power, the issue is not dissimilar. Figures for the land use requirements for solar are unclear but in the UK, the densest project is the one planned at Cleve Hill which is for up to 350 MW[73] and would cover around 1.89 mi^2.[74] On that basis, 120 GW of solar would take around 650 mi^2 of UK landmass.

These sorts of practicalities—rate of build of platforms, areas needed on land and at sea and the political effort involved in persuading the citizens of a country of the practicalities of these—remain very significant challenges which much modelling, at best, appears to gloss over.

6.11.6.2 Delivery of Energy to the End User

The second aspect of practicality that will need to be considered in the redesign of an energy system is the method of delivery of energy—whether primary or a derived vector such as hydrogen—to the end user. In the UK, as an example, about 17% of final energy is delivered to users as electricity, through the transmission and distribution system. The remaining ~80% is delivered as gases or liquids, as shown in Fig. 6.23.

Replacing the 76% of energy delivered as petroleum products or gas to a different *delivery* channel is an immense challenge. All the current plans for decarbonization of energy systems pretty much anywhere in the world will require a major increase

[73] https://www.clevehillsolar.com. Accessed 14 July 2021.

[74] https://www.kentwildlifetrust.org.uk/campaigns/planning-and-development/cleve-hill-solar-park. Accessed 14 July 2021.

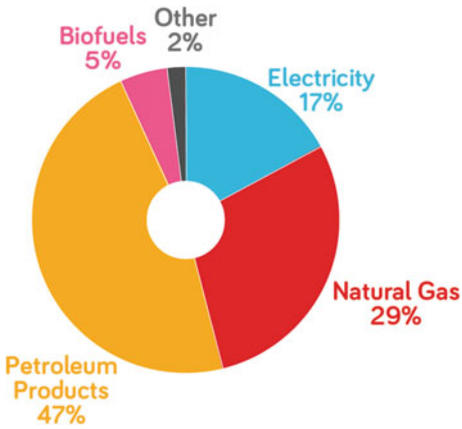

Fig. 6.23 UK energy delivery channels. *Source* Nuclear Industry Association

in electricity production. In the UK, suggestions of as much as four times current electricity have been mooted. However large the scale, the wholesale rebuilding of transmission and distribution systems seems unavoidable. Given the historical basis of design as set out in Sect. 6.2, a wholesale rebuilding is almost certainly justified but will need to be approached based on a final system design treated as a programme of many projects. The practical sensitivities of rebuilding the distribution systems and at least reinforcing the last mile—let alone the upgrading of domestic connections with potentially replacing major wiring within houses—will need buy-in by citizens which itself will take strong leadership by politicians. Hence, it may help if the 29% of energy currently delivered by natural gas could be replaced by the same amount of energy delivered by a different vector—hydrogen is currently the favoured route in many countries. Issues such as steel embrittlement of piping systems, and the profound ability of hydrogen to leak and its lower energy density, present challenges that are now thought to be tractable. Hydrogen has about one third of the energy per unit volume as natural gas, although it is believed that the higher compressibility of hydrogen should make delivery of about three times the current volumes of natural gas potentially practicable.

Replacing the energy delivered by liquids, not just gasoline but Avgas and all the other liquid petroleum fuels, again becomes an issue of physical practicalities. While hydrogen is enthusiastically supported by many as a major alternative energy vector, ammonia is increasingly gathering interest as a possible marine fuel—while it has too low a flame velocity to work as a fuel alone in the large engines in ships, the addition of a small amount of methane, hydrogen or diesel to the ammonia reportedly may solve that problem. Both MAN in Germany and Samsung in the Republic of Korea are reportedly working on such engines and are predicting an ammonia-powered tanker to be in operation by around 2024.

6.12 Our Options and Approach

6.12.1 How Might We Approach a Solution?

6.12.1.1 Bravery, Leadership and Decisions

First, given the short remaining time until 2050, achieving the pace and scale of change necessary will require big, bold political decisions and leadership. It will take a focus on maximizing GW/year of new low-carbon primary energy subject to a price cap rather than minimizing £/MWh. It will also need the measure of price to be in terms of price to the national economy, not at the point of connection from the source and an end to the misleading practices of 'socializing' externalities such as the cost of intermittency.

Secondly, this leadership will produce legacies. Different countries will have different solutions of course, but here the history books will be the judge of the effectiveness of the leadership. Like it or not, the decisions taken over the early to mid-2020s will define energy costs for generations to come and with that national economic competitiveness. The resulting legacies will be on a scale of the introduction of the Welfare State in the late 1940s in the UK if not greater. The global competitive landscape is likely to be materially changed by the energy policies of nations as they adapt to Net Zero. The challenge for the politicians now is that of bravery. About forgetting the temptation of pursuit of perfection and minimizing costs to levels of spurious accuracy. Creating a system that is lower/lowest cost to the national economy will inevitably imperfect, and recognizing that in taking big decisions soon will inevitably be the lowest risk route. Technological changes will undoubtedly continue to occur but the time during which any technology can reach a technological readiness level (TRL) capable of mass deployment in time to make any difference to the outcomes of 2050 is very likely to be too long to make a practical difference.

All the technologies which work well today or are at high TRLs should be built as fast as possible now in combinations which will great speed of delivery with low system cost. Clearly any planning needs to deal with off-ramps should material technological developments materialize but to bet on some silver bullet appearing will be at best a fool's errand and at worst damaging to a nation's prospects.

6.12.2 Low Regrets—Use Technology Deployable Now, Focus Investment There

So, what is deployable now at scale. Clearly, offshore wind has developed well and with the giant 14 MW GE Haliade-X turbines offshore wind is deployable at GW scale in the UK. Solar is not deployable at the same scale in countries like the UK. Steam reformed methane with CCUS may well be deployable at reasonable scale

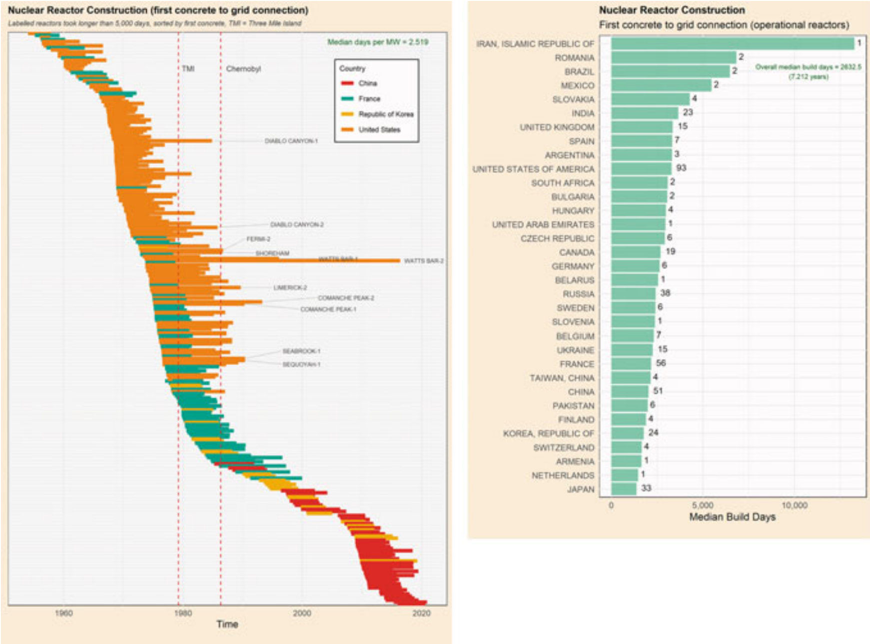

Fig. 6.24 Reactor construction times. *Source* @GrantChalmers

but only after the creation of a proven carbon capture and sequestration technology. This could deliver hydrogen at scale. Whether it will be cheaper than high temperature electrolysis or hydrogen from high temperature heat from advanced reactors remains to be seen. GW-scale nuclear reactors can be delivered at speed where the project management disciplines, coupled with a developed supply chain and experienced contractors are all in place and properly financed and governed. The speed of deployment of nuclear reactors can be seen clearly in Fig. 6.24.

The answer to the question "What are the low-regrets options?" depends entirely on the country of choice. Apart from the scale of renewable resource, the ability to construct the new system on time is probably the largest single determinant. In the nuclear world, it is important to consider exactly why the time to build nuclear reactors varies so dramatically between Japan and the Republic of Korea versus the USA and the UK. It is clear that a robust and consistent approach to project management is an important part of that difference and the useful Nuclear Cost Drivers study by the UK's Energy Technology Institute[75] particularly highlights this factor. Key findings from the study are set out in Table 6.6.

The reality, of course, is that nuclear power projects are large, complex projects of the scale and complexity which the fossil industry has mastered for many years. Those examples of nuclear projects which badly slip in time and cost are often not issues

[75] Energy Technologies Institute 2018.

Table 6.6 Nuclear cost drivers—low and high cost plant attributes

Low cost plants	High cost plants
Design at or near complete prior to construction	Lack of completed design before construction started
High degree of design reuse	Major regulatory interventions during construction
Experienced construction management	FOAK design
Low cost and highly productive labour	Litigation between project participants
Experienced EPC consortium	Significant delays and rework required due to supply chain
Experienced supply chain	Long construction schedule
Detailed construction planning prior to starting construction	Relatively higher labour rates and low productivity
Intentional new build programme focused on cost reduction and performance improvement	Insufficient oversight by owner
Multiple units at a single site	
NOAK design	

driven by unknown or misunderstood technology. They are generally classic example of problems in any large project. As part of any approach to a new energy system design in a country, there should be a proper examination of which technologies a country *could* build at pace and scale, taking into account the factors listed in Table 6.6. It is very instructive to consider how the United Arab Emirates managed to build its first reactor faster than the median time taken in either the UK or the USA although in a country which had no nuclear pedigree whatever. Clearly, there was a huge advantage in constructing a very close replica of a design which had been built repeatedly elsewhere, using the same teams to build it as before, accepting country-of-origin certification for the design while establishing an extremely experienced nuclear safety regulator which would have approval control of commissioning and operation. But the other factor which undoubtedly made a material difference was the quality of the thinking and preparation which took place before any construction began. The hiring of an experienced and proven project director, the development of a robust and thorough construction plan, the use of experienced contractors and the degree of completeness of the engineering design also helped. But the whole approach of building the project's reputation from the very outset was probably one of the other pivotal factors. A wise expert in reputation management sat next door to the chief executive from the very earliest days of the project and the focus of the chief executive on the importance of the project's reputation was crystal clear. There is no doubt that the ENEC project in Abu Dhabi has set an example for others to follow.

The ENEC project, whilst first in country was the nth of a kind in that the exact same reactors had been previously built and operated in the Republic of Korea. The ENEC reactors were indeed new to the country but by using precisely the same design as had been built in the Republic of Korea, the ENEC reactors had many of the attributes of the nth of a kind when considering success factors for building on time and on budget. And indeed, fleet build of a small number of reactor designs was at the heart of the restart of nuclear power construction as set out in the 2008 White Paper which triggered the UK's first major legislative move towards a low-carbon energy system. It will be interesting to see if the UK manages to achieve a fleet build of any nuclear technology—at the time of writing, Hinkley Point C is under construction and the second plant in the series, Sizewell C, is under consideration. But little else is clear. This is a major contrast with the attitudes now in Canada, China, increasingly in the USA and now many countries in Europe. Last time the UK built a new nuclear power station, Sizewell B, it was intended to be one of a larger fleet of up to ten units. Political will evaporated during the first unit even though that unit is probably the only currently operating source of low-carbon primary energy which will still be in operation in 2050 (assuming, of course, that it obtains a 20-year life extension).

Many other countries are watching the UK as a potentially important market for nuclear power but doing so with a degree of scepticism which will only be overcome by a strong injection of political leadership, will and true commitment. Without those, why would investors take on the financing (whether debt or equity) of a nuclear power station even when operational, let alone during construction even under RAB terms? Why would the supply chain invest even more ahead of time to build capability, capacity and resilience in their businesses in the UK? The Japanese stock market has already spoken its view through their refusal to support Hitachi's UK venture with Horizon. Investors are now far too scarred by political damage in energy markets—the memories of the Spanish government's about-face on the renewables market from 2010, culminating in the slashing of contractually binding feed-in-tariffs for operational projects, have not been forgotten.

The addition over recent years of investors' requirements for only Environmental, Social and Governance (ESG) qualified investments has further added to potential political risk. Pressures applied by major investors such as BlackRock[76] have intensified to squeeze out non-ESG investments. This has created a large battlefield for anti-nuclear sentiment from many sources. Governmental taxonomies in Europe and elsewhere[77] rarely start out as technology neutral—that was the case with the European taxonomy and despite the work of a technical expert group[78] concluding that "The analyses did not reveal any science-based evidence that nuclear energy does more harm to human health or to the environment than other electricity production technologies already included in the Taxonomy as activities supporting climate

[76] https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter. Accessed 14 July 2021 (Letter to clients).

[77] https://www.euractiv.com/section/energy-environment/news/germany-leads-call-to-keep-nuclear-out-of-eu-green-finance-taxonomy; https://ec.europa.eu/commission/presscorner/detail/it/qanda_19_6804. Accessed 14 July 2021.

[78] European Commission 2021.

change mitigation." Unless nuclear is properly recognized as a low-carbon, sustainable source of primary energy, it will be at risk of failing to attract a significant class of investors.

6.13 Final Thoughts

A US military leader, commenting on a reflection of the reactions of the USA to 9/11, said "When emotions are high, rationality's low, and poor decisions are made." Nuclear is, and continues to be, beset by emotions in many discussions about its possible use in a rational, balanced, secure and resilient energy system. Very poor decisions have been and continue to be made. The word 'nuclear' produces intellectual paralysis in too many policy makers and politicians because of the aggressive and rightly hated weapons connotations.

But society can deal with such cognitive contradictions elsewhere. Nitroglycerine (UK spelling) is in the mind of many of the public, the safe-cracker's explosive of choice—at least it is in the movies. For a smaller group of the population, it is also the substance which makes dynamite, and which made a young Alfred Nobel extremely rich and enabled him to endow the eponymous prize. But to a very small few, when taken into the emergency room with heart problems, when they are treated with a drug with names like "Nitrocot" or "Nitrostat", it is that same nitroglycerine—but in a non-explosive formulation. It is how the science is used, not the science itself which matters. Similarly, with radiation, if you sit out in the midday sun in Abu Dhabi in July for a couple of hours, you will be very badly sunburned. Sitting out in the moonlight that same evening will be entirely harmless (at least from the perspective of sunburn). It is exactly the same radiation—photons of the same (give or take) wavelengths, just different amounts. With ionizing radiation, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) is clear that for doses under 100 mSv, there is no evidence of increasing risk of cancer. That does not stop people panicking when told they have had a dose of one or two millisieverts—the ionizing radiation equivalent of moonlight. And while they panic about a millisievert or two, their friend receiving radiotherapy for cancer may well be receiving 20 sieverts—20,000 times more—designed to make their friend well. It is how the science is used, not the science itself.

For the public, politicians need to provide leadership. Not by the equivalent of eating hamburgers during the CJD epidemic but by discussion and using the skills which politicians are selected for—to convince voters that their leaders will overall make the voters' world a better place. And to create trust and confidence. If future energy policy is driven by emotion, bad decisions will result. The result will be a much poorer country for our grandchildren, and many may well end up moving abroad to a country which made the better decisions in the 2020s.

One thing is now clear. The world is out of time and must act now, flat out, maximizing the building of GW/year of new low-carbon capacity of primary energy production. In making the decisions around energy policy, legacies of the scale of the creation of the UK welfare state in 1948 will be made—huge legacies, by which names will be remembered including (for UK readers) Winston Churchill, Rab Butler, William Beveridge and Nye Bevin. But that is only for those politicians who have the bravery, insight, and willingness to learn and act following science, engineering and fact. For those who barge along dreaming of some whizzy new technology arriving next year to save them from making a decision today, or for those whose modus operandi is NIMTO—not in my term of office—their legacies will be millstones around the necks of their children, grandchildren and onwards and their names will be reviled in the history books.

Our leaders have a choice.

References

Black G, Aydogan F, Koerner C (2019) Economic Viability of Light Water Small Modular Nuclear Reactors: General Methodology and Vendor Data. Renewable and Sustainable Energy Reviews 103:248–258

Cheng V, Hammond G (2017) Life-Cycle Energy Densities and Land-Take Requirements of Various Power Generators: A UK Perspective. Journal of the Energy Institute 90:201–213

Chivers J, Foxon T, Galloway S, Hammond G, Infield D, Leach M, Pearson P, Strachan N, Strbac G, Thomson M (2017) Realising Transition Pathways for a More Electric, Low-Carbon Energy System in the United Kingdom: Challenges, Insights and Opportunities. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy 231:440–477

Climate Change Committee (2020) Sixth Carbon Budget https://www.theccc.org.uk/publication/sixth-carbon-budget. Accessed 14 July 2021

Department for Business, Energy and Industrial Strategy (2020a) RAB Model for Nuclear https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943762/Nuclear_RAB_Consultation_Government_Response-.pdf. Accessed 14 July 2021

Department for Business, Energy and Industrial Strategy (2020b) Modelling 2050: Electricity System Analysis
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943714/Modelling-2050-Electricity-System-Analysis.pdf. Accessed 14 July 2021

Department of Energy and Climate Change (2011) DECC Dynamic Dispatch Model (DDM)
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/65709/5425-decc-dynamic-dispatch-model-ddm.pdf. Accessed 14 July 2021

Elder R, Cumming D, Mongensen M (2015) High Temperature Electrolysis. In: Styring P, Quadrelli E A, Armstrong K (eds) Carbon Dioxide Utilisation: Closing the Carbon Cycle. Elsevier, pp 183–209

Energy Technologies Institute (2018) The ETI Nuclear Cost Drivers Project: Summary Report
https://d2umxnkyjne36n.cloudfront.net/documents/D7.3-ETI-Nuclear-Cost-Drivers-Summary-Report_April-20.pdf?mtime=20180426151016. Accessed 14 July 2021

European Commission (2021) Technical Assessment of Nuclear Energy with Respect to the 'Do No Significant Harm' Criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation'), JRC124193.
https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf. Accessed 14 July 2021

Fuchs C, Poehls A, Skau K, Kasten J (2021) Economics of Battery Use in Agriculture: Economic Viability of Renewable Energy Complemented with Batteries in Agriculture. Energies 14:2430

Funk J (2001) Thermochemical hydrogen production: past and present. International Journal of Hydrogen Energy 26:185–190

Gagnon L, Belanger C, Uchiyama Y (2002) Life-cycle assessment of electricity generation options: The status of research in year 2001. Energy Policy 30:267–1278.
Harris C (2006) Electricity Markets: Pricing, Structures and Economics. Wiley, Hoboken, NJ
HM Government (2020) The Ten Point Plan for a Green Industrial Revolution. https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution. Accessed 14 July 2021
International Atomic Energy Agency (IAEA) (2011) The Nuclear Fuel Cycle. https://www.iaea.org/sites/default/files/nfc0811.pdf. Accessed 14 July 2021
Keçebaşa A, Muhammet K, Mutlucan B (2019) Electrochemical hydrogen generation. In: Calise F, Dentice D'Accadia M, Santarelli M, Lanzini A, Ferrero D (eds) Solar Hydrogen Production. Academic Press, pp 299–317
Ling S, Sanny J, Moebs W (2016) Nuclear Binding Energy. In: Ling S, Sanny J, Moebs W (eds) University Physics Volume 3. OpenStax, Texas
LucidCatalyst (2020) Missing Link to a Livable Climate: How Hydrogen-Enabled Synthetic Fuels Can Help Deliver the Paris Goals. https://www.lucidcatalyst.com/hydrogen-report. Accessed 14 July 2021.
MacKay D (2009) Sustainable Energy—Without The Hot Air. UIT, Cambridge
Marx C (2014) Failed Solutions to the Energy Crises: Nuclear Power, Coal Conversion, and the Chemical Industry in West Germany since the 1960s. Historical Social Research / Historische Sozialforschung 39:251– 271
National Nuclear Laboratory (2021) UK Energy System Modelling: Net Zero 2050
https://www.nnl.co.uk/wp-content/uploads/2021/06/NNL-UK-Energy-System-Modelling-for-Net-Zero.pdf. Accessed 14 July 2021
Newbery (2020) Net Zero and Future Energy Scenarios: A Response to the National Infrastructure Commission's Report on Future Power Systems. EPRG. https://www.eprg.group.cam.ac.uk/wp-content/uploads/2020/03/D.-Newbery_Comment_26March2020.pdf. Accessed 14 July 2021
Nishihara T, Yan X, Tachibana Y, Shibata T, Ohashi H, Kubo S, Inaba Y, Nakagawa S, Goto M, Ueta S, Hirota N, Inagaki Y, Iigaki K, Hamamoto S, Kunitomi K (2018) Excellent Feature of Japanese HTGR Technologies. Japan Atomic Energy Agency, Ibaraki
OECD Nuclear Energy Agency (OECD/NEA) (2011) Technical and Economic Aspects of Load Following with Nuclear Power Plants. https://www.oecd-nea.org/ndd/reports/2011/load-following-npp.pdf. Accessed 14 July 2021.
Rajagopal (2015) The Butterfly Effect in Competitive Markets. Palgrave Macmillan, London
Secretary of State for Business, Energy and Industrial Strategy (2020) Energy White Paper: Powering Our Net Zero Future. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf. Accessed 14 July 2021
Simshauser P (2019) Lessons from Australia's National Electricity Market 1998–2018: The Strengths and Weaknesses of the Reform Experience. https://www.eprg.group.cam.ac.uk/wp-content/uploads/2019/08/1927-Text.pdf. Accessed 14 July 2021
UKRN (2019) Cost of Capital—Annual Update Report. https://www.ukrn.org.uk/wp-content/uploads/2019/09/2019-UKRN-Annual-Cost-of-Capital-Report-Final-1.pdf. Accessed 14 July 2021
World Nuclear Association (2021a) Advanced Nuclear Power Reactors. https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors.aspx. Accessed 14 July 2021
World Nuclear Association (2021b) Small Nuclear Power Reactors. https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx. Accessed 14 July 2021

Chapter 7
Legal Imputation of Radiation Harm to Radiation Exposure Situations

Abel Julio González

Contents

Abstract The doctrine for legal imputation (including the derivative concepts of legal charging, suing, indicting, prosecuting and judging) of detrimental health effects to those responsible for radiation exposure situations has been a matter of debate for many years and its resolution is still unclear. While the attribution of harm in the situations involving high radiation dose is basically straightforward, the challenge arises at medium doses and becomes a real conundrum for the very common situations of exposure to low radiation doses. The ambiguous situation could be construed to be a Damocles sword for the renaissance of endeavours involving occupational and public radiation exposure. This chapter describes the epistemological situation on the attribution of radiation health effects and the inference of radiation risks, relying on estimates from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported to the UN General Assembly. It discusses the implications of UNSCEAR's refined paradigm for assigning legal liability. The chapter concludes with a recommendation to develop an international legal doctrine on the ability to impute detrimental radiation health effects.

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Keywords Radiation exposure situations · Legal imputation · Radiation effect attribution · Radiation risk inference · Radiopathological attestation · Radioepidemiological attestation · United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) · Deterministic health effects · Stochastic health effects · Radiation safety

7.1 Aim

The purpose of this chapter is to address the *legal imputation*[1] *of radiation harm*[2] *to radiation exposure situations*.[3] The concept of legal imputation is used as a precursor of its derivative legal concepts of suing and prosecuting, charging, indicting and judging.

The legal imputation of radiation harm has been controversial, particularly for situations involving low radiation doses. The lack of clarity on such an important issue is a challenge for the normal development of human endeavours involving radiation exposure of people, such as the generation of nuclear electricity and the use of radiation and radioactivity in medicine, industry and research.

Therefore, this chapter aims to promote an international common understanding on the issue.

The chapter contains the following:

- A summary description of the basic scientific international consensus on radiation health effects, which is aimed at providing a background on the issue. This is followed by a discussion on estimating effects and imputing harm and a portrayal of the fundamental paradigm, including a discussion on verifiable facts vis-à-vis subjective conjectures.

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[1] The concept of *legal imputation* is used to mean actions based on law for attributing radiation harm to radiation exposure situations. It is used as a precursor of its derivative concepts of legal charging, suing, indicting, prosecuting and judging. In a legal context, imputing means ascribing to someone causing physical injury, actual or potential ill effects that are attributable to radiation exposure, namely ascribing responsibility for effects of radiation exposure. It is to be noted that attributing is different than imputing, but unfortunately the terms have been used internationally as synonyms. See ILO et al. 2010.

[2] The concept of *radiation harm* is used to mean any *radiation health effect* or physical injury incurred by people, namely identified individuals or populations as a whole, which can be attested as having been inflicted by radiation exposure, where *radiation* is used to mean ionizing radiation and *radiation health effect* is used to mean any health effect generated by exposure to radiation.

[3] The concept of *radiation exposure situations* is used to mean any set of circumstances in which people are subjected to states or conditions of being irradiated by ionizing radiation, either from a source outside the body or a source incorporated within the body, where a source is anything that may cause radiation exposure, such as by emitting ionizing radiation or by releasing radioactive substances or radioactive material.

- A discussion on the *attribution*[4] of radiation harm vis-à-vis the *inference*[5] of *radiation risk*[6] from radiation exposure situations.
- The related issue of *attestation*,[7] by the so-called *expert witness*,[8] of the factual occurrence of radiation health effects.
- The consequent possibilities of *legal imputation* of such radiation harm to those radiation exposure situations.

7.2 Summary of the Basic Scientific Consensus

A universal consensus on the estimates of radiation health effects has been agreed internationally over the years by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and routinely reported to the United

[4] *Attribution* is used to mean the ascribing of a health effect to radiation exposure using objective factual evidence.

[5] *Inference* (in contrast with attribution) is used to mean the process of drawing conclusions from subjective conjectures involving indirect scientific observations, evidence and reasoning in the presence of uncertainty (while the use of inference is usually focused on prospectively inferring risk, note that estimating an *assigned share* or *probability of causation* is also an inference, but retrospective).

[6] *Radiation risk* is used to mean the probability that a health effect associated to radiation exposure (e.g. onset of cancer) may occur (i.e. it is a prospective notion) during a given time period (e.g. the rest of life following an exposure). Radiation risks should only be attributed by using factual evidence from epidemiological investigations of disease rates in previously exposed populations (i.e. based on past observations); nonetheless, it is to be noted that the results from such retrospective analyses have been also used to make inferences about the risk for other exposure situations involving different populations for which direct epidemiological data were not available.

[7] *Attestation* is used to mean that an *expert witness* provides or serves clear evidence by formally declaring that a radiation effects exists or is the case.

[8] *Expert witness* is used to mean a specialist of radiation effects who may present his/her expert opinion without having been a witness to any occurrence relating to a radiation-related lawsuit or criminal case, but just to the factual occurrence of the effects, as follows:

Radiopathologists are expert witnesses of the factual occurrence of radiation health effects that can be diagnosed in individuals, namely they are recognized and certified scientists who study the causes and effects of radiation induced diseases, especially by examining laboratory samples of body tissue for diagnostic or forensic purposes.

Radioepidemiologists are expert witnesses of the factual occurrence of radiation health effects that are not individually diagnosable but can be only estimated in populations (i.e. they are recognized and certified scientists with expertise in medical statistics, the branch of medicine that deals with the incidence and distribution of diseases associated with radiation exposure).

Radiobiologists are expert witnesses of the factual occurrence of biological changes attributable to radiation exposure, by analysing specialized bioassay specimens, such as some haematological and cytogenetic samples (i.e. they are recognized and certified scientists with expertise in the branch of biology concerned with the effects of ionizing radiation on organisms, organs, tissues and cells).

Radioprotectionists (also known as radiation protection experts or health physicists) are expert witnesses associated with conjecturing and inferring radiation risks (i.e. they are certified scientists who are duly recognized as having expertise on the protection of people from harmful effects of exposure to ionizing radiation, and on the means for achieving such protection).

Nations General Assembly (UNGA). UNSCEAR is the international intergovernmental organization assigned by UNGA to estimate the global levels and effects of radiation.

The fundamental theses under the international paradigm, over which the chapter will be founded, are presented simplistically as follows:

- There is scientific consensus that exposure to high levels of radiation doses incurred over a relatively short time results in acute (i.e. critical, serious) harmful effects on the exposed individuals. These effects can be diagnosed, proven and *attested* by qualified *radiopathologists*. In sum, an observed health effect in an individual could be unequivocally attributed to radiation exposure if the individual were to experience tissue reactions (often referred to as 'deterministic' effects), and differential pathological diagnosis were achievable that eliminated possible alternative causes. Such deterministic effects are experienced as a result of high absorbed doses, incurred in a relatively short period of time, as might arise following exposure due to accidents or radiotherapy. Such deterministic effects can therefore be individually imputed to the situation through a classic *lawsuit*.[9]
- At lower doses, a collective harm can be incurred by the populations being exposed, which may be expressed as increases in the incidence of certain effects. Such increases can be assessed, proven and *attested* by qualified *radioepidemiologists*. These health effects in an individual that are known to be associated with radiation exposure—such as radiation inducible malignancies (and, in theory, hereditary effects in the descendants of the exposed population)—cannot be unequivocally attributed to radiation exposure, since radiation exposure is not the only possible cause and biomarkers that are specific to radiation exposure are not generally available at present. These effects are so-called 'stochastic' effects. Thus, unambiguous differential pathological diagnosis is not possible for stochastic effects. Only if the spontaneous incidence of a particular type of stochastic effect were low and the radiosensitivity for an effect of that type were high (as is the case with some paediatric thyroid cancers) could the attribution of an effect in a particular individual to radiation exposure be ostensible, particularly if that exposure were high. Even then, however, the effect in an individual cannot be attributed unequivocally to radiation exposure, owing to competing possible causes. In sum, an increased incidence of stochastic effects in a population could be attributed to radiation exposure through epidemiological analysis—provided that, inter alia, the increased incidence of cases of the stochastic effect were sufficient to overcome the inherent statistical uncertainties. In this case, an increase in the incidence of stochastic effects in the exposed population could be properly verified and attributed to exposure. It is to be noted that, although demonstrated in animal studies, an increase in the incidence of hereditary effects in human populations cannot at present be attributed to radiation exposure. One reason for this is the large fluctuation in the spontaneous incidence of these effects. In some

[9] The term *lawsuit* is used to mean proceedings by a party or parties with a *legal imputation* to another in a civil court of law.

jurisdictions, the radiation harm from stochastic effects could be *collectively* (but not individually) imputed to the situation, perhaps as a *class action lawsuit*.[10]

- Specialized bioassay specimens, such as some haematological and cytogenetic samples, that indicate biological changes attributable to radiation exposure can be diagnosed in exposed individuals by qualified *radiobiologists*. These can be used as biological indicators of radiation exposure even at very low exposure levels. It is to be noted, however, that the presence of such biological indicators in samples taken from an individual does not necessarily mean that the individual would experience health effects due to the exposure. It is not clear whether 'harm' can be imputed in these cases.
- There has recently been an international agreement that radiation health effects are not attributable situations involving low doses (e.g. doses similar to typical natural background doses), but that radiation risks could still be inferred from these situations, which can only be subjective conjectures. In sum, increases in the incidence of health effects in populations cannot be attributed reliably to chronic exposure to radiation at levels that are typical of average global background radiation levels. This is because of the uncertainties associated with the assessment of risks at low doses, the current absence of radiation specific biomarkers for health effects, and the insufficient statistical power of epidemiological studies. There is international consensus that the numbers of radiation induced health effects within a population exposed to incremental doses at levels equivalent to or lower than natural background levels can not be estimated by multiplying very low doses by large numbers of individuals. These situations are very common in practice and legal imputation of radiation harm hypothetically assigned to them is controversial. It has been noted that public health bodies need to allocate resources appropriately, and that this may involve making projections of numbers of health effects for comparative purposes. This method, though based on reasonable but untestable assumptions, could be useful for such purposes if it were applied consistently, the uncertainties in the assessments were taken fully into account, and it were not inferred that the projected health effects were other than notional.

7.3 From Estimating Effects to Imputing Harm

The legal imputation of radiation harm has generated controversy over the years while avoiding a universal resolution. The issue can be summarized as follows:

(a) Ascribing health effects to radiation exposure situations;
(b) Attesting their occurrence by qualified experts;
(c) Proceeding with legal actions such as imputation first and eventually charging, suing, indicting, prosecuting and judging, according to the legal practice

[10] The term *class action lawsuit* is used to mean a lawsuit where one of the parties is a group of people which is represented collectively by a member of that group.

in the applicable jurisdiction. The matter seems to be particularly difficult in situations involving low individual radiation doses.

While the origin of the issue can be traced back to the times of multiple nuclear weapons tests, it was revitalized in the aftermath of large nuclear accidents, such as those at the nuclear power plants of Three Mile Island, Chernobyl and Fukushima Daiichi, and by the relatively recent interest in the so-called 'misadministration' of radiation doses in medical practices such as radiotherapy and radiodiagnostics.

The debate heated up in the aftermath of the accident at the Chernobyl nuclear power plant and was first reported in the 1993 Symposium on Nuclear Accidents: Liabilities and Guarantees convened by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA).[11] At that meeting, the dilemma of causation associated with the radiological health consequences of the Chernobyl accident was addressed.[12] A decade after this initial debate, the influence of the issue in nuclear law was already a subject of discussion in legal literature.[13]

Thus, concerns were expressed early on about the epistemological constraints of attributing health effects to radiation exposure involving relatively low doses and its legal consequences. Notwithstanding these concerns, notional effects were being attributed to low radiation doses from the aftermath of the accident, not only in the refereed scientific literature,[14] but more noticeably at the academic level (e.g. in the Annals of the New York Academy of Sciences).[15] These opinions were in contradiction with estimates being reported by international organizations.[16] These contradictions caused serious concerns among members of the public and their representatives.

Unsurprisingly, following the accident at the Fukushima Daiichi nuclear power plant, the same type of reporting of unprovable effects became fashionable in scientific literature.[17] The reports were in full contrast with the scientific estimates by international organizations.[18]

Thus, the experts' controversy on the health effects of low level radiation has been at the centre of a confusing and puzzling debate. Not surprisingly, the legal response to cases involving exposure to relatively low radiation doses has been ambiguous: while legal claims were generally unsuccessful in most countries in the past years, a number of cases have been successful, particularly in Japan, and these might have numerous legal implications.[19]

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[11] OECD/NEA 1993.

[12] González 1993, p. 25.

[13] González 2002.

[14] See, for example, Cardis et al. 2006.

[15] Yablokov et al. 2010.

[16] IAEA 1996; UNSCEAR 2008.

[17] See, for example, Ten Hoeve and Jacobson 2012.

[18] UNSCEAR 2013; IAEA 2015; González et al. 2013.

[19] See for example https://www.bbc.com/news/world-asia-38843691. Accessed 11 October 2021.

The equivocal treatment of the issue and the surrounding legal ambiguity are predictably causing bewilderment among the general public and favouring sensationalism in the media, and have already cost a high price in terms of public fear of low dose radiation.[20] As a result, in a number of cases, the regulatory processes for preventing low level radiation exposure in order to avoid legal implications have imposed severe penalties on society and, unwittingly, hindered the utilization of beneficial practices involving radiation exposure.

Perhaps the problems first arose as a result of misinformation and miscommunication between legal experts and an inhomogeneous group of radiobiologists, radioepidemiologists, radiopathologists and radioprotectionists. Moreover, communication with the public and its political representatives has been far from good. These mishaps have been discussed amply,[21] but no solution has been found.

A major legal conundrum is how to handle the epistemological miscalculation in the attribution of radiation effects to exposure situations where these effects could be conjectured but are not provable. This problem has been sufficiently discussed in the literature,[22] but over the years it seems to have been ignored both in regulations and in the legal practice.

An important effort to address the issue was carried out by the International Labour Organization.[23] A report was issued on approaches to the attribution of detrimental health effects to occupational ionizing radiation exposure and their application in compensation programmes for cancer. Although limited in its scope (it just covered occupational exposure and focused on compensation), this was a significant attempt to make advances on the issue of imputation. The document, recalling ILO Convention No. 115, requires that workers who have developed cancer as a result of occupational exposure to radiation are compensated, recognizes that a process of compensating for the disease must be selected that is capable of distinguishing between those cases most likely to have been caused by occupational exposure and background cases that have developed due to other reasons.

Fortunately, however, an international intergovernmental consensus on the attribution of provable radiation health effects vis-à-vis the inference of conjectured risk has been achieved relatively recently. This important step was finally reached a few years ago by UNSCEAR.[24]

In 2012 UNSCEAR refined the understanding of this paradigm by addressing the attribution of health effects to radiation exposure and the inference of risks.[25] UNGA unanimously welcomed with appreciation this scientific report by UNSCEAR.[26] The UNSCEAR estimates have been summarized by the United Nations Environment Programme (UNEP) in a booklet, whose main relevant findings and illustration are

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[20] Waltar et al. 2016.

[21] IAEA 2018.

[22] González 2011.

[23] ILO et al. 2010.

[24] UNSCEAR 2012.

[25] Ibid.

[26] UNGA 2012.

used in this chapter.[27] This important global agreement was reported widely in the literature,[28] but it is still far from being implemented in regulatory practice. The Commission on Safety Standards (CSS) has been addressing the issue and a report is in preparation (the CSS is the international body endorsing the international safety standards being established under the aegis of the IAEA with the co-sponsorship of all relevant international organizations).

After a long journey it seems that the scientific community has under UNSCEAR reached a consensus on health effects at low doses: risk can be inferred but actual effects cannot be attributed. This important scientific consensus should now be converted into legal instruments that address the issues of imputation, suing, prosecuting, charging, indicting and judging, following radiation exposure situations. A discussion on the transit from scientific attribution and inference to legal imputation (and therefore to suing, prosecuting, charging, indicting and judging) followed these developments,[29] but has not yet crystallized in universal approaches.

7.4 The Fundamental Paradigm

This renewed UNSCEAR paradigm[30] is subtly more precise than previous estimates[31] that are currently used by international intergovernmental regulations to protect people against the detrimental effects of exposure to radiation,[32] and consequently, by the vast corpus of nuclear safety regulations. For instance, the current regulations do not make clear distinctions between attribution of factual effects and inference of conjectured risks. However, the renewed international paradigm provides the scientific and regulatory foundation for the legal issues associated with the imputation of harm to radiation exposure situations.

The paradigm can be simplistically summarized in an annotated dose-response relationship (see Sect. 7.4.1).

7.4.1 The Dose-Response Relationship

The relationship between the radiation doses incurred by people and the probability of occurrence of health effects (so called, *dose-response relationship*), which can be derived from the UNSCEAR estimates, has been synthesized by UNEP in the graph shown in Fig. 7.1.[33]

[27] UNEP 2016.

[28] González 2014b, c.

[29] González 2014a.

[30] UNSCEAR 2012; ICRP 2005.

[31] UNSCEAR 2008.

[32] IAEA 2014; ICRP (2007) 2010.

[33] UNEP 2016, p. 25.

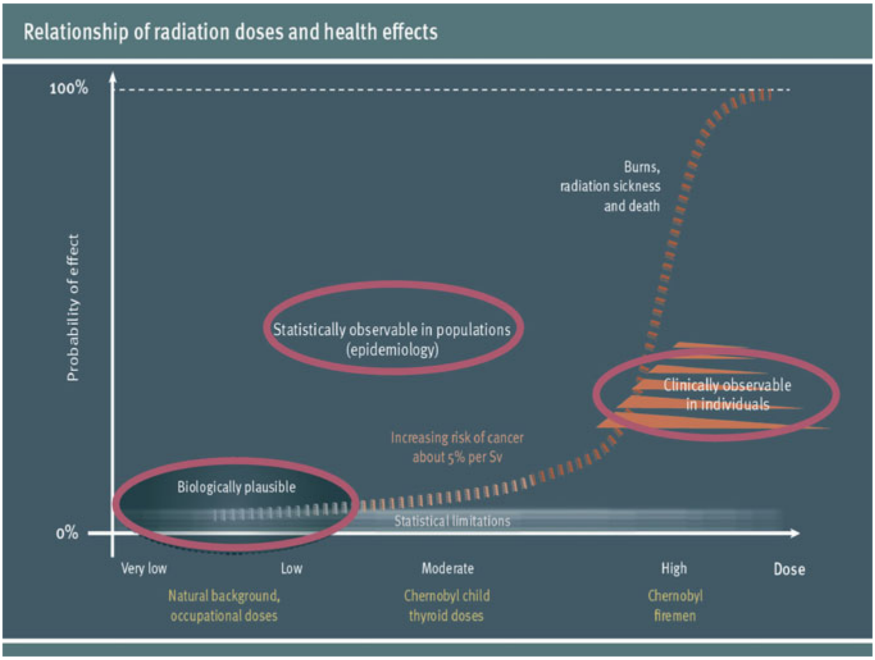

Fig. 7.1 The dose-response relationship. *Source* UNEP 2016, p. 25

The doses are expressed as:

- *'High doses'* (around a 'sievert' of effective dose [note that the average natural background dose is 0.0024 sieverts per annum, therefore one sievert is thousands of times higher than the annual levels of natural background radiation]);
- *'Moderate doses'* (around hundreds of thousandths of sievert [a thousandth of a sievert is termed 'millisievert']);
- *'Low doses'* (about tens of millisieverts);
- *'Very low doses'* (around a millisievert).

The probabilities are expressed in percentages of between 0 and 100%, where:

- 100% corresponds to the certainty that *the effect will occur*;
- 0% corresponds to the certainty that *the effect will not occur.*

It is to be noted that the probabilities estimated by UNSCEAR are of two distinguishable types:

- *Frequentist probabilities*, which are in the high dose area, based on the truthful and verifiable existence of radiation health effects, and are defined as the limit of the relative frequency of incidence of the effect in a series of certifiable epidemiological studies;

- *Subjective probabilities* (also called 'Bayesian'), which are in the low dose area, are expressed as a possible expectation that radiation health effects might occur, and are quantified by a personal belief or expert's judgement that is not substantiated by the frequency or propensity that the effects actually occur.

Both frequentist and subjective probabilities are mathematically compatible but epistemologically very different: the former is based on *fact* and the latter is based on *conjecture.*

UNSCEAR has highlighted the importance of distinguishing between:

- *Verified observations of health effects* in exposed individuals and populations, which allow such effects to be unambiguously attributed to the exposure situations that generated them;
- *Theoretical projections of health effects*, for which occurrence is feasible but not verifiable—namely those projections only allowing some inferring of risks.

For both situations, it is important to take into account both the uncertainties and the inaccuracies associated with the estimates.

Given the current state of knowledge, certain effects on the health of specific people exposed to radiation, the '*deterministic effects',* can be attributed with confidence if they were diagnosed by a specialist. These effects are usually acute and occur early in individuals exposed to high doses of radiation. They are termed deterministic because they are determined to occur if the dose exceeds a certain threshold value that has already been deemed to be a high dose.

It is also possible to attribute to radiation increases in the normal incidence of certain effects in populations, the '*stochastic effects'* (e.g. increases in the incidence of cancers, which have been observed in populations exposed to high doses). These effects can manifest themselves in certain cohorts exposed to moderate and high doses of radiation, and appear after long periods of latency. They can be attributed to exposure by observing their incidence in affected populations, but only if the observed change in the base incidence of the effects is high enough to overcome statistical and epistemic uncertainties. Owing to the randomness of their appearance, they are called '*stochastic effects'*. The probability of occurrence of stochastic effects is calculated on the basis of the measured frequency of the effects, and it is generically termed 'risk of radiation', or simply 'risk'; such risk is usually expressed as a dimensionless number per unit dose of radiation incurred.

Currently there are no biomarkers available to distinguish whether a stochastic effect in an individual has been caused by exposure to radiation or by another cause, or is simply a natural occurrence. That is, there are no biological specimen standards that allow for specific diagnoses of stochastic effects in individuals. For this reason, stochastic effects are not attributable to the exposure incurred by specific individuals, but only to the collective exposure incurred by a population. Here they are expressed as a change in the base incidence of the effect.

No changes have been confirmed in the incidence of health effects, in situations in which the level of exposure to radiation is low or very low (e.g. in typical situations of exposure to environmental and occupational radiation). Among other reasons, the statistical and epistemic uncertainties of epidemiological studies at low and very low doses make this confirmation impossible.

Notwithstanding this, the silent occurrence of such effects cannot in principle be discarded and a probability might be assigned to such hypothetical occurrence. Thus, *the probability that stochastic effects occur at low and very low doses can only be inferred subjectively through expert judgements*. Therefore, at low and very low doses, it is necessary to make assumptions and use mathematical models to estimate a subjective probability of the occurrence of health effects, which leads to results that are uncertain. This subjective probability is also often referred to as 'risk'.

Consequently, for low and very low radiation doses, UNSCEAR has chosen not to use such mathematical models in its evaluations for projecting numbers of radiation health effects (or even deaths), owing to the resulting unacceptable uncertainties that are intrinsic to the predictions. However, UNSCEAR estimates that these calculations can be applied to make suppositions that can be used for public health comparisons or for radiological protection purposes, provided—as UNSCEAR has warned—that uncertainties are taken into account and limitations are clearly explained.

In summary, as marked with ovals in Fig. 7.1, UNSCEAR made a clear distinction between three separate regions of the dose-response relationship, in relation to the observance of the effects, namely:

- The region where the effects are clinically observable in individuals, through a radiopathological diagnosis and attestation by certification;
- The region where the effects are only statistically observable in populations (but not identifiable in individuals), through radioepidemiological estimates and attestation or certification;

    (in both of these situations the available probabilities are frequentist),
- The region where the effects are not observable but can be biologically plausible, and can only be inferred through the subjective judgement of experts (i.e. subjective probabilities are only possible here).

7.5 Verifiable Facts Vis-à-Vis Subjective Conjectures

It follows from the previous discussion on the paradigm that the abscissa of the dose-response relationship, which quantifies the dose, can be divided into two distinguishable areas, as presented in Fig. 7.2 and described in this section:

- Doses that lead to effects resulting from objectively verifiable facts, that is, truthful instead of interpretable events, those that take place indisputably and are not influenced by personal feelings or opinions;
- Doses that only lead to subjective inferences based on conjectures, that is, on opinions or conclusions based on incomplete information not proven and perhaps influenced by personal feelings or opinions.

It follows that the two distinguishable areas are:

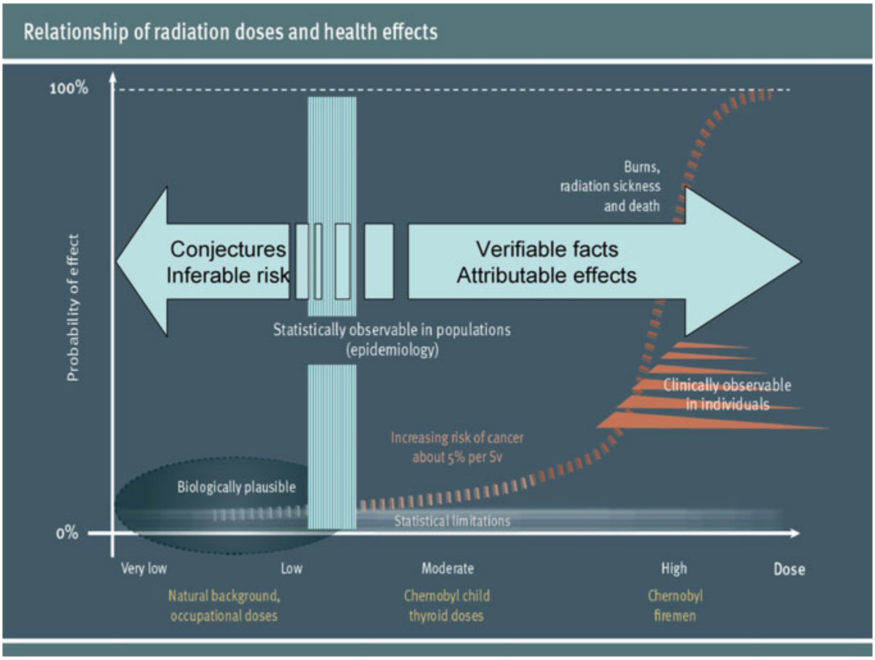

Fig. 7.2 The abscissa of the dose-response relationship divided into two distinguishable areas. *Source* UNEP 2016, p. 25 (adapted)

- The area where it is feasible to attribute effects objectively to radiation exposure situations;
- The area where it is not feasible to attribute effects objectively, although there is the possibility of inferring risks subjectively.

7.6 Attestation

As discussed previously, the attestation of occurrence of radiation effects can be done by radiopathologists for determinist effects in individuals and by radioepidemiologists for stochastic effects on populations. Attestation is not feasible when only expert judgement exists.

The area of the dose-response relationship where the effects are attributable can still be divided into two sub-areas, as follows and as shown in Fig. 7.3.

- In the high dose region, the occurrence of the effects can be *diagnosed* in the exposed individuals.
- In the moderate dose region, only changes in the incidence of effects in exposed populations can be assessed, usually by statistical calculations, namely estimated throughout *epidemiological* studies.

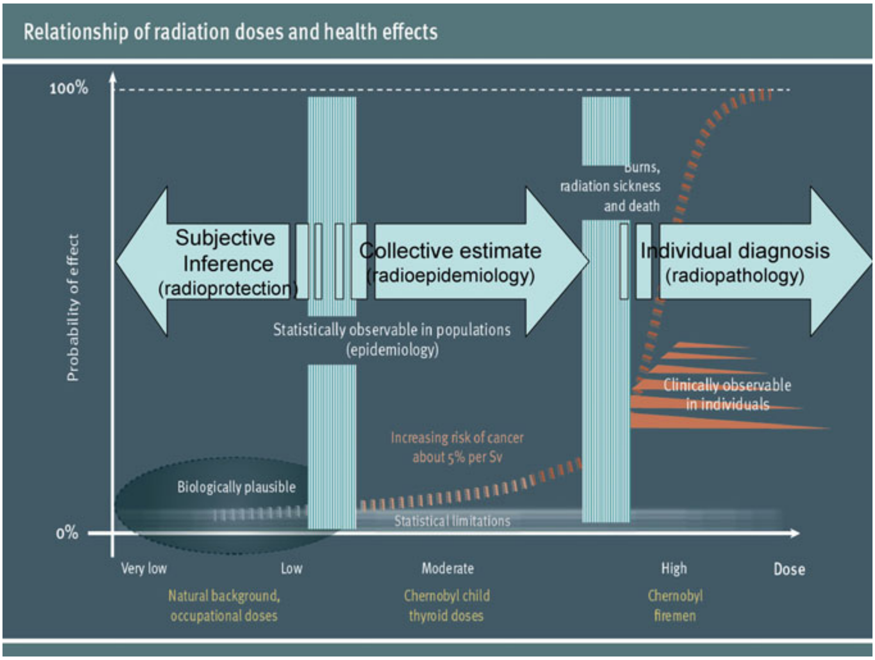

Fig. 7.3 Sub-areas of dose-response relationship where the effects are attributable. *Source* UNEP 2016, p. 25 (adapted)

- In the low and very low dose region, there is only the possibility of *expert judgement* and an extrapolation of knowledge, but there is no possibility of individual diagnosis in the exposed person or of determinations of changes in the collective incidence of effects in the exposed populations by epidemiological studies.

Therefore, a further distinction is possible in the attribution of effects, as presented in Fig. 7.3:

- In the area of the high dose zone, the effects can be attributed individually, that is, it can be diagnosed and attested by pathological procedures that an exposed individual has incurred the effect;
- In the area of the moderate dose zone, the effects can be estimated collectively, that is, it can be evaluated if there is an increase in the incidence of effects in an exposed population, although it is not feasible to diagnose these effects individually;
- In the remaining area of the low dose zone, the effects cannot be attributed, either individually or collectively, although a 'risk' can be inferred expressed as a subjective probability that is not based on measurable frequencies but on personal judgements of experts or regulatory decisions.

As shown in Fig. 7.3, the process requires different professional attestations, as follows:

- Individual attribution of effects can only be made through a diagnosis followed by a certificate of formal attestation issued by a qualified *radiopathologist*;
- Collective attribution of effects can only be done by statistical estimation followed by a certificate of formal attestation by a qualified *radioepidemiologist*;
- Subjective inference of effects might require a consensus opinion of a professional body of relevant specialists, mainly radiobiologists and radioepidemiologists acting as radioprotectionists, who must express their 'expert judgement' about the risks, if any, as well as their uncertainties and limitations; such judgement should be validated by regulatory decisions.

7.7 Legal Consequences

The ability to attribute health effects to specific exposure situations can influence the capability to legally impute damages by those who suffered the effects. The imputation may include assigning liabilities for physical injuries or harmful effects deliberately inflicted on those who cause exposure. For example, workers can impute their employers; members of the public can impute licensees of installations operating in their habitat. However, the legislation related to the attribution of radiation health effects, to the inference of radiation risk and, in particular, to the imputation of damage is inhomogeneous, incoherent and inconsistent among countries as well as in cases held in jurisdictions within a country. An important distinction results from comparing jurisprudential legislation with codified legislation.

The noun *imputation*, the verb *to impute* and its gerund *imputing* are all of very common usage in many legal jurisdictions (e.g. in legal regions of Ibero–America). However, the usage of imputing is not so common in some legal cultures (e.g. in some Anglo–Saxon jurisdictions). Imputation and its derivatives are grammatically correct, as they mean attributing something bad (in this case something bad caused by radiation exposure) to someone (e.g. to employers by radiation exposed workers, or to radiation-related operators by affected members of the public). In sum, imputing means ascribing guilt to someone, be a real or a legal person.[34] Other related terms are used for similar legal purposes, including the following: *suing and prosecuting*, which refer to the institution of legal proceedings following radiation exposure; *charging*, which refers to the formal accusation of a law offence (e.g. violating radiation protection regulations); *indicting*, which is used to mean formally accusing of a crime (e.g. killing a person with radiation); and, of course, *judging*, which is used to mean giving a verdict by a public officer appointed to decide cases in a law court. It is underlined that the descriptions in this chapter are applicable mutatis mutandis to any of these concepts.

[34] The term is derived from the Latin *imputare* meaning to 'enter in the account'.

7.7.1 Jurisprudential (Case-by-Case) Legislation

Case-by-case legislation based on jurisprudential hermeneutics is distinguished from codified statutory legislation by its flexibility. This legislation can easily deal with situations involving deterministic effects and it is malleable to interpret probabilistic situations such as the damage attributable or inferable following radiation exposure at moderate, low and very low doses.

For example, in some countries where this type of legislation prevails, the concept of *assigned share*[35] has been used to settle cases of imputation owing to radiation damage due to stochastic effects.

The *assigned share* is equal to the fraction of the total number of cases of a specific type of cancer diagnosed among individuals that is in excess of the baseline number of cases for persons who share the same attributes, such as absorbed organ dose, age, time since last exposure, sex, smoking history. The assigned share is quantified as the relation between the *excess relative risk* and the *relative risk*.[36] The *assigned share* is often referred to as the 'attributable fraction' or 'probability of causation' assuming that the calculated excess relative risk represents the net consequences of mechanisms of disease manifestation for a given individual diagnosed with disease.

7.7.2 Codified Legislation

Many legal systems in large regions (e.g. in Ibero–America) have 'codified' legislation, namely legislation following the process of compiling and reformulating the law, generally by subject, forming a legal code, that is, a codex of the law. The movement towards codification gained momentum during the Enlightenment and became widespread after the promulgation of the Napoleonic Code.

The codified legal system prevents arbitrariness and discrimination, which was years ago relatively widespread in authoritarian monarchical regimes. However, it must be recognized that a codified legal system is fundamentally a deterministic system, a system which is predetermined by the codification.

Therefore, the codified legal system is tailored to deal with exposure situations leading to deterministic effects, given that there are dose thresholds that define whether an effect is determined to occur or not, namely whether it is attributable

[35] *Assigned share* is used to mean the probability that an observed health effect (either deterministic or stochastic) in an individual was caused by a specific radiation exposure.

[36] *Relative risk* is used to mean the ratio of disease rates in different groups (e.g. an exposed and unexposed group) or for different exposure conditions (e.g. people exposed at high dose rates and people exposed at low dose rates); it is often useful to view the relative risk as a function of variables, such as dose, sex or age (it is noted that while this ratio is commonly called a relative risk, this is a misnomer; it is actually a ratio of rates, as are statistics derived from it); strictly, while the ratios involved are statistically calculated from observed frequencies/rates, the excess relative risk is a prospective estimate inferred from the data and reasoning. *Excess relative risk* is used to mean the *relative risk* minus one, and it is often considered as a function of dose and other factors.

or not. The effect occurrence can be attested unambiguously by a competent expert with credentials in radiopathology and since penalties can be codified, the imputation becomes straightforward. But the system is not completely tailored to deal with probabilistic situations, especially situations of low probability, such as those related to the possible damage of radiation exposure where the probabilities are not even sustained by factual frequencies of occurrences but are just an 'experts' subjective judgement', which is not tailored to codification. The codified legislation is therefore problematic to solve cases of imputation of stochastic effects.

7.7.3 *Individual Imputation Vis-à-Vis Collective Imputation Vis-à-Vis Fictional Imputation*

The imputation of harm associated with radiation exposure continues to be a legal conundrum. It might be simpler to resolve in jurisprudential, case-by-case legal systems but it is particularly cumbersome for codified legislation where case-by-case approaches are not feasible. As presented in Fig. 7.4, the following situations are possible:

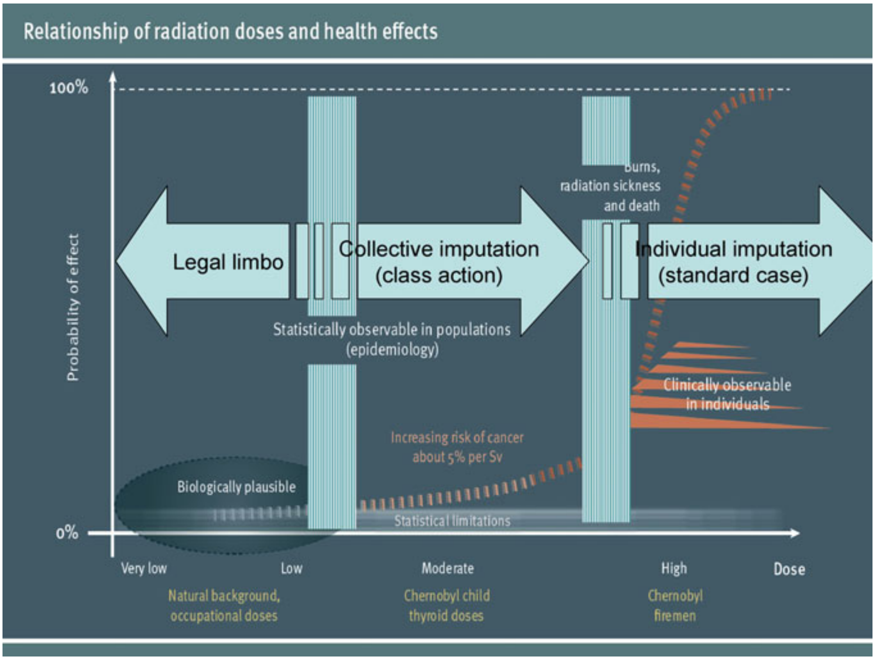

Fig. 7.4 Schematic representation of the ability to impute following different radiation doses is presented. *Source* UNEP 2016, p. 25 (adapted)

- In the high dose region, the imputation is direct from the affected individual to the culprit.
- In the middle dose region, it would seem that only a collective or group imputation is feasible.
- In the low dose region, the situation is at least questionable. Is it possible to impute perceived consequences owing to radiation risks based on subjective judgements?

In the high-dose region, individual health effects are clinically attributable and attestable, and imputation of harm from the affected individual is therefore feasible. In the middle dose region, increased incidences of harmful effects in population groups are epidemiologically attributable and attestable, and imputation from the affected group is therefore feasible. In the low dose area, where radiation harm is neither attributable nor attestable, neither individually nor collectible, but also radiation risk might be inferred, the situation seems to be in a legal limbo.

7.8 Conclusion

After a long journey it seems that the scientific community has reached under UNSCEAR a consensus on the attributability of harm to radiation exposure situations. This important scientific consensus should now be converted into legal instruments that address the issue of legal imputation, and its derivatives of suing, prosecuting, charging, indicting and judging, following radiation exposure situations. While, following these developments, the transit from scientific attribution and inference to legal imputation has been preliminary discussed,[37] it has not yet been crystallized in universal approaches.

The time now seems to be ripe for legal experts to convert into legal guidance the scientific achievements on attribution of radiation effects and inference of radiation risks following radiation exposure situations.

Given the cultural, regulatory and legislative differences among countries, it is considered prudent and necessary to address internationally this legal issue with two fundamental objectives:

(a) Fostering a common legal understanding on policy related to radiation harm attributed to radiation exposure situations;
(b) Exploring the feasibility of a universal legislative interpretation to regulate the application of the law in these situations, which might serve as a potential input to different national legislations.

The onus is now on the legal experts on nuclear law.

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[37] González 2014a.

References

Cardis E, Krewski D, Boniol M, Drozdovitch V, Darby S C, Gilbert E S, Akiba S, Benichou J, Ferlay F, Gandini S, Hill C, Howe G, Kesminiene A, Moser M, Sanchez M, Storm H, Voisin L, Boyle P (2006) Estimates of the Cancer Burden in Europe from Radioactive Fallout from the Chernobyl Accident. International Journal of Cancer 119:1224–35

González A J (1993) The Radiological Health Consequences of Chernobyl: The Dilemma of Causation. In: Nuclear Accidents: Liabilities and Guarantees. OECD/NEA, Paris

González A J (2002) The debate on the health effects attributable to low radiation exposure. Pierce Law Review 1:39–67

González A J (2011) Epistemology on the Attribution of Radiation Risks and Effects to Low Radiation Dose Exposure Situations. International Journal of Low Radiation 8

González A J (2014a) Key Note Address: Imputability of Health Effects to Low-Dose Radiation Exposure Situations. In: Manóvil R M (ed) Nuclear Law in Progress. Legis Argentina S.A., Buenos Aires

González A J (2014b) Clarifying the Paradigm on Radiation Effects & Safety Management: UNSCEAR Report on Attribution of Effects and Inference of Risks. Nuclear Engineering and Technology 46:467–474

González A J (2014c) Clarifying the Paradigm for Protection Against Low Radiation Doses: Retrospective Attribution of Effects Vis-à-Vis Prospective Inference of Risk. Radiation Protection in Australasia 31:2–12

González A J, Akashi M, Boice Jr J D, Chino M, Homma T, Ishigure N, Kai M, Kusumi S, Lee J–K, Menzel H–G, Niwa O, Sakai K, Weiss W, Yamashita S, Yonekura Y (2013) Radiological Protection Issues Arising During and After the Fukushima Nuclear Reactor Accident. Journal of Radiological Protection 33:497–571

International Atomic Energy Agency (IAEA) (1996) One Decade After Chernobyl: Summing up the Consequences of the Accident. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2014) Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. Co-sponsored by European Commission, Food and Agriculture Organization of the United Nations, International Labour Organization, OECD Nuclear Energy Agency, Pan American Health Organization, United Nations Environment Programme, World Health Organization. IAEA Safety Standards Series No. GSR Part 3. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2015) The Fukushima Daiichi Accident. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2018) Report of the 2018 International Symposium on Communicating Nuclear and Radiological Emergencies to the Public. https://www.iaea.org/sites/default/files/19/01/cn-265-report.pdf. Accessed 3 October 2021

International Commission on Radiological Protection (ICRP) (2005) Low dose Extrapolation of Radiation-Related Cancer Risk. Elsevier, Amsterdam

International Commission on Radiological Protection (ICRP) (2007) The 2007 Recommendations of the International Commission on Radiological Protection. Elsevier, Amsterdam

International Labour Organization (ILO), International Atomic Energy Agency (IAEA), World Health Organization (WHO) (2010) Approaches to Attribution of Detrimental Health Effects to Occupational Ionizing Radiation Exposure and Their Application in Compensation Programmes for Cancer: A Practical Guide. ILO, Geneva

OECD Nuclear Energy Agency (OECD/NEA) (1993) Nuclear Accidents: Liabilities and Guarantees. OECD/NEA, Paris

Ten Hoeve J E, Jacobson M Z (2012) Worldwide Health Effects of the Fukushima Daiichi Nuclear Accident. Energy & Environmental Science 5:8743–57

United Nations Environment Programme (UNEP) (2016) Radiation: Effects and Sources. Nairobi, Kenya

United Nations General Assembly (UNGA) (2012) Effects of Atomic Radiation, A/RES/67/112

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2008) Sources and Effects of Ionizing Radiation. Report to the General Assembly with Scientific Annexes. https://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Report_Vol.I-CORR.pdf. https://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Report_Vol.II.pdf. Accessed 3 October 2021

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2012) Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly with Scientific Annexes. https://www.unscear.org/docs/publications/2012/UNSCEAR_2012_Report.pdf. Accessed 3 October 2021

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2013) Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly with Scientific Annexes. https://www.unscear.org/docs/publications/2013/UNSCEAR_2013_Report_Vol.I.pdf. https://www.unscear.org/docs/publications/2013/UNSCEAR_2013_Report_Vol.II.pdf. Accessed 3 October 2021

Waltar A E, Brooks A L, Cuttler J M, Feinendegen L E, González A J, Morgan W F (2016) The High Price of Public Fear of Low-Dose Radiation. Journal of Radiological Protection 36:387

Yablokov A V, Nesterenko V B, Nesterenko A V (2010) Chernobyl: Consequences of the Catastrophe for People and the Environment. In: Sherman-Nevinger J D (ed) Annals of the New York Academy of Sciences. Blackwell, Boston

Chapter 8
The Efficacy of the Global Nuclear Security Legal Regime and States' Implementation Capacity in Light of the Forthcoming Development of Advanced Nuclear Reactor Technologies

Bonnie Denise Jenkins

Contents

Abstract The forthcoming arrival of small modular reactors and other advanced nuclear reactor technologies can be an immensely beneficial development in the world's collective pursuit of energy security and meeting climate change objectives. The key question is whether or not these new reactor technologies significantly alter the fundamental premises underlying the existing nuclear security legal regime. The Convention on the Physical Protection of Nuclear Material and its Amendment (A/CPPNM) are the only legally binding international instruments governing the physical protection of nuclear materials and nuclear facilities. Together the A/CPPNM and the international guidance on nuclear security comprise the current legal framework for nuclear security. This chapter examines whether the A/CPPNM

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adequately covers advanced reactor technologies; and whether the States that are interested in acquiring these new reactor technologies have the capacity to effectively implement the associated legal requirements, regulatory standards, and international guidance that comes along with such technologies. The analysis touches upon the role of the International Atomic Energy Agency (IAEA), the IAEA Nuclear Security Guidance, and issues of cybersecurity.

Keywords Convention on the Physical Protection of Nuclear Material (CPPNM) · The Amendment to the Convention on the Physical Protection of Nuclear Material · Physical protection · Small modular reactors (SMRs) · Advanced nuclear reactor technologies · Cybersecurity · IAEA nuclear security series · Supplier states · Suppliers

8.1 Introduction

As the use of nuclear energy became more widespread in the 1960s and 1970s, the international community became increasingly aware of the need for a shared set of practices to ensure the appropriate physical security of nuclear material under civilian use. At the time, light water reactor technology was the only widely commercialized type of civilian reactor and the international community's efforts to develop nuclear security-related agreements, regulations and guidance were consequently developed with it in mind. Looking into the future, it appears likely that over the next few decades the dominance of light water reactors will fade and give way to advanced reactor technologies, including small modular reactors (SMRs). With this in mind, practitioners responsible for the long term effectiveness of the global nuclear security legal regime are compelled to question if the existing regime will need to be updated. The key question is whether or not these new reactor technologies significantly alter the fundamental premises underlying the existing nuclear security legal regime. Is the scope of the relevant international convention, the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment (A/CPPNM),[1] sufficiently broad to ensure their provisions apply to advanced reactor technologies? Is other relevant international guidance sufficiently broad? Will States that are interested in acquiring these new reactor technologies have the capacity to effectively implement the associated legal requirements, regulatory standards and international guidance that come along with such technologies?

In order to review these questions, we must first examine the A/CPPNM and associated international guidance which together establish our current legal framework. The second key question relates to the ability of States to undertake their primary responsibility for physical security of nuclear material and nuclear facilities under their jurisdiction once these new reactor technologies become a reality. In the end, we

[1] Convention on the Physical Protection of Nuclear Material, opened for signature 3 March 1980, entered into force 8 February 1987 (CPPNM); Amendment to the CPPNM, entered into force 8 May 2016 (A/CPPNM).

believe that there does not need to be widespread revision of the current nuclear security legal regime and related guidance to account for newly emerging civil nuclear reactor technologies and wish to lay out the basis behind that conclusion.

8.2 Reviewing the Primary International Components of the Global Nuclear Security Legal Regime

8.2.1 The Convention on the Physical Protection of Nuclear Material and Its Amendment

In recognition of the growing need for a common set of international standards defining adequate physical security for the international transport of nuclear material, the CPPNM was opened for signature on 3 March 1980, and entered into force on 8 February 1987. By the late 1990s, and particularly subsequent to the events of 11 September 2001, a large number of States maintaining nuclear material recognized the need to expand the scope of the CPPNM to include the physical protection of nuclear material in domestic use, storage and transport, and the protection of nuclear materials and facilities against sabotage. Consequently, States Parties to the CPPNM adopted by consensus an Amendment to the Convention on 8 July 2005, which entered into force on 8 May 2016, in accordance with Article 20.2 of the Convention. The CPPNM and its Amendment together comprise the only legally binding international convention governing the physical protection of nuclear materials and nuclear facilities. In the context of advanced nuclear reactor technologies, it is vital to note that unlike the CPPNM, the A/CPPNM includes nuclear facilities within its scope.

When considering the question of whether the A/CPPNM adequately covers advanced reactor technologies, we must examine Articles 1, 2, and 2A, which relate to its scope. Article 1(d) defines "nuclear facility", for purposes of the A/CPPNM, as "a facility (including associated buildings and equipment) in which nuclear material is produced, processed, used, handled, stored or disposed of, if damage to or interference with such facility could lead to the release of significant amounts of radiation or radioactive material".[2] Article 2 states that the Convention "shall apply to nuclear material used for peaceful purposes in use, storage and transport and to nuclear facilities used for peaceful purposes".[3] Article 2A requires that each State Party shall "establish, implement and maintain an appropriate physical protection regime applicable to nuclear material and nuclear facilities under its jurisdiction with the aim of: (a) protecting against theft and other unlawful taking of nuclear material in use, storage and transport;… [and] (b) protecting nuclear material and

[2] A/CPPNM, above n.1.

[3] A/CPPNM, above n.1.

nuclear facilities against sabotage".[4] Article 2A(3) also requires each State Party to apply a set of Fundamental Principles of Physical Protection of Nuclear Material and Nuclear Facilities.

Several of these Fundamental Principles relate to the nature of the nuclear facility in question. Fundamental Principle F (Security Culture) provides that "[a]ll organizations involved in implementing physical protection should give due priority to the security culture, to its development and maintenance necessary to ensure its effective implementation in the entire organization."[5] Fundamental Principle G (Threat) provides that a State's physical protection "should be based on the State's current evaluation of the threat."[6] Fundamental Principle H (Graded Approach) states, in part, that physical protection requirements "should be based on a graded approach, taking into account the current evaluation of the threat ... and potential consequences associated with ... sabotage against ... nuclear facilities."[7] Fundamental Principle I (Defence in Depth) provides that a State's physical protection "should reflect a concept of several layers and methods of protection ... that have to be overcome or circumvented by an adversary in order to achieve his objectives."[8]

With these requirements identified, we must turn to examining if any of them suggest changes are in order in light of forthcoming advanced reactor designs. The definition of "nuclear facility" in Article 1 of the A/CPPNM does not specify any type of nuclear technology or the nature of the operation of the reactor. The requirements of Article 2 do not impose any such limits either. Article 2A's specific requirements related to theft, unlawful taking and sabotage similarly do not limit the scope of their applicability based on the type of facility or reactor technology in any way. Fundamental Principles F, G, H and I therefore all contain sufficiently inclusive language so as to obviate the need to amend them for the purpose of capturing these new technologies.

Accordingly, no amendments to the A/CPPNM would be required to adequately cover future advanced reactor technologies within its scope.

8.2.2 INFCIRC/225/Rev.5

In 1975, the IAEA Director General convened a group of experts to review a draft booklet of recommendations for IAEA Member States for the physical protection of nuclear material.[9] These recommendations were subsequently updated and brought to the attention of IAEA Member States in the form of INFCIRC/225[10] published

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[4] A/CPPNM, above n.1.

[5] A/CPPNM, above n.1.

[6] A/CPPNM, above n.1.

[7] A/CPPNM, above n.1.

[8] A/CPPNM, above n.1.

[9] IAEA 1975.

[10] Ibid.

in September 1975. In the ensuing years, INFCIRC/225 has been significantly updated and expanded in scope. The current version is published as Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev.5)[11] and was released in January 2011. INFCIRC/225/Rev.5 reflects the IAEA's most thorough and comprehensive set of recommendations on the physical protection of nuclear material and nuclear facilities. It is an important step forward as it provides guidance for the first time on a number of new issues, including protecting digital systems used for physical protection, nuclear safety, and nuclear material accountancy and control against a cyberattack.[12] Revision 5 also references concern about insider threats and stresses the importance of developing an appropriate security culture within a State's nuclear programme.[13]

While Sections 1 and 2 are introductory in nature, Section 3 of INFCIRC/225/Rev.5 lists the elements of a State's physical protection regime for nuclear material and nuclear facilities and corresponds to the Fundamental Principles in the A/CPPNM. How these elements are applied will depend on what type of nuclear facility is in question. Section 3 recommends the creation of a threat assessment and, if appropriate, a design basis threat. It recommends that physical protection requirements should be based on a graded approach taking into account the nature of the nuclear material, and the potential consequences associated with the unauthorized removal of material and with the sabotage of the nuclear material or facility.[14] The section recommends that physical protection reflect a concept of several layers of protection that have to be overcome by an adversary,[15] and stresses the need to prioritize the development and maintenance of a security culture.[16]

Section 4 of INFCIRC/225/Rev.5 reviews in greater detail requirements for measures against unauthorized removal of nuclear material in use and from storage. Section 4.9 recommends that the physical protection system of a nuclear facility should be integrated and effective against both sabotage and unauthorized removal.[17] Sections 4.13–4.49 list specific physical security recommendations for facilities holding Category I material, but the recommendations do not have applicability to any specific reactor technology. Section 5 lists specific requirements for measures against sabotage of nuclear facilities and nuclear material in use or storage. It highlights a number of different ways in which the physical protection system of a facility can be designed in order to mitigate the risks of sabotage.[18] The section also highlights a number of spatially related issues (e.g. establishment of specifically defined

[11] IAEA 2011.

[12] Bunn et al. 2020.

[13] Ibid.

[14] IAEA 2011.

[15] Ibid.

[16] Ibid.

[17] Ibid.

[18] Ibid.

and distinct areas, vehicle barriers installed at an appropriate distance from vital areas) but none that are limited to any specific reactor technology.[19]

In sum, a detailed review of the specific provisions of Sections 3–5 of INFCIRC/225/Rev.5 reveals that while there are many recommendations that pertain to the construction and operation of a nuclear facility, none of its provisions are specific to the type of nuclear facility. Accordingly, it is not foreseen that any changes will need to be made to INFCIRC/225/Rev.5 for the specific purpose of capturing advanced reactor designs.

8.2.3 IAEA Nuclear Security Series

In March 2002, the IAEA Board of Governors approved the Agency's first "Nuclear Security Plan (for 2002–2005)."[20] The Plan included the development of "standards, guidelines, and recommendations" across the broadened scope of the Agency's nuclear security activities as approved by the Board.[21] That same year, the IAEA Director General established a group of experts to provide advice on the content and priorities of the IAEA's nuclear security activities—the IAEA Advisory Committee on Nuclear Security (AdSec). Upon the Board's adoption of the Plan, AdSec became immediately involved in the development of such standards, guidelines and recommendations.[22] With AdSec's recommendation, the IAEA Publications Committee approved the establishment of the Nuclear Security Series in 2004.[23] From 2006 onward, IAEA Nuclear Security Series publications have been issued in the following four categories:

- Nuclear Security Fundamentals to contain objectives, concepts and principles of nuclear security and provide the basis for security recommendations;
- Recommendations to present best practices that should be adopted by Member States in the application of the Nuclear Security Fundamentals;
- Implementing Guides to provide further elaboration of the Recommendations in broad areas and suggest measures for their implementation;
- Technical Guidance publications to include: Reference Manuals, with detailed measures and/or guidance on how to apply the Implementing Guides in specific fields or activities; Training Guides, covering the syllabus and/or manuals for IAEA training courses in the area of nuclear security; and Service Guides, which provide guidance on the conduct and scope of IAEA nuclear security advisory missions.[24]

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[19] IAEA 2011, paras 5.25–5.31.

[20] IAEA Nuclear Security Guidance Committee (NSGC)—Chairman's Report of the NSGC's First 3-Year Term (2012–2014), p. 6.

[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] Ibid.

Both the Nuclear Security Fundamentals and Recommendations documents are written at high levels and consequently, neither the Fundamentals nor any of the Recommendations documents are sufficiently detailed to be reactor design-specific in any way. The Implementing Guides and the Technical Guidance are more detailed in nature, and accordingly, it is appropriate to examine a few of the most likely documents to contain such language.

Nuclear Security Series (NSS) Implementing Guide No. 8-G (Rev. 1) entitled Preventive and Protective Measures Against Inside Threats discusses specific protective measures related to detection, delay, response and emergency plans but there are no reactor technology-specific provisions.[25] NSS Implementing Guide No. 10-G (Rev. 1) entitled National Nuclear Security Threat Assessment, Design Basis Threats and Representative Threat Statements provides guidance on conducting threat assessments and developing and maintaining a design basis threat for a specific facility but it does not include any reactor technology-specific recommendations.[26] NSS Implementing Guide No. 27-G entitled Physical Protection of Nuclear Material and Nuclear Facilities (Implementation of INFCIRC/225/Revision 5) is the lead Implementing Guide in a suite of guidance to States on implementing the recommendations of INFCIRC/225/Rev.5. However, it too does not reach the level of specificity where reactor technology-dependent language is utilized. Accordingly, as with the A/CPPNM and INFCIRC/225/Rev.5, all existing provisions in the NSS guidance are sufficiently inclusive to capture advanced nuclear reactor technologies.

Taken as a whole, the international community's existing set of legally binding agreements and guidance is sufficiently broad to account for the advent of advanced nuclear technologies. That said, complexities may arise in how individual States implement the aforementioned requirements and guidance in a way that effectively meets the specific nuclear security challenges and risks in their territory. As States construct and operate these new reactors, lessons will be learned and updated or additional IAEA guidance at the Implementing Guide and/or Technical Guidance level may prove useful.

8.2.4 Cybersecurity

Beyond the specific Convention and related guidance described earlier, there is one unique subject that merits particular consideration: cybersecurity. At this time, all advanced nuclear reactor designs are forecasted to include digital automation as an integral component of their operations. As a consequence of this automation, the risks of a cybersecurity-related incident increase. The IAEA has previously published several relevant Implementing Guides and Technical Guidance (which refers to cybersecurity as computer security) that bear directly and/or indirectly on

[25] IAEA 2020.

[26] IAEA 2009.

developing mitigation techniques to thwart cybersecurity risks. The existing Implementing Guides and Technical Guidance are written broadly enough to apply to advanced reactor technologies, but as these new technologies become available online, the IAEA and its Member States should consider the benefits of developing additional specific Implementing Guides or Technical Guidance on the specific cybersecurity-related challenges to the physical security of advanced reactor designs.

8.3 Reviewing the Ability of States to Implement any New Nuclear Security-Related Requirements or Guidance

In addition to considering the adequacy of international legal requirements and recommendations related to nuclear security to cover advanced reactor designs, the second key question is whether States interested in acquiring these new technologies will have the capacity to effectively implement the associated legal requirements, regulatory standards, and complementary guidance that comes with such technologies. As the responsibility for the establishment, implementation and maintenance of a physical protection regime rests entirely with the State, if it lacks such a capacity, what are some ways to assist States to acquire it? While the global nuclear security legal regime is sound, there is a continuing need to strengthen domestic legal and regulatory frameworks.

8.3.1 Role of Supplier States and Suppliers

In the design and construction of new reactor technologies, both supplier States (through their licensing authorities) and suppliers must be mindful of all elements of an adequate nuclear security system, including security culture, threat (including the development of an appropriate design basis threat), a graded approach, and defence in depth principles as discussed earlier. As representatives of governments, licensing authorities carry the ultimate responsibility for ensuring that the supply of these reactors occurs in accordance with the highest global standards of safety, security and non-proliferation. Accordingly, licensing authorities have a heightened and specific duty to ensure that physical security considerations specific to these new technologies are factored into their decision making process. They should proactively assert to suppliers the importance of incorporating security culture, threat, graded approach and defence in depth principles into their reactor designs. Similarly, suppliers should be encouraged to consult with their licensing authorities early on to ensure that reactor designs are consistent with international legal requirements and guidance.

The United States of America (USA) takes these responsibilities very seriously and has been preparing for the nuclear security-related implications of advanced reactor technologies for many years. The US Nuclear Regulatory Commission (NRC) has been focused on the licensing impacts of these technologies and has created a number of internal working groups to study their implications and its ability to license them in a comprehensive and timely manner. In 2019, the NRC identified the need to amend its regulations to develop more specific physical security requirements for advanced reactors. This action was designed to provide a "clear set of performance-based requirements and guidance for advanced reactor physical security" as well as "establish greater regulatory stability, predictability, and clarity" for advance reactor licence applicants.[27]

Working with NRC, the US nuclear industry also engaged as early as 2015 to meet the forthcoming changes in nuclear security practices due to the rise of advanced nuclear technologies. The US Nuclear Energy Institute, a Washington, DC based policy organization of the nuclear technologies industry, published two white papers in November 2015 and December 2016, respectively, proposing new physical security requirements for advanced reactor concepts and urged the NRC to use the paper as a basis for rulemaking. NRC continues to collaborate with US nuclear industry officials as NRC works to undertake the rule-making cited previously.

Bilateral government-to-government cooperation in this area is another vehicle for ensuring operating States have the tools they need. The USA, for its part, provides a broad array of bilateral and multilateral nuclear security-related assistance. For decades, the US Department of Energy and NRC technical experts have engaged with foreign partners to help ensure the security of partners' nuclear facilities and plans to continue this type of cooperation going forward as new reactor designs emerge. The USA engages bilaterally with nuclear cooperation partners as they consider the potential of advanced reactor technologies. In April 2021, the White House announced the USA's most recent initiative in this regard at the Leaders' Climate Summit: the Foundational Infrastructure for Responsible Use of Small Modular Reactor Technology (FIRST) programme. The FIRST programme provides capacity building support consistent with the IAEA Milestones Approach to enable partner countries to benefit from advanced nuclear technologies and meet their clean energy goals under the highest standards of nuclear security, safety and non-proliferation.

8.3.2 Role of the IAEA

In addition to the bilateral government-to-government and public–private sector partnerships described earlier, the IAEA will also need to play an integral role in assisting States, at their request, to meet their physical security obligations at advanced reactor facilities.

The IAEA should be prepared to provide advisory services through its International Physical Protection Advisory Service (IPPAS) and International Nuclear Security Advisory Service (INSServ) missions. It should also offer training to interested Member States on any identified specific challenges associated with advanced

[27] United States Nuclear Regulatory Commission 2019.

reactor designs. Finally, the IAEA should also work to ensure that as users of these new technologies gain more experience globally, it will serve not only as the repository of that collective wisdom but also as an active disseminator of guidance and good practices to all users through various outreach activities. IAEA Member States must ensure that the IAEA has sufficient resources to develop needed guidance and provide appropriate training and advisory services to assist Member States who choose to access these technologies.

8.4 Conclusion

The forthcoming arrival of small modular reactors and other advanced nuclear reactor technologies can be an immensely beneficial development in the world's collective pursuit of energy security and meeting climate change objectives. For these technologies to successfully contribute to these goals, all stakeholders in the global civil nuclear cooperation community must be actively involved in this process. Fortunately, our existing global nuclear security-related legal regime is already properly designed to facilitate these benefits. In order to ensure that States can access these benefits, they must work collaboratively with supplier States, suppliers and the IAEA. It is only through the concerted and thoughtful efforts of everyone involved that we will ensure that as these new reactors come to market, the States operating them have the tools to ensure adequate physical security at their facilities.

References

Bunn M, Holgate L, Kovchegin D, Tobey W (2020) IAEA Nuclear Security Recommendations (INFCIRC/225): The Next Generation. https://www.stimson.org/2020/iaea-nuclear-security-recommendations-infcirc-225-the-next-generation. Accessed 11 October 2021

International Atomic Energy Agency (IAEA) (1975) The Physical Protection of Nuclear Material, INFCIRC/225. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2009) Development, Use and Maintenance of the Design Basis Threat, IAEA Nuclear Security Series No. 10-G (Rev. 1). IAEA, Vienna

International Atomic Energy Agency (IAEA) (2011) Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5). IAEA, Vienna

International Atomic Energy Agency (IAEA) (2020), Preventive and Protective Measures Against Inside Threats, IAEA Nuclear Security Series No. 8-G (Rev. 1). IAEA, Vienna

United States Nuclear Regulatory Commission (2019) Physical Security for Advanced Reactors—Regulatory Basis for Public Comment.

Chapter 9
Building a Nuclear Security Regime: Questions to Be Asked

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Contents

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Abstract This chapter outlines some of the key questions to be asked by a State when considering a nuclear programme and thus a nuclear security regime. In the context of globalization and the emergence of a world in which States are interdependent, it is recognized that the way one State carries out its mission to protect nuclear materials and nuclear activities concerns other States also. In response to this, and despite the reluctance of States to expose their sovereign security practices, an international framework, composed of legally binding or non-binding tools, has been built up with the idea of promoting greater consistency and thus providing guarantees to all States. It is also important, for this one State, to comprehend the national and international context beyond nuclear security within which it falls. This State has then to question itself, in the light of security issues and the fundamental principle of State sovereignty, on the essential concepts that are found in certain components of the nuclear field, such as the positioning of the competent authority, the protection of information, transparency or the place of the operator.

Keywords Nuclear security · Nuclear security regime · Threat assessment · Design basis threat (DBT) · International framework · Legislative and regulatory framework · State sovereignty and responsibility · Convention on the Physical Protection of Nuclear Material (CPPNM) · 2005 amendment to the CPPNM · Prescriptive approach · Performance-based approach · Transport · Confidentiality

9.1 Introduction

The field of nuclear energy, and more particularly that of civil nuclear energy, leads a State to take into account multiple components when it considers setting up nuclear facilities or activities for industrial (nuclear energy for instance), medical or research purposes. Preventing any risk of unacceptable consequences for the population and the environment is one of the fundamental elements that a State must take into consideration at all times during its nuclear programme. This fundamental element has three components: nuclear safety and radiation protection, the guarantee of the peaceful use of nuclear activities (safeguards), and nuclear security.

Nuclear security was historically developed in the context of the Cold War, when the predominant threat was the use of nuclear materials to make a nuclear weapon.

This context led to the establishment of an international framework dedicated to the fight against nuclear proliferation (notably with the signing of the Non-Proliferation Treaty, which entered into force in 1970).[1] This framework sets out the obligations that a State must implement to prove that its facilities and the nuclear activities it carries out are not misused and that nuclear materials are not diverted by this State from their peaceful uses. To complement this principle of safeguards, nuclear security was initially developed to prevent the risk of theft and misappropriation of nuclear materials used in nuclear activities by malicious persons. Afterwards, this concept has been extended to all malicious acts and terrorist actions that could lead to radiological consequences. This includes sabotage of nuclear materials and other radioactive substances, of their facilities and transportation, as well as the risk of theft or misappropriation for the manufacture of radiological dispersion devices. It is therefore commonly accepted that the term nuclear security covers the prevention, detection and response to any act of theft, sabotage, unauthorized access, illicit trafficking or any other form of malicious act involving nuclear materials, radioactive substances or nuclear facilities.

The last decades have marked the international stage by the universalization of the challenges and a world where States are more and more economically, politically and socially interdependent. Therefore, multilateralism is a necessary step to meet some of these challenges.

The nuclear field is particularly concerned by this statement because of its universalization and the risks to go beyond the strict framework of the borders of a State. Terrorism is a mode of action and sometimes an objective. No State can escape from it. Everyone must therefore be prepared for this highly evolving threat, which follows and takes advantage of the slightest technological developments. The nuclear industry can be a prime target for this type of action, not only because of the consequences but also because of its impact on the population. This is why nuclear terrorism can take various forms.

Because of the universalization of nuclear challenges, it is commonly accepted that the way one State carries out its mission to protect nuclear materials, radioactive substances or nuclear facilities concerns other States also. That is the reason why, over the last three decades, a number of international instruments (legally binding, such as the Convention on the Physical Protection of Nuclear Material (CPPNM) and its 2005 Amendment,[2] or non-binding, such as codes of conduct or the IAEA's series of recommendations on nuclear security) have been drawn up. This international framework aims at both helping the States to strengthen their nuclear security regime and providing guarantees to others. This requires particular attention to consistency in the provisions put in place for this area of high challenges.

[1] Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968, entered into force 5 March 1970 (NPT).

[2] Convention on the Physical Protection of Nuclear Material, opened for signature 3 March 1980, entered into force 8 February 1987 (CPPNM). Amendment to the CPPNM, entered into force 8 May 2016 (A/CPPNM).

However, it is important to note that what falls within the scope of national security corresponds to the fundamental principle of a State's sovereignty. The nuclear security measures put in place by a State, although they also aim to meet international objectives, are initially part of a national approach to protect its populations and its environment, related to its local context. Thus, the fundamental concept of sovereignty, which responds to the principles of the Westphalian system at the origin of the current international system, remains an essential element in the development of the international framework and in the work carried out in the various multilateral forums.

The purpose of this chapter is to present the important steps that a State wishing to establish a nuclear programme must take into account to build a nuclear security regime that responds, on the one hand, to its national context and challenges, and on the other hand, to the recommendations and good practices set by the international framework.

9.2 State Sovereignty and Responsibility

9.2.1 What Place for Nuclear Security Within the State's Global Security System?

It is internationally recognized that responsibility for nuclear security rests entirely with a State, as specified by two principles of the 2005 Amendment to the CPPNM[3]:

> FUNDAMENTAL PRINCIPLE A: Responsibility of the State
>
> The responsibility for the establishment, implementation and maintenance of a physical protection regime within a State rests entirely with that State.
>
> FUNDAMENTAL PRINCIPLE B: Responsibilities During International Transport
>
> The responsibility of a State for ensuring that nuclear material is adequately protected extends to the international transport thereof, until that responsibility is properly transferred to another State, as appropriate.

Nuclear security is an important component of national security and as such, it is fundamentally the role of a State. Since at least the 19th century, States have increasingly understood defence and security in a global way, war and economy being intrinsically linked.

Similarly, it is no longer possible to dissociate internal and external security. Recent events only confirm that external actions have a strong influence on internal security and vice versa. For example, the rise of the terrorist threat in France in recent years is inextricably linked to the international context and in particular to the actions of Al Qaeda and the self-proclaimed Islamic State, as well as to French policy against these organizations.

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[3] A/CPPNM, above n. 1, Article 2a, para 3.

Thus, there is a continuum between crime, terrorism and State threats, and these different components of threats may have strong links.

In this context, nuclear materials, facilities and transportation, as well as the development of a nuclear programme, can represent important targets. To illustrate this, we can consider the computer attack carried out with the Stuxnet worm in 2010 on a uranium enrichment facility in the Islamic Republic of Iran, or the reading of Anders Breivik's manifesto,[4] which calls for "using European nuclear power plants as a weapon of mass destruction".

Thus, a State that wishes to develop a nuclear programme will have to consider very early on the impacts of this programme on its defence and national security.

The first question to ask is the risk acceptance associated with nuclear power. The establishment of a nuclear security regime will therefore be an essential part to manage threats and risk. It should be borne in mind that the lower the risk that a State is prepared to accept, the higher the level of protection will be and therefore the more expensive it will be. Moreover, this level of acceptable risk, an eminently political choice, must be periodically confronted with changes in threats. Thus, in France, over the last few years, the combined effect of a greater demand for risk control by the population and a high level of threat has led to a very significant increase in the level of security required, and consequently in the human and financial efforts, both for the State and for nuclear operators. This aspect should not be underestimated because the cost of security can be significant and must therefore be taken into account in the economics of a project.

The State already has laws, regulations and institutions in place to deal with national security. It will therefore have to determine how to integrate nuclear security into this context (see Sect. 9.5.3) to establish its regime. For example, in France, nuclear security is regulated by the Code of Defence,[5] which includes aspects related to the physical protection of nuclear materials, their installations and their transport (Article 1333) and aspects related to the protection of vital installations (Article 1332), dedicated to economic defence. Nuclear security is consequently dealt separately from nuclear safety, which is covered by the environmental code considering the prevention of pollution and environmental risks.

The fact that nuclear security is primarily a matter for States is significant, because it imposes particular constraints that are less common for nuclear safety. Indeed, if the responsibility for the implementation of safety can be entirely given to the operators, this is not the case for security, which always requires State resources. The choices made by the States will have a strong influence on the way to develop international cooperation (see Sect. 9.4), the legislative and regulatory framework (see Sects. 9.5.3 and 9.6) and communication (see Sect. 9.9).

[4] Breivik 2011.

[5] Code de la Défense 2021, pp. 236–252. https://codes.droit.org/PDF/Code%20de%20la%20d%C3%A9fense.pdf. Accessed 30 August 2021.

9.3 The Threat: Threat Assessment and Design Basis Threat

9.3.1 Against What Do We Need to Protect Ourselves?

One of the main markers of a State's sovereignty in the field of nuclear security is its design basis threat (DBT). This is generally national and confidential security information, which is protected accordingly.

Regardless of the fact that a protection system for nuclear activities must meet obligations of means (prescriptive approach) or objectives of results (performance-based approach), the purpose is always the same: to protect against an identified and characterized threat.

Among the many responsibilities of a State, a primary question will be to identify the threats that its country faces and therefore that could affect its activities. This analysis requires the involvement of government services and agencies in charge of national security (e.g. police, intelligence, cybersecurity). It must be based on known events in the country but must also include what is happening abroad.

9.3.2 What Security Burden to Be Placed on the Operator? What Level of Threat to Be Taken Into Account for Nuclear Security Regulations?

When it comes to protecting specific activities, such as those related to the nuclear sector, which are particularly relevant to the terrorist threat, the State faces a political choice. It is difficult to imagine, considering the exhaustiveness of the threats identified, that a State would decide to place the protection of nuclear activities exclusively on its operators. The State can therefore decide either to carry sole responsibility or to adopt a complementary approach between the public authorities and the operators. The use of the first solution by a State would lead to a complete disengagement of the operators, which would not make sense.

Effective security cannot exist without the benefit of the knowledge and experience of the operators, especially when dealing with facilities as technically and organizationally complex as those that we find in the nuclear sector (e.g. interfaces between security and other risks inherent to the facility). The insider threat is a relevant example that highlights the major role of operators both to prevent the emergence of such a threat within their own organization, but also to protect themselves as effectively as possible from it (anticipatory measures). It is true that the State plays an essential role, particularly in the context of a trustworthiness programme, but alone it would not be effective.

Thus, it is commonly accepted by the international community that a complementary approach is preferable to ensure the protection of a nuclear activity. This is particularly expressed in security plans aimed at defining the strategies adopted to detect, slow down, stop the progression and neutralize the threat. In this situation, the State must decide which of the previously identified threats the operator must be able to respond to with its own resources. This is generally referred to as the design basis threat, or DBT, used for the design and evaluation of protection systems in the IAEA recommendations.

9.3.3 How to Take Into Account the Threat From the Design Phase?

To be effective, nuclear security must be considered as early as possible in the design of a project (whether it is a new activity or a modification of an existing activity).

This implies that States must begin by defining a DBT when they wish to embark on a nuclear programme. The applicable national legislative and regulatory provisions must be added to this DBT. This set of elements is essential for any State wishing to promote a 'security by design' approach. This approach is achieved by combining an inherently secure design with inherent features of the facility that will help reduce the number of targets, allow better mitigation of the potential consequences of the remaining vulnerabilities, and thus facilitate proactive physical protection to address the facility's vulnerabilities. Such a 'security by design' approach is qualified as an 'integrated approach' since it includes safety aspects and maintenance in addition to nuclear security.

Threat modes of action and means evolve over time. The concept of 'security by design' makes it easier to take into account both current threats and to anticipate their evolution during the lifetime of a facility. For example, space can be designed for additional physical protection systems. In the continuity of the constant evolution of the threat, it is relevant for a State to periodically foresee a re-examination of its DBT and of the obligations of the legislative and regulatory framework that result from it.

As mentioned above, this DBT applies to the operator, but it is also an essential element for the State internal security forces concerned. As part of a complementary approach, the State internal security forces can intervene on the facility to provide assistance to the operator's forces to secure the area, or to stop the security crisis.

Some threats, such as cyberattacks or even overflights of drones, are means available to malicious persons to make more difficult or even prevent the intervention of State internal security forces. It will then be relevant to identify appropriate interdisciplinary practices to enable an effective response in all circumstances and to define coordinated strategies for managing potential malicious acts.

9.4 The International Framework

9.4.1 How Does Nuclear Security Fit in at the International Level?

The objective of nuclear law, as presented in the literature,[6] is to provide a legal framework to conduct activities, which involve nuclear energy and ionizing radiation in a manner that adequately protects individuals, property and the environment. As mentioned above, the universalization of civil nuclear issues has led to the development of a number of international instruments, both to help strengthen physical protection and to promote greater coherence in the provisions of the nuclear field. However, nuclear security, like the other components of the nuclear field, brings together several tools (legally binding or not), both at the international and national levels (see Sect. 9.5.3). At the international level, each of these different components responds to specific logics and aims to achieve broader objectives related to security, or even to other areas closely linked to nuclear security, without this being its main concern. It is therefore necessary for a State to be able to know and understand these important interfaces in order to adopt a policy that meets both national needs and expectations, while responding to the various international concerns.

To understand the international framework for nuclear security, it is necessary to begin with the United Nations (UN), whose history is linked to that of nuclear power. The very first resolution adopted by the UN General Assembly on 24 January 1946,[7] was to establish a committee to deal with the problems raised by the discovery of atomic energy and other related issues. The normative role of the UN to fight against terrorism has led them to take a large number of decisions, often in the form of resolutions. Among these various resolutions, some relate to nuclear security. For example, UN Security Council Resolution 1540 (2004),[8] although primarily concerned with preventing the proliferation of nuclear weapons, refers to measures “required by the Convention on the Physical Protection of Nuclear Materials and those recommended by the IAEA Code of Conduct on the Safety and Security of Radioactive Sources”. It calls on States to “develop and maintain appropriate effective physical protection measures”. With its resolution 51/210 of December 1996,[9] the United Nations initiated three international treaties that are relevant to the international framework for nuclear security: the International Convention for the Suppression of Terrorist Bombings, the International Convention for the Suppression of the Financing of Terrorism and the International Convention for the Suppression of Acts of Nuclear Terrorism.[10]

[6] Stoiber et al. 2003.

[7] UNGA 1946.

[8] UNSC 2004, pp. 2–3.

[9] UNGA 1997.

[10] International Convention for the Suppression of Terrorist Bombings, opened for signature 12 January 1998, entered into force 23 May 2001. International Convention for the Suppression of the

The main objective of the International Atomic Energy Agency (IAEA) is to promote, together with its Member States, the safe, secure and peaceful use of nuclear technologies and applications. To this end, it encourages Member States to ratify the conventions and codes of conduct of which it is the depository. It also conducts a wide ranging assessment of nuclear security, needs, priorities and threats, particularly those related to terrorism. The IAEA thus supports the establishment of international partnerships and networks. It also develops non-legally binding instruments, consisting of recommendations, guides and technical or operational procedures that form the Nuclear Security Series of publications. The IAEA also offers services to States, such as the International Nuclear Security Advisory Service (INSServ). This service is designed to assist States in establishing and maintaining effective nuclear security regimes. There is also the International Physical Protection Advisory Service (IPPAS) programme, which is a fundamental element of the IAEA's nuclear security strategy. It proposes assistance to Member States, upon request, in evaluating their physical protection regimes. This evaluation includes a review, at the national level, of the legal and regulatory framework, as well as the measures and procedures implemented in facilities and during transport to meet regulatory requirements. The assessment is based on the requirements defined in international instruments, as well as in IAEA recommendations and guidance. These include the main texts listed here, together with all other relevant IAEA documents, including the Nuclear Security Series of publications or other guidance/recommendations: the CPPNM and its 2005 Amendment, the Fundamental Principles and Objectives of Physical Protection (IAEA GOV/2001/41),[11] the IAEA's Code of Conduct on the Safety and Security of Radioactive Sources,[12] as well as IAEA Nuclear Security Series publications No. 20, No. 13 and No. 14.[13]

The CPPNM is an international treaty adopted on 26 October 1979. It came into force on 8 February 1987.[14] It is one of many international tools against terrorism and remains the only legally binding instrument dedicated to the physical protection of nuclear materials. It is a convention whose technical provisions deal with the protection of nuclear materials during international transport, while its penal provisions, and those relating to judicial cooperation, are also applicable to nuclear materials in use, storage or transport on national territory. In 2005, an amendment to the CPPNM was adopted. It aims, in particular, to extend the scope of application of the CPPNM to nuclear materials in use, storage and transport on national territory. It also introduces the twelve fundamental principles of the physical protection (responsibility of the State, responsibilities during international transport, legislative and regulatory framework, competent authority, responsibility of the licence holders, security

Financing of Terrorism, opened for signature 10 January 2002, entered into force 10 April 2002. International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 September 2005, entered into force 7 July 2007.

[11] Fundamental Principles and Objectives of Physical Protection (IAEA GOV/2001/41).

[12] IAEA 2004.

[13] IAEA 2011a, b, 2013.

[14] CPPNM, above n. 1.

culture, threat, graded approach, defence in depth, quality assurance, contingency plans, and confidentiality). Therefore, when a State considers embarking on a civil nuclear programme, it is strongly recommended that it becomes Party to these two international instruments: the CPPNM and its Amendment.

9.4.2 How to Manage Interfaces?

This brief introduction, which defines the main tools that constitute the international framework for nuclear security, illustrates that nuclear security is intrinsically linked to a much larger set of international laws that address specific concerns and that may sometimes go beyond the nuclear sector.

Nuclear security is only one part of the nuclear issues. An identical situation exists for nuclear safety and radiation protection, as well as for safeguards. These different components, although responding to a common objective of protecting the population and the environment from the risks represented by nuclear energy, have their own goals and therefore have their own logic. It is therefore important to identify and evaluate the necessary interfaces so that each of the components can achieve its fundamental objective without compromising the global finality. The current international organization consists in allowing the development of an international framework specific to each component of the nuclear sector under the supervision of a single organization, the IAEA. The IAEA has put in place an organization that allows experts from the different Member States to efficiently build and develop the international framework related to their field of specialization. This allows them to take into account the considerations of other related fields outside the nuclear sector, while providing the necessary bridges to identify and deal efficiently with the interfaces with the other components of the nuclear field. This approach avoids the situation where all nuclear issues are brought together under a single international framework. Although this approach could be understood from the point of view of interface management, it may have disadvantages that should not be overlooked.

One of the main risks would be to fall into a restrictive nuclear approach, with the effect of distancing experts from a particular field in favour of generalist profiles. Such a situation would not allow the necessary relationships with other related components. In the long term, this could lead to isolating the nuclear sector from the broader context in which it is embedded and with which interfaces are indispensable.

9.4.3 How to Balance International and National Issues?

As mentioned before, nuclear security is a component, sometimes a very important one, of a State's national security. The current context is marked by the universalization of issues and a world where States are increasingly interdependent. This does not mean that certain major principles that have governed international relations for many decades have disappeared, such as the sovereignty of States, the self-interest of States (the COVID-19 health crisis is a concrete and recent example), or the tensions between States that evolve over time. In this context, nuclear security must be approached in an international context with great caution. The fundamental principle of confidentiality, introduced by the 2005 Amendment to the CPPNM, has a very particular relevance in the framework of multilateral relations set up in order to face the challenges of the global threat of the nuclear sector, even if its scope is primarily national. To guarantee the confidentiality of sensitive information of the physical protection system, for example, is an essential element.

In other nuclear fields (such as nuclear safety or radiation protection), transparency associated with a convergence of practices representing the state of the art makes sense. The risk to which the measures in these fields must respond are climatic hazards, material failures or the result of human actions without malicious intent. It is certainly evolving, but it does not adapt to the situation it faces. This standardized approach therefore makes it possible to respond efficiently to the objective of a high level of protection shared by all and to the need for confidence in their implementation requested by the various States and by the civil society. The consequences of a nuclear accident will necessarily have a transboundary, radiological, economic or social effect.

In the area of nuclear security, and security in general, the threat faced by States has this capacity to adapt itself, since by definition it is a malicious human action. Thus, contrary to the objectives in areas that allow transparency, it is appropriate to think that any attempt to move towards more transparency and convergence on common practices in nuclear security may be suspected of false naivety from some States, or even of manipulation, in order to obtain information. In this context, the fundamental principle of confidentiality is of particular importance for States, and refers to the importance, in the field of security, of finding the right balance between what can be shared and what must remain known only to those who need to know.

The emergence of international treaties in recent decades is explained by a growing adhesion to various elements of the international society. Common interests of States, which face problems that they cannot solve alone, drive the need to address issues in a multilateral framework. As highlighted earlier in this chapter, today's nuclear security challenges are global. There is therefore a strong need for States to engage the international community in addressing these issues. Conventions, such as the CPPNM and its Amendment, are the most appropriate instruments. Encouraging States to ratify these instruments and to participate in review conferences is the first, and certainly the most important, step to ensure a global strengthening of nuclear security. However, there are different degrees of application of these tools. On the one hand, there is a political aspect, where the objective is to ensure that the States Parties share a common appreciation of the challenges and of the efforts that need to be made to address them. On the other hand, there is a technical aspect, the aim of which is to ensure that international instruments can have a concrete effect on the physical protection measures taken by the States Parties.

These two aspects highlight the basic principle of the enforcement of any international treaty, which is based on the good faith of States Parties and its inherent unverifiability. This reflects the need for trust (to be understood in the sense of reliance on one's word) among the parties, which is the essential for good faith concept. This is particularly relevant when tools such as the CPPNM and its Amendment are considered from a technical perspective. Verifying, in a concrete and qualitative way, that the measures taken by States allow them to achieve a sufficient level of security with respect to the threat they face, is difficult to achieve in the framework of a multilateral forum. The principles of confidentiality and sovereignty of States in the security area will constrain the exchanges, referring to the need for trust between States. Potentially, certain barriers could be removed in more limited exchanges, such as at regional or even bilateral levels, when common interests are found and when a relationship of trust can be established. These constraints are duly taken into account for IAEA peer review missions (IPPAS), where the host country can choose, among a pool of international experts from several countries, experts from countries with an appropriate relationship.

After many years of development under the leadership of the IAEA, the international nuclear security framework has reached such a level of maturity that it is difficult to identify any short term needs for structural development. This observation is in accordance with the fact that relations are to be further developed at the regional and even bilateral levels. Nevertheless, it is necessary for the IAEA to maintain a central role to coordinate international cooperation. This means, in particular, assistance to States such as the organization of training and peer review missions (IPPAS) or the provision of services such as INSServ.

The IAEA must continue to facilitate international cooperation to enable States to maintain an adequate level of nuclear security in the long term. Furthermore, workshops, conferences and other events allow the establishment or maintenance of an international network of specialists, where each State can find good level partners when it wishes to share and obtain a reference information on an identified subject. The IAEA's role is also essential to enable the establishment of the bridges that are crucial to the identification and an appropriate management of the interfaces between the three components of the nuclear sector, while guaranteeing the respect of their singularity for the proper integration of considerations from their related environments going beyond the concerns of the nuclear sector.

9.5 The Legislative and Regulatory Framework

Another important responsibility of the State is to establish the legislative and regulatory framework, as reiterated by Fundamental Principle C of the CPPNM[15]:

FUNDAMENTAL PRINCIPLE C: Legislative and Regulatory Framework

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[15] A/CPPNM, above n. 1, Article 2a, para 3.

> The State is responsible for establishing and maintaining a legislative and regulatory framework to govern physical protection. This framework should provide for the establishment of applicable physical protection requirements and include a system of evaluation and licensing or other procedures to grant authorization. This framework should include a system of inspection of nuclear facilities and transport to verify compliance with applicable requirements and conditions of the license or other authorizing document, and to establish a means to enforce applicable requirements and conditions, including effective sanctions.

9.5.1 How can Nuclear Security Best be Integrated into the Global National Framework?

The regulation on nuclear security is part of a rich legislative and regulatory framework already in place. As the IAEA Handbook on Nuclear Law reminds us,[16] it is important to note that there is no single definitive model for nuclear regulation. This is particularly true for nuclear security, considering its many regulatory interfaces with other regulations:

- Protection of information;
- Protection of vital infrastructures;
- Protection of information systems;
- Regulated professions, linked to national security, for which administrative inquiries or vetting may be required;
- Regime for the possession and use of weapons;
- Regulation and limitation of land, air and sea space;
- Crisis management.

In view of the above-mentioned interfaces and as indicated in Sect. 9.2, nuclear security is a component of national security. As such, it will be part of the public debate on security and its balancing with public liberties.

For example, a trustworthiness inquiry is required to identify situations where people may present vulnerabilities, which do not allow them to access nuclear sites or to perform sensitive functions in the nuclear field. In France, the operator requests such an inquiry by the competent administrative authority. They may seem intrusive and contrary to freedoms. However, it is essential to note that the rules that are imposed are public and known to all and offer possibilities of appeal for people who feel they have been unfairly excluded from sensitive positions for which they have applied. The freedoms are not absolute but are exercised within the legislative and regulatory framework that governs them. The administrative authority gives the operator an opinion on the vulnerability that the person may represent. The decision to give access is then up to the operator.

It is therefore essential to define, with the utmost rigour, the notion of a 'sensitive position or sensitive information' in order to ensure a good balance that meets the security challenges. For example, many people may be involved in the preparation

[16] Stoiber et al. 2003.

of a transport of nuclear material, which requires complex logistics. This could lead to the organization of controls on a large number of people. The question of the feasibility and proportionality of the measures in relation to the impact on public liberties must be taken into account.

The security challenges are so important that the legislator has decided to make access to installations or information subject either to a trustworthiness inquiry procedure or to a national defence clearance procedure, which is based on a strengthened trustworthiness inquiry. This is the case for the nuclear industry. The clearance procedure must be applied to jobs listed in a catalogue established by the competent ministry. The absence of a clearance procedure is cause for dismissal.

In response to threats, the question of an armed response inevitably arises. The possession and use of weapons is cultural and therefore varies greatly among countries. In France, it is highly regulated and is only possible outside the State forces in very specific cases governed by the code of internal security. In the nuclear sector, operators may have an internal armed service or, more recently, may call on an armed service from an external source.[17] This answers the need for a first response to the threat, which requires a rapid kinetic.

9.5.2 How to Choose Between a Dedicated Administrative Regime and a Common One with Other Areas?

What place should nuclear security have in the regulatory framework of a State? It is undoubtedly possible to integrate nuclear security into existing processes for safety, the environment protection, critical installations, defence, national security, radiation protection, etc. However, there is a risk that the specificities of nuclear security will not be properly addressed, that certain conflicts of objectives or means will not be identified, and that choosing between options will not be possible. This is why France has chosen a regime specific to nuclear security and decided to assign its responsibility to a State authority.

9.5.3 Prescriptive Approach or Performance-Based Approach? What Approach Should a State Prefer?

A prescriptive approach consists in setting out very precisely the obligations of an operator, and in particular the means to be used. This approach has the advantage of being more comprehensive and easier to implement by the operator and by the competent authority to control.

[17] Decree No. 2017-1844 of 29 December 2017, and Ministerial Order of 15 November 2019, issued to implement Article 35 of the Decree.

This approach is well adapted to setting a minimum level of requirements even in a context where operators are not familiar with security culture. This approach is used in France for the security of radioactive sources and in the case of nuclear materials for transport and installations with the lowest risk (categories III and below). However, it has limits because the requirements may become obsolete in the short to medium term with changes in technology and in terms of the threat. Particular care must also be taken to avoid any conflict with the requirements of other fields such as nuclear safety and radiation protection. For example, in the case of radioactive sources, information concerning the location of their detention was initially considered as sensitive, and therefore should have been restricted. However, from the point of view of radiation protection, which requires the reporting of any potential danger linked to a source, this information must be communicated widely.

A performance-based approach consists of setting results-based objectives for the operator and leaving it up to the operator to determine the means to achieve them. This approach makes it possible to achieve higher levels of protection but requires a very high level of expertise on the part of the operators and the people in charge of control.

This approach has the advantage of being able to adapt more easily to the different installations encountered, to operating regimes, to the location, etc., but also to technological developments and to changes in the threat. It also allows the development of original solutions, specific to each operator and therefore less known. Finally, it does not need to be revised frequently in order to keep up with current events. In France, this approach prevails for high risk nuclear facilities. The requirements set in 2009 have remained valid despite changes, feedback and lessons learned from computer threats, drones attacks, etc.

The performance-based approach also makes it possible to achieve very high levels of security, because it forces the operator to design a nuclear security system that is very effective and very well adapted to the object to be protected. In particular, assessing the performance reached allows to identify residual vulnerabilities and to plan the necessary reinforcements. Typically, in France, this approach has led to substantial progress. Security resources that seemed very strong at first turned out to be insufficient: a very important lesson was to show that it is not enough to put together a huge set of resources to be effective. This has led several operators to change their security strategy and to design different and often more important means in order to reach the required performance.

Such an approach requires a very high level of expertise, both from the operators and from the authorities. This has required an increase in skills and staff within the authority. In fact, the assessment of performance achievement is evaluated during the examination of applications for authorization, both at the time of the initial application and at the time of periodic re-evaluations or when changes are made to the infrastructure or operating procedures.

Over the past five years, the French authority has therefore set up a special authorization process called 'in-depth technical examination'. This process consists, first, in identifying the most important technical questions in an operator's security demonstration and, second, for the authority to refer the matter to its technical support (in

France, the IRSN),[18] which will discuss the issues raised with the operator and provide the authority with argued recommendations. Depending on the nature of the requests for expertise and the complexity of the subjects, this analysis may take several months, even years. This process will include meetings during which the authority will decide on potential differences of opinion between the operator and the IRSN.

Of course, this file examination is only one part of the evaluation. The authority also carries out a number of on-site inspections to test the operator's strategy. These checks can lead to questioning solutions that seemed solid on paper. Tests, including destructive ones, may also be requested to support the operator's demonstration, for example to test the resistance of barriers to crossing or destruction by explosives. Finally, exercises to assess overall security are also implemented and are used to identify any weakness in the operator's security demonstration.

This approach is the one that allows the best response to fit with changes. This is a challenge when you consider that nuclear facilities have a lifetime of several decades. It is therefore necessary to have a vision that goes beyond present conditions. A forward looking vision that considers possible evolution is important.

9.6 The Nuclear Security Authority

Nuclear security, to be effective, must be controlled by an authority as provided for in Principle D of the CPPNM[19]:

> FUNDAMENTAL PRINCIPLE D: Competent Authority
>
> The State should establish or designate a competent authority which is responsible for the implementation of the legislative and regulatory framework, and is provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities. The State should take steps to ensure an effective independence between the functions of the State's competent authority and those of any other body in charge of the promotion or utilization of nuclear energy.

9.6.1 An Authority Dedicated to Nuclear Security?

The question may then arise of setting up an authority separate from that in charge of nuclear safety, for example.

The principle adopted in France is that of a single authority in charge of regulating nuclear safety and nuclear security, the minister in charge of energy, who has two different departments: one in charge of safety, the General Directorate for Risk Prevention (DGPR), and one in charge of security, the Department of the High Official for Defense and Security/Department of Nuclear Security (SHFDS/DSN). The

[18] IRSN: Institut de Radioprotection et de Sûreté Nucléaire.

[19] A/CPPNM, above n. 1, Article 2a, para 3.

law has also designated an authority independent from the government,[20] the Autorité de Sûreté Nucléaire (ASN) to control the implementation of safety regulations by operators.

The choice of an authority independent from the government cannot be made for security, since the control concerns not only the operators but also the government services that contribute to nuclear security as explained above. The advantage of this system is that it ensures a global vision and a high degree of coherence between the actors, whether they are State authorities or private authorities.

Many countries, especially when they start drawing up the development of a nuclear security regime, will be interested in the creation of an authority that will be in charge of all the aspects of nuclear energy. This of course often makes a lot of sense, especially from a practical point of view. However, we must not forget all the issues mentioned above.

The nuclear security authority will necessarily need to have strong links with ministries and other agencies. In this respect, there should be no misunderstanding about the independent nature of the authority. In matters of nuclear security, this independence could only be relative. It is difficult to see how an authority independent from the government could evaluate the response provided by the ministries involved in national security. However, as was indicated earlier, nuclear security should not be reduced to the premises of the operators alone. Nevertheless, it is important that the choice of a State authority is not contradictory to Fundamental Principle D: independence is required with respect to the organizations responsible for the promotion and use of nuclear energy.

9.6.2 *How to Guarantee the Level of Requirement Applicable to this Authority?*

The main reason for requiring independence regarding the promotion of nuclear activities is to ensure that the authority cannot be influenced in its decision process by political or economic issues.

One option is to limit the role of the competent authority strictly to that of control and to have a regulatory body that must also meet the objective of independence. Under these conditions, the authority in charge of control does not set the rules itself. It ensures only that the legislative and regulatory framework is implemented. If the framework provides that any failure to comply with the rules must be acted upon by the competent authority, this authority will not be in a position to modify the rules in order to take a decision in favour of the operator. It will therefore have to act appropriately in accordance with the national legislative and regulatory framework.

[20] Independent administrative authority: a State entity, with no legal duty but with its own power, in charge of one of the following missions: to ensure the protection of citizens" rights and freedoms, to ensure the proper functioning of the Administration in its relations with its citizens or to participate in the regulation of certain sectors of activity.

However, such an organization is not sufficient. A national regulation, whose objectives are not in line with the minimum requirements set by the international framework (the CPPNM, its Amendment and application guides), will be considered adequate by the national authority without guaranteeing a sufficient level of security.

Compliance with the international framework is therefore a very important protection. To this end, a process to promote universalization of the CPPNM and its 2005 Amendment is needed. It includes inviting all States to demonstrate compliance with the international framework through the information required under Article 14.1 of the CPPNM, encouraging them to use IPPAS missions to ensure that their regime complies with the CPPNM and to demonstrate to the rest of the international community their commitment.

While the requirements of the CPPNM should be seen as the minimum level required, they are not necessarily sufficient for a State, which must therefore compare this level with the threats it has assessed. For States with high risk nuclear facilities, this review again argues for the implementation of a performance-based approach (see Sect. 9.5.3).

The ability of a State to have a high level of security will depend on the capacity of its services to evaluate in a simple and sincere way the efficiency of the system it has set up. This requires courage, when the expectations are more often to reassure politicians and the population than to raise awareness of the challenges, to demonstrate efficiency and competence rather than to point out the limitations and the need for progress. An efficient evaluation requires full-scale exercises or simulations, which combine the response provided by the operator's and the State's resources, and which are based on scenarios consistent with the relevant threat level. We need of course scenarios, which are unexpected. Nothing is worse than a long-prepared exercise, where everyone expects what is going to happen and has been able to plan how to react, only to have the 'scenario' played out. Additional evaluation methods exist via simulations (reduced scale or numerical tools) but also via experience feedback.

9.6.3 How to Guarantee the Level of Competence of the Authority?

At the technical level, nuclear security requires a wide range of skills that are not necessarily all gathered within the nuclear security authority. For example, in the field of drones or computer security, the nuclear security authority must often rely on the expertise developed by other State services. If the specificities of the nuclear industry can be reduced to identifying the targets to be protected, the evaluation of the offensive capacities of the threat and the means to face them are common to all domains (banking domain, penitentiary domain, etc.). Specialists can be found in other authorities involved in national security. In France, for example, we can mention the National Agency for Security of Information Systems (ANSSI).[21]

[21] This agency depends on the Prime Minister.

The essential cooperation as indicated above leads to the need of, in matters of nuclear security, an authority placed at a good hierarchical level in a government to be able to set a relevant legislative and regulatory framework.

The various competencies will thus be coordinated, under the leadership of the nuclear security authority. The various actors will be able to participate in the implementation of the control. This will be the case, for example, for the police or the army to control the armed response measures of the operators, or for cybersecurity agencies to control the protection of information systems, etc.

In France, it has been decided that no additional requirements should be introduced for nuclear security to those that already exist in the general regulatory framework for information system security. Therefore, work is being carried out in cooperation with the ANSSI to specify how to apply this general framework to the specific subject of nuclear security and to take advantage of synergies and complementarities of approaches, particularly in the context of the control of operators (inspections and exercises).

9.7 Operators' Responsibility

Another fundamental principle established by the CPPNM is the responsibility of operators[22]:

> FUNDAMENTAL PRINCIPLE E: Responsibility of the License Holders
>
> The responsibilities for implementing the various elements of physical protection within a State should be clearly identified. The State should ensure that the prime responsibility for the implementation of physical protection of nuclear material or of nuclear facilities rests with the holders of the relevant licenses or of other authorizing documents (e.g., operators or shippers).

However, in some regulatory models such as the French one, the place of the operator in nuclear security is not as obvious as it may seem.

9.7.1 What Is the Place and Responsibility of the Operator in Nuclear Security?

The State must consider the place and responsibility of the operator in relation to that of the State. At first glance, in a model such as the one in France, it does not seem obvious that nuclear security should be given to an operator. Indeed, the Civil Code,[23] one of the fundamental texts of French law, virtually unchanged since Napoleon I, sets out the principles of liability:

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[22] A/CPPNM, above n. 1, Article 2a, para 3.

[23] Translations taken from Cartwright et al. 2016.

Article 1241

Everyone is liable for harm which he has caused not only by his action, but also by his failure to act or his lack of care.

Article 1242

One is liable not only for the harm which one causes by one's own action, but also for that which is caused by the action of persons for whom one is responsible, or of things which one has in one's keeping.

The responsibility of an operator in matters of nuclear safety can be interpreted as the application of these above-mentioned principles to the particular case of nuclear field: the operator has a nuclear installation under his responsibility. The operator is in charge of operating a nuclear installation that presents risks likely to cause very significant damage, and it is the operator's responsibility to apply measures proportionate to these risks.

However, what about nuclear security? These above-mentioned principles imply that one is not responsible for damage caused by the act of others. This is illustrated by the Franck decision of 2 December 1941,[24] famous for having set an important case law. In this case, Dr. Franck had lent his car to his son. The car was stolen and the thief, whose identity remained unknown, struck and fatally injured a postal worker. The court then ruled that Dr. Franck was not liable for the damage caused to the postal worker.

Thus, if we come back to the nuclear field, is the operator considered responsible if a malicious person intentionally attacks an operator to cause damage to its facilities?

If we return to the international framework, and to the conditions of nuclear liability, we see that these above-mentioned principles, provided in particular by the Paris Convention,[25] are adapted to cases of accidents due to a nuclear safety problem. However, its application in the case of malicious acts, in particular terrorist acts, seems less obvious.

Thus, in France, nuclear security is based on conditions that must be met by operators in order to carry out their nuclear activities. Their responsibility in this area is not engaged automatically. It is strictly limited to the application of the provisions required by the regulations. This is a fundamental difference from nuclear safety, where the operator's responsibility is engaged systematically and where it is up to the operator to determine the means to ensure nuclear safety.

[24] Cour de cassation - Chambre réunies, *Connot v Franck*, 2 December 1941, No. N, Bull. civ., N. 292 p. 523. https://www.doctrine.fr/d/CASS/1941/JURITEXT000006953144.

[25] Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960, as amended by the Additional Protocol of 28 January 1964 and by the Protocol of 16 November 1982. https://www.oecd-nea.org/jcms/pl_31788/paris-convention-full-text. Accessed 30 August 2021.

9.7.2 *Why an Operator's Responsibility?*

Thus, the State must first ask itself what is the responsibility of the operator in the field of nuclear security. Why should nuclear security be the responsibility of the operator rather than of the State? Several reasons can be given.

Logic dictates that nuclear security measures are most effective when they are located as close as possible to the materials and facilities to be protected. Thus, they must be taken into the operator's organization and be coordinated with other requirements, in particular those of nuclear safety. Only the operator can ensure this appropriate integration. This is particularly true in the case of security crisis management, where it may be necessary to deal with malicious actors and at the same time with the consequences of their actions for nuclear safety. The involvement of the operator is therefore essential.

In addition, nuclear security must be everyone's business. At the operator, each employee must understand the importance of nuclear security measures and participate in their implementation. This ensures that a malicious act or attempted of malicious act can be detected as soon as possible. This is the meaning of the Fundamental Principle F[26]:

> FUNDAMENTAL PRINCIPLE F: Security Culture
>
> All organizations involved in implementing physical protection should give due priority to the security culture, to its development and maintenance necessary to ensure its effective implementation in the entire organization.

Insider threat constitutes an important vulnerability for nuclear security. Because of the proximity and hierarchical links with personnel, who could potentially be responsible for malicious acts or facilitate them, the operator has an essential role. The operator must be organized to prevent this threat as well as to detect it and to confront it.

Thus, even in a country such as France, where it has long been considered that security is the prerogative of the State, it is not possible to implement a good level of nuclear security without the involvement and a very strong contribution of the operators. However, the role of the State will always remain important and decisive.

9.7.3 *What Are the Nuclear Security Obligations of the Operator?*

In practice, nuclear security is therefore a matter of complementary responsibilities between the State and the operator. The national regulations must therefore specify what the responsibility of the operator is.

If the State chooses a performance-based approach, the operator sets up its protection system on the DBTs. If the State considers that operators must be able to deal,

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[26] A/CPPNM, above n. 1, Article 2a, para 3.

on their own, with all of the identified threats that the country has to face, the DBTs should include all of these threats. However, a State may consider it inappropriate to require operators to deal with all threats alone. In France, it is considered that the operator's armed forces cannot manage the crisis alone. They will give the State forces time to intervene. It is a configuration of a complementarity and coordinated response. In this case, the DBTs will be able to take up only part of the threats identified by the State. For example, in the French case, the national security directive for the civil nuclear sub-sector, in which the DBTs specific to the nuclear sector are described, clearly specifies which missions are under the responsibility of operators and which are under the responsibility of the State.

9.7.4 What Cooperation with Other Government Departments?

The role of the operator is limited by the prerogatives and means that can be given to a private person, for example:

- The possibility to collect information and to gather intelligence;
- The possibility to use weapons, in particular weapons of war;
- The possibility to intervene with weapons in public space or only on private property;
- The use of cameras, detectors, etc. outside private property (beyond the perimeter of the premises, sea and air, approaches to private property, etc.);
- The possibility to control people, to stop them, etc.;
- The possibility to regulate objects to be introduced onto private property and to search a person or a vehicle, etc.

All these issues are often already regulated in a country and will strongly influence the way roles in nuclear security can be shared between the State and the operator.

Because these means are highly regulated and controlled in countries committed to individual liberties, the State keeps a preponderant role in nuclear security, for example in terms of intelligence, counter terrorism (interruption of malicious acts before they are perpetrated), air and maritime security, armed response in the event of a terrorist attack, judicial investigations and criminal sanctions, etc.

9.8 Choice of Technological Options, Sites and Transport Routes

9.8.1 How Can Nuclear Security Be Integrated Into the Choice of Technology?

When a State considers implementing a nuclear programme, nuclear security must be one of its first concerns, in the same way that other issues such as nuclear safety are to be taken into consideration. The concept of 'security by design' mentioned earlier focuses on taking into account the DBT to better define the protection measures for the installation that need to be adapted to its operation.

This approach may lead to the choice of one technology over another, particularly after having evaluated the various existing technological choices regarding the national framework and the applicable DBT.

The difficulty that a State may have to face with concerns the sharing of sensitive information from the point of view of national defence (DBT) with a foreign entity. It is always good to remember Alexandre Dumas's citation: "Today's friends are tomorrow's enemies" and vice versa.

It is therefore normal for a State to question what it is willing to share with a foreign entity, even though the decision to choose this technology may be the result of a relationship of trust with the manufacturer, or even with the State from which the manufacturer originates.

As mentioned above, the DBT is the result of a State's decision to require that an operator is able to protect their facility from some of the threats that the State itself has to face.

In assessing a foreign technology, the State may choose to define a standard with an appropriate level of information that can be shared without compromising the integrity of its national security while ensuring its complementary responsibility in the protection of the facility.

9.8.2 What Are the Transport Issues?

'Security by design' can also be extended to the whole chain necessary for the operation of the nuclear activity and its security. Generally, a nuclear activity can hardly exist by itself. It depends on other related activities linked to its life cycle, such as the supply of fuel or materials required for its operation, the reprocessing of spent fuel, storage of the materials, etc.

These various activities may be carried out close to or far from each other (in particular to respond to land planning challenges, which are often of political concern, but which have non-negligible impacts in terms of security). This raises the issue of the transport of nuclear materials and other radioactive substances, which includes inherent risks. Of course, this implies the need for special provisions for the physical protection of these transports, both at the national and international level when the State has to import or export such products.

As far as nuclear materials are concerned, the CPPNM, before being extended by its amendment to nuclear facilities, already set out obligations on transport. The implementation of these international requirements is specified by recommendations recognized by the international community, without legally binding value, contained in INFCIRC/225/Rev.5.[27] The purpose of these transports is to bring nuclear materials or other radioactive substances to the facility. Consequently, it is also important, from the design phase of a nuclear facility, to take into account this transport component (arrival/departure) and find the most suitable way to secure it.

9.8.3 How Can Security Be Integrated with Respect to the Site Chosen and Its Environment?

Land planning challenges have been indicated above and echo the important principle of ‘security by design’: the choice of the location of the facility at which the nuclear activity will be operated. This choice may often respond to interests other than those related to security: political, economic, social (particularly in terms of the acceptability of the project by the local populations), operational constraints, etc.

However, security shall not be neglected in the choices made. In the field of security, there is no single solution (a standardized security solution) that can be adapted without taking into account the local context. Protection strategies must be different in order to be best adapted to the facility and in particular to its environment. Operational modes and tactics of the adversary will depend on the location of the facility. This requires an appropriate protection system for the facility as well as from the State response, which need to be dimensioned accordingly.

Let us illustrate this with an example from outside the nuclear sector. It shows that these concepts are not so new. The example of the Palais Garnier (one of the two opera houses in Paris) is a concrete example that illustrates these two components of the ‘security by design’ principle. On 14 January 1858, Napoleon III was the victim of a bomb attack in front of the opera house which was located at that time on rue Le Peletier. After this attack, he decided to build a new opera house, more prestigious but also better secured. It is one of the most famous monuments of Paris we have today, the Palais Garnier. Security was therefore one of the major concerns to the building. Feedback from the attack led to the idea of a short, fast and secure route between the emperor’s place of residence and this new opera house. The result was the creation of the Avenue de l’Opéra, which was large enough and connected the two places in a straight line to make it very difficult to plan an attack during the journey.

[27] IAEA 2011a.

This perfectly echoes the need to have an integrated assessment of the industrial context around the nuclear facility and the need for transport to be considered at the very beginning, from the phase of reflection on the location of the activity. Another interesting element of the original design of the Palais Garnier is the 'Emperor's Rotunda'. This construction offers secure access reserved for the emperor, since it provides effective protection against any remote attack.

This highlights the importance of this transitional phase, which can sometimes present significant vulnerabilities if not anticipated, when a transport of nuclear materials or radioactive substances arrives at the facility.

9.9 Confidentiality, Transparency and Communication

Confidentiality is one of the twelve fundamental principles of nuclear security included in the 2005 Amendment[28]:

> FUNDAMENTAL PRINCIPLE L: Confidentiality
>
> The State should establish requirements for protecting the confidentiality of information, the unauthorized disclosure of which could compromise the physical protection of nuclear material and nuclear facilities.

Therefore, States apply, as referred to several times in this chapter, this principle both at the national and international levels, particularly in the development and drafting of international instruments. It also interacts with other elements specific to the nuclear sector, such as the principle of transparency, or of the management of a radiological crisis and the associated communication needed.

9.9.1 What Are the Communication Challenges in the Face of Terrorism?

In the field of security, the threat is generally characterized by a motivation (an ideology, a personal cause, etc.), a capability (accessible material and human resources, knowledge of the relevant field, etc.), and a target, which is attractive to the adversary. This last aspect covers the symbolic dimension that the target represents. At present, the main threat against which States are protecting themselves is terrorism. Without wishing to give a universal definition to this concept that is difficult to characterize, it is interesting to quote Raymond Aron who defines terrorism in the following way: "A violent action is called terrorist when its psychological effects are out of proportion with its purely physical results."[29] Another way of characterizing terrorism, which reflects the symbolism that a potential target may have, is the

[28] A/CPPNM, above n. 1, Article 2a, para 3.

[29] Aron 1962, p. 276.

following proverb: "It is better to kill one and be seen by a thousand than to kill a thousand and be seen by one." When one thinks of a nuclear activity, especially in certain highly nuclearized countries, the symbolic aspect is obvious. Thus, in the event of a terrorist act, the issue of communication and acceptance of nuclear energy will necessarily be essential, and each State must be well prepared.

9.9.2 Why Protect the Information?

More pragmatically, the attractiveness of a target is characterized by the fact that it can be reached with the means available to the adversary. Among the various measures that can be taken to make a target more difficult to reach is the principle of deterrence. There are several ways to achieve this objective: to provide for sanctions in the national legislative framework, to bring to light the high security of the facility (e.g. imposing barriers, numerous cameras), to set up random patrols of guards and of intervention forces inside and outside the restricted zone of a nuclear facility, etc. However, deterrence does not require total transparency, which would obviously make it easier for an adversary to plan a malicious act. It is therefore necessary to evaluate carefully the information that is essential to protect.

9.9.3 How to Balance the Protection of Information and the Principle of Transparency in the Nuclear Sector?

In the nuclear sector, transparency is often set up as a fundamental value. In France, the main law in the nuclear field is called the law on transparency and security in the nuclear field.[30] It defines transparency as "all the measures taken to guarantee the public's right to access a reliable information on nuclear security". This principle therefore interacts with the confidentiality objectives relating to nuclear security mentioned above. It is necessary to find the right balance between what can be communicated and what must remain known only to those who need to know. This highlights the importance of the interfaces between nuclear safety and nuclear security when it comes to communication, especially from a technical perspective. For example, when a significant safety or radiation protection event occurs in France, there is an associated communication. This communication is graded according to the importance of the event and its scope. The communication may consequently remain local or be national or even international. In order to respect the objectives of the law indicated above, technical details of the origin and consequences of the event may be included in the communications. The information can potentially create

[30] In this law, nuclear security includes nuclear safety, radiation protection, and prevention against malicious acts as well as civil security actions in case of accident.

vulnerabilities for the facility concerned, and can be misused by certain persons. The High Committee for Transparency and Information on Nuclear Security (HCTISN) is, in France, a body in charge of public information and the organization of consultations and debates on the risks associated with nuclear activities. Numerous debates within this institution have led to guidance to better define the information that needs to be protected for the purpose of nuclear security.

9.9.4 How to Protect Information During the Management of a Crisis?

Transparency provisions also apply when managing a security crisis. Communication must be balanced, knowing that there will be media pressure to cover the event and give information to the public.

In the case where the origin of the crisis is security, certain communications or behaviours can interfere with the proper conduct of the actions of State security forces. France was affected by major attacks in 2015. Some media behaviours may have disturbed security operations during the crisis. The information mission of the media may have led them to communicate information that was used by the terrorists. For example, one of the terrorists regularly used a computer to watch different news channels to be informed of the external situation (in particular, the organization of the State security forces present on site). Again, in this context, we highlight the importance of managing the interfaces with all the actors, considering the differences in their objectives.

In France, any major crisis is managed at the national level within a single framework, regardless of its origin: nuclear (technological, natural, malicious, etc.), terrorist or of any other nature. A single authority manages it. A nuclear crisis with a malicious origin will be managed primarily by the authorities that usually deal with counterterrorism (services of the Prime Minister and the Ministry of the Interior). The authorities in charge of nuclear safety and nuclear security[31] will provide advice and situation updates in their field of competence, but will not have any decisional role. It should be noted that the decision making authorities are generally not directly involved in the work carried out by the IAEA. The interface is therefore ensured at the national level by the experts of the nuclear security authority on the matters related to their field of competence. These experts will preferably use their international communication channels developed in accordance with their needs and objectives. This underlines the importance of the IAEA's role in coordinating the development of tools that meet the specific challenges of the nuclear sector.

[31] In France, the security authority is in charge of the regulations and of the control of their implementation. It is therefore the privileged interlocutor in multilateral bodies such as the IAEA.

9.10 Conclusion

The purpose of this chapter is not to outline in a few pages the entire process required to create a nuclear security regime, but rather to provide an overview of some of the major questions that a State must consider when planning to engage a nuclear programme and consequently to develop a nuclear security regime.

It is essential for the State to understand that nuclear security is part of a context of intense national cooperation, especially in areas where there are strong interfaces, such as intelligence, screening, cooperation with State security forces, and computer security. It is therefore crucial to set up a national governance. The competent authority for nuclear security, whose position is adapted to the national security environment, should participate, as necessary, in this coordination in order to contribute to the coherence of the national and international framework for nuclear security. This authority is also in interaction with the other components of the nuclear sector and with civil society. As a rule, transparency is a fundamental value that conflicts with the need for confidentiality or protection of information. In order to avoid possible isolation of the competent authority from all its partners, it is necessary to find the best balance between protection and sharing.

The threat that an operator faces is another particularity of nuclear security, since the malicious act is a human act able to adapt, whereas the operator must take into account natural or unintentional aggressions in the field of risk prevention. In the design and authorization processes, it is essential for the operator and the competent authority to conduct their analysis from the point of view of the malicious person. This paradigm change is not intuitive, as the logic in the risk evaluation is usually done from the point of view of the 'defender'. Some measures promoted to secure a nuclear activity are initially designed to ensure nuclear safety functions. It is therefore essential to ensure that these measures are effective and robust against one or more individuals with malicious intent. This also allows us to identify certain operational modes or malicious scenarios that are difficult to predict otherwise.

It is always useful to remember that, despite the sovereign responsibility of States, nuclear security is part of global security issues. Terrorist threats are often international and require effective international cooperation to combat them. The consequences of malicious acts on nuclear activities are such that each State is concerned about the way other States approach nuclear security issues.

Nuclear security, as a field related to national security, has very specific aspects, particularly in terms of sovereignty and protection of information, which make it different from other components of the nuclear sector. It is linked to a larger set of international law that responds to specific concerns, through its own logic and objectives. This situation also exists for nuclear safety and safeguards. An overly nuclear approach could have the effect of distancing thematic experts in favour of cross-cutting profiles; this would not ensure coherence with related environments beyond the concerns of the nuclear sector, for example security in the broad sense at both the national and international levels. Using this logic, the IAEA plays an essential coordinating role to enable the establishment of the bridges that are indispensable for the identification and relevant treatment of the interfaces between the three components of the nuclear sector, while guaranteeing the maintenance of their singularity for the proper integration of the considerations mentioned above.

International cooperation is essential for sharing good practices among nuclear security specialists and for establishing recommendations that are recognized by the international community.

In this respect, the IAEA occupies a central place, whether through its Nuclear Security Series, the numerous training courses, workshops and conferences it organizes, or the various services it offers to States.

However, one shall bear in mind that in many areas it may also be appropriate to use regional or bilateral relationships. As an example, there is an association of nuclear security authorities of several European countries called the European Nuclear Security Regulators Association (ENSRA). It offers the opportunity to discuss specific issues and exchange information more freely than in the more open framework of the IAEA. In addition, States usually establish bilateral cooperation agreements with other States, which contain confidentiality rules.

9.11 To Go Further…

Although the CPPNM can be seen primarily as a political instrument (the States Parties say that they respect the obligations of the Convention without detailing the modalities of their implementation), this does not mean that the States Parties will not act in good faith in implementing their commitments. Some States Parties take a different view and consider that the objective of the Convention is to ensure, in a very concrete way, that other States provide effective protection of their facilities and provide guarantees to them. It could be expected from these States that a verification mechanism be established. However, this vision runs up against the above-mentioned principles.

The possibility for States Parties to convene a conference under Article 16 of the CPPNM and its Amendment is a method of assessment that is again based on the principle of good faith. It is generally accepted that States must rely on the accuracy and completeness of the information provided by each party for this type of exercise. Civil nuclear energy is a sensitive subject at both the national and international levels, since civil society has a real concern as regards this technology. This raises the following question: to what extent is a State ready to share on the international scene, in a very transparent manner, any weaknesses in its facilities or organization? Even if this information is not accessible to the public, keeping a good reputation is an important consideration for States.

Because of these constraints, it seems difficult that the conference is the most appropriate tool to guarantee to all States, in a concrete and valuable way, the respect of the obligations of the Convention from a technical point of view.

As mentioned above, the IAEA has an IPPAS programme to evaluate a State's physical protection regime based on the obligations of the CPPNM, its 2005 Amendment and INFCIRC/225/Rev.5. This assessment includes a detailed examination, at the national level, of the legal and regulatory framework, as well as the measures and procedures implemented by the State in accordance with the provisions of the international framework. This programme, proposed by the IAEA, offers a secure peer review framework, perfectly adapted to nuclear security. It allows the country concerned to receive a detailed report, following a detailed analysis by a team of recognized international experts. Although the most sensitive information cannot be shared with the experts, this tool is well adapted to the objective of guarantee that some States Parties may wish to assign to the Convention. It is therefore appropriate to encourage all States Parties to host an initial IPPAS mission and to plan to request further periodic missions.

References

Aron R (1962) Paix et guerre entre les nations. Calmann-Lévy, Paris

Breivik A (2011) 2083—A European Declaration of Independence. https://info.publicintelligence.net/AndersBehringBreivikManifesto.pdf. Accessed 20 August 2021

Cartwright J, Fauvarque-Cosson B, Whittaker S (2016) The Law of Contract, The General Regime of Obligations, and Proof of Obligations. The New Provisions of the Code Civil Created by Ordonnance n° 2016-131 of 10 February 2016 Translated into English. http://www.textes.justice.gouv.fr/art_pix/THE-LAW-OF-CONTRACT-2-5-16.pdf, https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000032004939/. Accessed 20 August 2021

Code de la Défense (2021) https://www.legifrance.gouv.fr/codes/id/LEGITEXT000006071307/. Accessed 20 August 2021

International Atomic Energy Agency (IAEA) (2004) Code of Conduct on the Safety and Security of Radioactive Sources, IAEA/CODEOC/200. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2011a) Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2011b) Nuclear Security Recommendations on Radioactive Material and Associated Facilities, IAEA Nuclear Security Series No. 14. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2013) Objective and Essential Elements of a State's Nuclear Security Regime: Nuclear Security Fundamentals, IAEA Nuclear Security Series No. 20. IAEA, Vienna

Stoiber C, Baer A, Pelzer N, Tonhauser W (2003) Handbook on Nuclear Law. IAEA, Vienna

United Nations General Assembly (UNGA) (1946) Establishment of a Commission to Deal with the Problems Raised by the Discovery of Atomic Energy, Resolution 1(I). https://undocs.org/en/A/RES/1(I). Accessed 20 August 2021

United Nations General Assembly (UNGA) (1997) Resolution 51/210, A/RES/51/210. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N97/761/65/PDF/N9776165.pdf. Accessed 20 August 2021

United Nations Security Council (UNSC) (2004) Resolution 1540, S/RES/1540. https://www.un.org/ga/search/view_doc.asp?symbol=S/RES/1540%20(2004). Accessed 20 August 2021

Chapter 10
IAEA Safeguards: Correctness and Completeness of States' Safeguards Declarations

Laura Rockwood

Contents

Abstract In the light of the occasional challenges in recent years to the legal authority of the International Atomic Energy Agency (IAEA) to verify the correctness and completeness of States' declarations under comprehensive safeguards agreements, the chapter assesses the law and practice on this issue since the early 1990s. In particular, the chapter focuses right and obligation of the IAEA to verify the correctness and completeness of States' declarations—one of the most fundamental principles in the implementation of comprehensive safeguards agreements. The chapter provides a detailed textual and historical analysis indicating that, in fulfilling that obligation, the IAEA is not limited to access to information about nuclear material which has been declared by the Agency, or to locations where such material has been declared by the Agency. A contrary interpretation would cause the IAEA to revert to a pre-1991 approach to verification that focused primarily on declared nuclear

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material, which resulted in the IAEA's failure to detect Iraq's undeclared nuclear programme.

Keywords International Atomic Energy Agency (IAEA) · The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) · Safeguards · Correctness and completeness · Comprehensive safeguards agreements · IAEA Board of Governors · IAEA Director General · Nuclear material from declared activities · Undeclared nuclear activities · Additional protocol

10.1 Introduction

In the context of international safeguards, fewer legal issues have been as keenly debated as the authority of the International Atomic Energy Agency (IAEA) to verify the correctness and completeness of States' declarations under comprehensive safeguards agreements. Put more precisely, the issue is whether the IAEA has the mandate and the authority to verify that no declared nuclear material is diverted for prohibited purposes and that there are no undeclared nuclear material or activities in a State which has concluded such an agreement.[1]

While the law and practice in that regard have well established an affirmative response since the early 1990s, in the light of the occasional challenges to that authority in recent years, it bears restating the most fundamental principles in the implementation of the comprehensive safeguards agreements: that the IAEA has the right and obligation to verify the correctness and completeness of State declarations and that that right and obligation derive from the agreements themselves.

10.2 Historical Overview

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT)[2] tasked the IAEA with the verification of the fulfilment by non-nuclear-weapon States (NNWSs) of their obligations under the treaty "with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices." To that end, the NPT required each NNWS to conclude with the IAEA an agreement for the application of safeguards on all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or

[1] Much of the material contained in this chapter is derived, with permission, from several publications authored or co-authored by Laura Rockwood, who served for 28 years as the senior legal adviser on all aspects of the negotiation, interpretation and implementation of IAEA safeguards, and was the principal author of the document that became the Model Additional Protocol. The publications include Rockwood and Johnson 2015; Rockwood 2014. The author also drew on material from Albright et al. 2012.

[2] Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968, entered into force 5 March 1970 (NPT).

carried out under its control anywhere—so-called ‘full scope’ or ‘comprehensive’ safeguards agreements (comprehensive safeguards agreements).

With the entry into force of the NPT in 1970, the Member States of the IAEA, in an open-ended committee of the Board of Governors (Committee 22), negotiated the document that serves as the basis for all comprehensive safeguards agreements: INFCIRC/153 (Corr.), The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons. All comprehensive safeguards agreements concluded by the IAEA since then have been based on INFCIRC/153 and the model agreement derived from it reproduced in GOV/INF/276.[3]

The IAEA had been implementing safeguards under comprehensive safeguards agreements for 20 years at the time it uncovered the hidden nuclear programme of Iraq in 1991. During those two decades, the Agency’s safeguards activities were, as a practical matter rather than due to a lack of legal authority, focused primarily on verifying declared nuclear material at declared facilities. Safeguards were implemented and evaluated on a facility-by-facility basis, rather than by examination of the State as a whole. As a consequence of this approach, although the Agency routinely sought to verify that there was no undeclared production of nuclear material at declared facilities, in particular at research reactors, it did not seek to verify that there was no undeclared nuclear material elsewhere in the State.

The flaw in that approach became evident with the discovery of Iraq’s undeclared nuclear activities and clandestine nuclear weapons programme in 1991. This discovery triggered a reassessment of the then-conventional, albeit ill-founded, belief that the IAEA’s legal authority under comprehensive safeguards agreements was limited to verifying nuclear material and facilities declared by the State.

Member States of the IAEA made it clear that more should, and could, be done by the IAEA with a view to providing assurances not just of the non-diversion of declared nuclear material, but of the absence of undeclared nuclear material and activities in such States. In conjunction with the IAEA Secretariat, the Board of Governors re-examined the Agency’s focus on declared nuclear material and concluded that, based on the existing legal authority reflected in INFCIRC/153, the IAEA had the right and obligation to verify the correctness and the completeness of States’ declarations.

As detailed later in this chapter, between 1991 and 1993, the IAEA Board and General Conference took a number of decisions reaffirming that right and obligation to ensure that, in a State with a comprehensive safeguards agreement, no nuclear material, whether declared or undeclared, is diverted to nuclear weapons or other nuclear explosive devices. It bears noting that all of these decisions were taken long before the IAEA even contemplated additional legal authority, and that this right and obligation has been confirmed consistently by the policy making organs of the IAEA since the early 1990s.

At the end of 1993, the IAEA Secretariat, at the request of the Board of Governors, initiated an ambitious programme to develop a comprehensive set of measures for strengthening safeguards: Programme 93+2. These measures, which were presented

[3] IAEA 1974.

to the Board in February 1995,[4] comprised two parts. The first part consisted of measures that could be implemented under the existing legal authority of comprehensive safeguards agreements. The most significant of these measures was a profound change in the IAEA's evaluation of information available to it about a State. Instead of assessing the results of its verification activities separately for each individual facility in a State, the IAEA would visualize the State's nuclear programme in a coherent and connected way by looking at the State as a whole. The second part consisted of measures that the Secretariat proposed be implemented on the basis of a new legal instrument. These measures were eventually transformed into the Model Additional Protocol, which the Board approved in May 1997.[5]

The Model Additional Protocol was negotiated by another open-ended committee of the Board of Governors (Committee 24). It was designed as a model for protocols to be concluded with States party to comprehensive safeguards agreements, with a view to strengthening the IAEA's ability to fulfil its obligations under such agreements by providing the IAEA with complementary authority to request access, on a more routine basis, to additional information and locations related to a State's nuclear fuel cycle.

We have come a long way since then, but we still hear questions about the legal basis for the IAEA's actions. Some of that is because people are new to the issues and unfamiliar with the history; some are motivated by a wish to constrain the IAEA's authority to take those actions. Whatever the reason, it is important to be clear about that authority.

10.3 Treaty Interpretation

An extensive analysis of the application of the general rules of treaty interpretation is published in Nuclear Non-Proliferation in International Law, Volume II: Verification and Compliance.[6] The following draws on that analysis.

In accordance with the general rules of interpretation codified in both the Vienna Convention on the Law of Treaties between States and the Vienna Convention on the Law of Treaties between States and International Organizations or between International Organizations (collectively referred to as the 'VCLTs'),[7] these safeguards agreements must be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the agreements in their context and in the light of their object and purpose. Account is also to be taken of any subsequent agreement between the

[4] IAEA 1995, Annexes 1 and 4.

[5] IAEA 1997.

[6] Rockwood and Johnson 2015, pp. 57–94.

[7] Vienna Convention on the Law of Treaties, opened for signature 23 May 1969, entered into force 27 January 1980; Vienna Convention on the Law of Treaties between States and International Organizations or between International Organizations, opened for signature 21 March 1986, not yet in force.

parties regarding the interpretation of the agreements or the application of its provisions and any subsequent practice in the application of the treaty which establishes the agreement of the parties regarding its interpretation.

A plain reading of INFCIRC/153 makes clear that a comprehensive safeguards agreement requires the IAEA to provide assurances that all declared nuclear material of a State is under safeguards and that the State has declared and placed under safeguards all nuclear material that is required to be declared. Paragraphs 1 and 2 of INFCIRC/153 relate, respectively, to the basic undertaking of the State to accept safeguards (para 1) and the IAEA's right and obligation to apply safeguards (para 2). Each comprehensive safeguards agreement contains articles which correspond to those paragraphs.

Paragraph 1 of INFCIRC/153 requires the State to "accept safeguards, … on *all* source or special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices" (emphasis added).

Paragraph 2 of INFCIRC/153 provides for the Agency's "*right and obligation to ensure that safeguards will be applied, … on all source or special fissionable material* in all peaceful nuclear activities within the territory of the State, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices" (emphasis added). The drafters of INFCIRC/153 agreed on this formulation of para 2 after due consideration and explicit rejection of a proposal by one member State that "safeguarding and inspection … shall be concerned solely with the material reported upon by the State concerned."[8]

A review of other provisions of INFCIRC/153 further supports this interpretation.

INFCIRC/153 requires that, upon entry into force of a comprehensive safeguards agreement, the State is to submit to the IAEA an initial report of all nuclear material which is to be subject to safeguards and information with respect to all existing nuclear facilities.[9] It authorizes the IAEA to request access to the State to verify such information in the form of inspections (ad hoc, routine and special inspections) and design information verification.

Ad hoc inspections are utilized, inter alia, for verifying the information contained in the State's initial declaration of nuclear material [para 71(a)]. Paragraph 76(a) provides that ad hoc inspections for such purposes may be carried out at "any location where the initial report *or any inspections carried out in connection with [the initial report] indicate that nuclear material is present*" (emphasis added), thereby permitting the IAEA to request access not only to locations declared by the State in its initial report, but to other locations not declared by the State.

Routine inspections are carried out at facilities, and at locations outside facilities where nuclear material is customarily used (LOFs), to verify consistency of the State's reports with its records, to verify "the location, identify, quantity and composition of

[8] International Energy Associates Ltd 1984, pp. 33–44.

[9] IAEA 1972, paras 62 and 42.

all nuclear material subject to safeguards under the Agreement" and to verify possible causes of certain discrepancies. Pursuant to para 76(c) of INFCIRC/153, access to carry out routine inspections is limited to agreed strategic points and to the records maintained pursuant to the comprehensive safeguards agreement. Paragraphs 78–82 limit the number, frequency and intensity of routine inspections.

Paragraph 73(b) of INFCIRC/153 authorizes the Agency to carry out special inspections, inter alia, if it "considers that information made available by the State, including explanations from the State and information obtained from routine inspections, *is not adequate for the Agency to fulfil its responsibilities under the Agreement*" (emphasis added). As reflected in para 2 of INFCIRC/153, those responsibilities include ensuring that safeguards are applied on *all* nuclear material required to be declared by the State. Paragraph 73 explicitly provides that an inspection shall be deemed to be special when it is either additional to the routine inspection effort provided for in paras 78–82, or "*involves access to information or locations in addition to the access specified in paragraph 76 for ad hoc and routine inspections, or both*" (emphasis added).

Paragraph 19 of INFCIRC/153 provides that, "if the Board, upon examination of relevant information reported to it by the Director General finds that the Agency is not able to verify that there has been no diversion of nuclear material *required to be safeguarded under the Agreement* to nuclear weapons or other nuclear explosive devices"[10] (emphasis added), the Board "may make the reports provided for in para C of Article XII of the Statute and may also take, where applicable, the other measures provided for in that paragraph."[11] The formulation of para 19 reaffirms the Agency's right to ensure not just that no declared nuclear material is diverted to proscribed purposes, but that no nuclear material, whether declared or undeclared, is diverted for such purposes.[12]

As described in para 28 of INFCIRC/153, the objective of safeguards under comprehensive safeguards agreements is twofold:

> The Agreement should provide that the objective of safeguards is the *timely detection of diversion* of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other nuclear explosive devices or for purposes unknown, and *deterrence of such diversion by the risk of early detection* (emphasis added).

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[10] IAEA 1972.

[11] Article XII.C of the IAEA Statute requires the Director General to transmit to the Board of Governors reports of non-compliance. It provides further that the Board "shall call upon the recipient State or States to remedy forthwith any non-compliance which it finds to have occurred. The Board shall report the non-compliance to all members of the Security Council and General Assembly of the United Nations."

[12] There are numerous other provisions in INFCIRC/153 which demonstrate the drafters' clear intention. Paragraphs 7, 8, 11, 12, 13 and 18 of INFCIRC/153 all refer to "nuclear material subject to safeguards", which was understood by the Committee to mean not simply that material which was being safeguarded but that which is required to be safeguarded. According to Myron Kratzer, the lead US negotiator of INFCIRC/153, the more explicit term "nuclear material required to be safeguarded" was used in para 19 in recognition that "the meaning was perhaps clearer, but not different from that of 'nuclear materials subject to safeguards'", International Energy Associates Ltd. 1984.

As noted in the analysis referred to previously, it follows that the ordinary meaning of the terms of INFCIRC/153 and the comprehensive safeguards agreements concluded by the IAEA on the basis of that document, in their context and in the light of their object and purpose, "were intended to provide for verification of the non-misuse of any nuclear material in a State, whether declared or undeclared. If anything, the text of INFCIRC/153 makes even clearer that agreements based on that document provide for IAEA verification of the correctness and completeness of States' declarations."[13]

Clearly it would defeat the very object and purpose of such safeguards agreements if the IAEA were precluded from assuring itself that no nuclear material remained outside of safeguards and available for proscribed activities.

Under the VCLTs, in interpreting a treaty, account is also to be taken of any subsequent agreement between the parties regarding the interpretation of the agreements or the application of its provisions and any subsequent practice in the application of the treaty which establishes the agreement of the parties regarding its interpretation. The following section describes the subsequent agreements and practices that collectively reaffirm the interpretation.

10.4 The Fundamentals of Comprehensive Safeguards

10.4.1 A State is Required Under a Comprehensive Safeguards Agreement to Declare All Nuclear Material to the Agency; A Failure to Do So Is Inconsistent with That Obligation

Based on a plain reading of INFCIRC/153, as well as decisions by the Board of Governors, a State is required, by virtue of para 1 of its comprehensive safeguards agreement, to declare *all* nuclear material and facilities to the Agency, and a failure to do so is inconsistent with that obligation.

(a) INFCIRC/153: Paragraph 1 of INFCIRC/153 requires that a State "accept safeguards, in accordance with the terms of the Agreement, on *all* source or special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices" (emphasis added). Paragraph 62 also requires an initial report by the State of "all *nuclear material* which is to be subject to safeguards".

The word "all" is also included, for example, in paras 7, 31 and 32 (on the State's obligation to establish and maintain a system of accounting for and

[13] Rockwood and Johnson 2015, pp. 57–94.

control of "all nuclear material subject to safeguards" and para 41 (requiring the Agency to establish a unified inventory of "all nuclear material in the State subject to safeguards").

The negotiating history of INFCIRC/153 makes clear that the reference to nuclear material "in peaceful nuclear activities" was used in the light of the fact that the NPT permitted the use of nuclear material in a non-proscribed (non-explosive) military activity, and that nuclear material required to be safeguarded under the agreement could be withdrawn from the agreement in accordance with arrangements to be made with the Agency.

It was not intended, and should not be interpreted as meaning, that a State may exclude nuclear material from its declarations simply by placing it in a non-peaceful/military activity. Reading into para 1 an exclusion for nuclear material which is in a military activity would defeat the fundamental object and purposes of a comprehensive safeguards agreement, in contravention of Article 31(1) of the VCLTs.

(b) Board Decisions: That a State is obliged to declare *all* nuclear material to the IAEA under a comprehensive safeguards agreement, and that a failure to do so constitutes a breach of that obligation, has been confirmed by the Board of Governors on numerous occasions:

- In the Director General's first substantive report to the Board on the IAEA's findings in Iraq, in July 1991,[14] he informed the Board of Iraq's failure to declare nuclear material under its comprehensive safeguards agreement, concluding that Iraq had not been in compliance with its obligations under its safeguards agreement, "in particular with respect to the obligation to accept safeguards on all nuclear material in all peaceful nuclear activities". Based on that report, on 18 July 1991, the Board adopted resolution GOV/2532[15] condemning Iraq's non-compliance with its obligation to accept safeguards on all nuclear material in all peaceful nuclear activities as a consequence of its failure to declare certain nuclear material and activities to the Agency. In September 1991, the Board noted Iraq's further non-compliance with its reporting,[16] and requested that the Director General report such non-compliance to the Security Council.
- In June 1992, the Board, acting through a chairman's summary, took note of the Director General's report on non-compliance by the former regime in Romania for its failure to declare activities related to the reprocessing of a small amount of plutonium in 1985[17] (which had been brought to the IAEA's attention by the successor Romanian government), and requested

[14] IAEA 1991f.
[15] IAEA 1991g.
[16] IAEA 1991h, paras 46–47.
[17] Findlay 2015.

that the Director General report the non-compliance to the UN Security Council "for information purposes."[18]

- On 25 February 1993, the Board of Governors adopted resolution GOV/2636[19] in connection with the Democratic People's Republic of Korea (DPRK), in which, noting inconsistencies between DPRK declarations and the Secretariat's findings that had given rise to doubts about the completeness of the DPRK's initial nuclear material declarations, it recalled its December 1992 session, in which the Board had stressed that it was "essential to verify the correctness and assess the completeness of the [DPRK's] Initial Report", and decided that the access to additional information and two additional sites requested by the Director General in accordance with the provisions in connection with special inspections was "essential and urgent in order to resolve differences and to ensure verification of compliance with INFCIRC/403".
- When the DPRK was not forthcoming with the requested access, on 1 April 1993 the Board adopted resolution GOV/2645[20] in which it found, pursuant to Article 19 of the DPRK's safeguards agreement, that the Agency was not able to verify that there had been no diversion of nuclear material required to be safeguarded under the terms of the safeguards agreement to nuclear weapons or other nuclear explosive devices, and decided to report the DPRK's non-compliance to the Security Council.
- In September 2003, the Board adopted resolution GOV/2003/69 (12 September 2003)[21] in which it recalled the Director General's report of 6 June 2003 (GOV/2003/40)[22] which had expressed concern over failures by Iran to report material, facilities and activities pursuant to its comprehensive safeguards agreement, and called upon Iran to ensure that there were no further "failures to report material, facilities and activities that Iran [was] obliged to report pursuant to its [comprehensive] safeguards agreement".
- In November 2003, the Board adopted another resolution in which, noting with deep concern that Iran had failed in a number of instances over an extended period of time to "meet its obligations under its [comprehensive safeguards agreement] with respect to the reporting of nuclear material, and its processing and use, as well as the declaration of facilities where such material has been processed and stored", "noting in particular with the gravest concern that Iran enriched uranium and separated plutonium in undeclared facilities in the absence of IAEA safeguards", and stressing the need for effective safeguards in order to prevent the use of nuclear material for prohibited purposes in contravention of [comprehensive safeguards agreements], requested the Director General "to take all steps necessary to

[18] IAEA 1992a.
[19] IAEA 1993a.
[20] IAEA 1993b.
[21] IAEA 2003a.
[22] IAEA 2003b.

confirm that the information by Iran on its past and present nuclear activities is correct and complete as well as to resolve such issues as remain outstanding" (OP 4).

Thus, it cannot be challenged that the presence in a State with a comprehensive safeguards agreement of undeclared nuclear material, facilities or activities required to be declared to the Agency under a comprehensive safeguards agreement constitutes a breach of the State's obligations thereunder.

10.4.2 The Agency Is Required to Verify Under a Comprehensive Safeguards Agreement that Safeguards Are in Fact Applied to All Such Material

Based on a plain reading of INFCIRC/153, as well as decisions by the Board of Governors and the General Conference, the Agency is required, by virtue of para 2 to verify not just the correctness, but the completeness of States' declarations concerning nuclear material, facilities and activities:

(a) INFCIRC/153: In accordance with para 2 of INFCIRC/153, the Agency has the right, and the obligation, to ensure that safeguards are applied on "*all"* peaceful nuclear activities. Indeed, as noted, during the negotiation of INFCIRC/153, a proposal was made to limit the Agency's obligation to nuclear material which has been reported by the State; this proposal was rejected, and replaced with "all". In that context, the Secretariat noted that "the deliberate failure by the State to inform the Agency of nuclear material might also be considered to imply diversion". The word "all" is also included, for example, in para 72(b) (pursuant to which the Agency may make routine inspections to "verify the location, identify, quantity and composition of all *nuclear material* subject to safeguards") and para 74(b) (which authorizes the Agency to make independent measurements of "all *nuclear material* subject to safeguards").

Paragraph 76(a), which refers to ad hoc inspections, specifically anticipates the possibility of Agency access to a location other than those identified in the State's initial report, providing that the Agency may also carry out such inspections at any location where an inspection carried out in connection with the initial report merely "indicates" that nuclear material is present.

As indicated above, para 19 provides that, "if the Board upon examination of relevant information reported to it by the Director General finds that the Agency is not able to verify that there has been no diversion of *nuclear material required to be safeguarded under the Agreement* to nuclear weapons or other nuclear explosive devices" (emphasis added), the Board "may make the reports provided for in para C of Article XII of the Statute and may also take, where applicable, the other measures provided for in that paragraph."[23] The phrase "required to be safeguarded" used in para 19[24] is not different, but rather a clearer, and more explicit, formulation of the term.

(b) Board and General Conference:

- In September 1991, IAEA Member States, in resolutions adopted by the Board of Governors[25] and the General Conference,[26] requested the Director General to verify the "correctness and completeness of the inventory of South Africa's nuclear installations and material" under its newly approved comprehensive safeguards agreement.
- In February 1992, the Board, acting through a chairman's summary, reaffirmed the IAEA's right under comprehensive safeguards agreements to ensure that all nuclear material in all peaceful nuclear activities is under safeguards.[27]
- In February 1993, the Director General submitted a report to the Board of Governors informing it of an anomaly the Secretariat had discovered in the DPRK. The anomaly had given rise to doubts about the completeness of the country's initial report of nuclear material under its comprehensive safeguards agreement. Based on the Director General's report and a detailed briefing by the Secretariat, the Board adopted a resolution in which it stressed that it was "essential to verify the correctness and assess the completeness" of the DPRK's initial report and decided that the access to additional information and locations requested by the Director General was "essential and urgent in order to resolve differences and to ensure verification of compliance" by the DPRK with its comprehensive safeguards agreement.[28]
- In October 1993, under a new agenda item on strengthening safeguards, the General Conference adopted a decision noting the decisions taken by the

[23] Article XII.C of the IAEA Statute requires the Director General to transmit to the Board of Governors reports of non-compliance. It provides further that the Board "shall call upon the recipient State or States to remedy forthwith any non-compliance which it finds to have occurred. The Board shall report the non-compliance to all members of the Security Council and General Assembly of the United Nations."

[24] The same phrase is used in para 14 on the non-application of safeguards to nuclear material to be used in non-peaceful activities. Paragraph 14 prescribes certain procedures "if the State intends to exercise its discretion to use *nuclear material which is required to be safeguarded* thereunder in a nuclear activity which does not require the application of safeguards under the Agreement" (emphasis added).

[25] IAEA 1991a. The draft resolution, submitted by Zaire on behalf of the African Group, was adopted without a vote.

[26] IAEA 1991b.

[27] IAEA 1992b, paras 48, 83 and 84.

[28] IAEA 1993a. The draft resolution was adopted without a vote. The Director General's report and the official records of the Board's discussion, which was held in closed session, have not been publicly released by the IAEA.

Board over the previous 12 months to strengthen safeguards, and called on Member States to cooperate in implementing them.[29]

All of these actions took place well before the announcement of Programme 93+2 in December 1993.

In February 1995, the Director General provided an overview of the proposed measures for strengthening the SG system in a systematic and integrated manner, providing information on each of the proposed measures, including costs, benefits and whether a legal basis already existed for the Secretariat to implement that measure or complementary authority would be needed.

At the conclusion of its consideration of that report, the Board of Governors decided to approve the Chairman's summing up of its deliberations, in which it:

> [reiterated] that the purpose of comprehensive safeguards agreements, where safeguards are applied to all nuclear material in all nuclear activities within the territory of a State party to such an agreement, under its jurisdiction or carried out under its control anywhere, is to verify that such material is not diverted to nuclear weapons or other nuclear explosive devices. To this end, the safeguards system for implementing *comprehensive safeguards agreements should be designed to provide for verification by the Agency of the correctness and completeness of States' declarations, so that there is credible assurance of the non-diversion of nuclear material from declared activities and of the absence of undeclared nuclear activities* (emphasis added).

10.4.3 In Fulfilling Its Obligation, the Agency Access Is Not Limited to Declared Nuclear Material or Locations

In fulfilling its obligation to verify the correctness and completeness of States' declarations under comprehensive safeguards agreements, the Agency is not limited to access to information about nuclear material which has been declared by the Agency, or to locations where such material has been declared by the Agency:

(a) INFCIRC/153: The provisions related to ad hoc inspections affirm the Agency's right of access not only to nuclear material declared by the State, but to locations where there are indications of the presence of nuclear material. Under special inspections, access to information and locations in addition to that provided for under ad hoc and routine inspections, even if there is no indication of the presence of nuclear material at such locations.

(b) Decisions of the Board: The 25 February 1993 resolution regarding the DPRK adopted by the Board of Governors (GOV/2636) decided that the access to additional information and two additional sites requested by the Director General in accordance with the provisions in connection with special inspections was "essential and urgent in order to resolve differences and to ensure verification of compliance with INFCIRC/403". The two sites were previously undeclared to the IAEA. Moreover, access to the two sites was not requested because of

[29] IAEA 1993c.

suspicions of the presence of undeclared nuclear material at those sites, but rather because access was necessary for the IAEA to sample waste at those sites with a view to ascertaining if undeclared reprocessing had taken place in the DPRK and, if so, to what extent.

10.4.4 In Assessing Whether a State's Declarations Are Correct and Complete, the Agency Has the Authority to Use All Information Available to It

The Agency has the authority to use all information available to it in assessing whether a State has in fact declared to it all nuclear material required to be safeguarded under its comprehensive safeguards agreement.

(a) INFCIRC/153: In his 1991 analysis of special inspections contained in GOV/2554, the Director General outlined the categories of information that should be available to the IAEA. They included (1) information collected in the course of routine safeguards activities; (2) information publicly available; and (3) information obtained by Member States through national means.[30]

In his statement to the Board on 5 December 1991, the Director General stated that the crucial element in strengthening the ability of the safeguards system to detect any clandestine nuclear activities in States with comprehensive safeguards agreements was information. In an extensive statement recorded in the official records of the Board, he added:

> If the State itself conceals a nuclear activity, the inspectorate must—as in the case of Iraq—have some other information as to where it should look. No inspectorate could "roam the entire territory of the State in a blind search for undeclared nuclear facilities." For those reasons, he said, a fundamental modification needed to be made in the Agency's practices: in making more extensive use of such information as the Agency already possessed, and in being prepared to accept critically examined information that might be offered to the Agency from outside. One sometimes heard the comment that the Agency should take account only of information communicated through official channels and that other information (whether from media or national intelligence services) was questionable. His own belief was that all information—whether official or non-official—had to be examined critically. He acknowledged the risk that information might be offered for ulterior motives, and it would be a mistake to rely on it. However, it would be a worse mistake to refuse to accept any other information. That was not to say that such information should automatically trigger requests for explanations by the States concerned. The information should be assessed carefully and critically, and the Director General would have to judge whether he/she

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[30] IAEA 1991c.

should endorse or decline the suggestion that a special inspection would be warranted.[31]

It is worth noting that Article VIII.A provides that Member States should make available such information as would, in the judgement of the Member State, be helpful to the Agency.

(b) Decisions of the Board:

The most classic example of the Board's implicit approval of the Agency's use of information provided by a Member State other than the safeguarded State is the case of the DPRK in February 1993. Based on the Director General's report, the Board adopted, without a vote, a resolution in which it decided that access under special inspections to additional information and locations was "essential and urgent". The Director General made clear that, the Agency, while having identified the anomaly through its own verification activities, had availed itself of satellite imagery obtained through "national technical means" to identify locations, access to which it believed would be helpful in resolving the outstanding issues concerning the DPRK's failure to declare nuclear material.

It should also be noted that the Agency did not seek access to the locations in question because it believed that there was undeclared nuclear material at those locations, but rather that access to sample the waste stored at those locations would assist in the resolution of the anomaly.

10.4.5 The Agency's Right and Obligation to Verify the Completeness of a State's Declarations Derives from the Comprehensive Safeguards Agreement

The fact that the Board took decisions requesting the Agency to verify completeness long before there was any consideration of additional legal authority demonstrates its acceptance that the Agency's obligation to verify completeness of a State's declarations derives from the comprehensive safeguards agreement itself, and is not dependent on the existence of an additional protocol. While the IAEA looks for indications of undeclared nuclear material and activities in all States with comprehensive safeguards agreements, it chooses as a matter of policy not to report on the absence of undeclared nuclear material in a State without the additional assurances provided by the measures contained in an additional protocol.

That the additional protocol provides us with additional tools to do that job better and on a more routine basis has been articulated in numerous annual Safeguards Implementation Reports and other Agency publications. The Board has never challenged that view.

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[31] IAEA 1992c; IAEA 1992d, paras 131–132.

10.5 Summary

It is simply disingenuous to contend, as a few States have recently, that the examples of decisions by the Board and the General Conference are not germane to the issue of IAEA authority under comprehensive safeguards agreements either because they were related to the implementation of safeguards in specific States or because the acceptance of a chairman's summary does not constitute a formal decision.[32] The safeguards agreements of South Africa and the DPRK are substantively identical, as are all comprehensive safeguards agreements. Furthermore, the Board has taken decisions on many occasions through the mechanism of a chairman's summary of its deliberations, including decisions with respect to the most sensitive of issues, non-compliance. This was the case for Iraq as well as Romania.[33]

It is likewise disingenuous to argue that the IAEA's obligation under a comprehensive safeguards agreement to verify completeness derives exclusively from an additional protocol. The push by Member States for the IAEA to provide assurances of the absence of undeclared nuclear material and activities under such agreements—and, indeed, the Board and General Conference decisions confirming IAEA authority to do so—predated even the contemplation of new legal authority.

Some States question the need for an additional protocol if the IAEA already has the right to verify completeness of a State's declarations under a comprehensive safeguards agreement. The answer is straightforward: the IAEA's right and obligation to verify correctness and completeness derive from the comprehensive safeguards agreement, but in such an agreement, there are limited tools for doing so, such as special inspections. An additional protocol secures for the IAEA broader access to information and locations on a more routine, predictable, and reliable basis. This permits the IAEA to detect indications of undeclared nuclear material and activities earlier and more effectively than it otherwise would.

Another challenge to IAEA authority to verify the absence of undeclared nuclear material and activities in a State has been that proving a negative is impossible. In one of his reports to the Board on Programme 93+2, Hans Blix acknowledged that "[n]o safeguards system, no matter how extensive the measures, can provide absolute assurance that there has been no diversion of nuclear material or that there are no undeclared nuclear activities in a State."[34] The IAEA made that point again in 2003 in its reports on Iraq to the UN Security Council, in which it acknowledged that

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[32] IAEA 2014, paras 25–160.

[33] In July and September 1991, the Board found that Iraq's failure to declare nuclear material and facilities in connection with its clandestine uranium-enrichment and plutonium-separation programmes constituted non-compliance with its comprehensive safeguards agreement and requested the Director General to report the matter to the UN Security Council. The first decision was taken by a resolution, and the second decision was made through the mechanism of consensus adoption of a chairman's summary of the Board's deliberations. IAEA 1991d, e.

[34] IAEA 1995, Annex 1, para 15.

proving a negative was not possible even with the authority granted under Security Council resolutions.[35]

Yet, the IAEA can look for indications of undeclared activities. In the case of Iraq in 2003, having sought such indications and not found any, the Agency could conclude with a high degree of confidence that Iraq had not resumed its nuclear weapons programme. As it turned out, the IAEA was right.

Some critics contend that, although the IAEA has the right to follow up on indications of undeclared nuclear material and activities, it does not have the right to look for such indications. Again, the argument is disingenuous. If one does not look for something, one is not likely to find it. Would critics of completeness efforts conclude that the IAEA should not even try to determine whether such indications exist? Blix addressed that point in 1995 by invoking a person "looking for a lost key near a lighted street lamp who, when asked whether he was sure he had lost the key there, said 'No, but it's easier to look here.'"[36]

As I noted in a publication cited earlier, the most immediate practical impact of acceding to such a reinterpretation would be to permit a State that has only a comprehensive safeguards agreement and no additional protocol to prevent the IAEA from investigating indications of undeclared nuclear material and activities in that State. If that reinterpretation is not addressed directly and rejected explicitly, safeguards could be forced to revert to a pre-1991 approach to verification that focused primarily on declared nuclear material, which resulted in the IAEA's failure to detect Iraq's undeclared nuclear programme. It is incumbent on all parties to understand what has already been achieved in strengthening safeguards so that it is not necessary to reinvent those achievements.

References

Albright D, Heinonen O, Kittrie O (2012) Understanding the IAEA's Mandate in Iran: Avoiding Misinterpretations. https://www.belfercenter.org/sites/default/files/files/publication/Misinterpreting_the_IAEA_27Nov2012.pdf. Accessed 14 September 2021

Findlay T (2015) Proliferation Alert! The IAEA and Non-Compliance Reporting. https://www.belfercenter.org/sites/default/files/files/publication/proliferationalert-web.pdf. Accessed 14 September 2021

International Atomic Energy Agency (IAEA) (1972) The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153

[35] "It is important to emphasize that there is always some degree of uncertainty in the verification process, and the Agency cannot provide absolute guarantees regarding the absence of small-scale nuclear activities, such as simulations on personal computers or lab work by a few scientists (or indeed, direct acquisition by a State of weapons usable nuclear material). … Nevertheless, an intrusive inspection system [such as the one that the IAEA was implementing in Iraq] can minimize the risk of prohibited activities going undetected, and deter, through the risk of early detection, the revival of a nuclear weapons programme." United Nations Security Council 2003 (containing the IAEA work programme in Iraq pursuant to Security Council Resolution 1284).

[36] IAEA 1995, Annex 3, para 49.

International Atomic Energy Agency (IAEA) (1974) The Standard Text of Safeguards Agreements in connection with the Treaty on the Non-Proliferation of Nuclear Weapons, GOV/INF/276, Annex A

International Atomic Energy Agency (IAEA) (1991a) Safeguards: Draft Resolution Submitted by Egypt, Morocco, Nigeria and Tunisia on Behalf of the African Group, GOV/2547/Rev.1

International Atomic Energy Agency (IAEA) (1991b) South Africa's Nuclear Capabilities, GC(XXXV)/RES/567

International Atomic Energy Agency (IAEA) (1991c) Strengthening of Agency Safeguards: The Provision and Use of Design Information, GOV/2554

International Atomic Energy Agency (IAEA) (1991d) Iraq's Non-Compliance with Its Safeguards Obligations, GC(XXXV)/978

International Atomic Energy Agency (IAEA) (1991e) Iraq's Non-Compliance with Its Safeguards Obligations, GC(XXXV)/978/Add.1

International Atomic Energy Agency (IAEA) (1991f) A Report by the Director General on Non-Compliance by Iraq with its Obligations under the Safeguards Agreement Concluded with the Agency, GOV/2530

International Atomic Energy Agency (IAEA) (1991g) Iraq's Non-Compliance with its Safeguards Obligations, GOV/2532

International Atomic Energy Agency (IAEA) (1991h) Record of GOV/OR Meeting 763, GOV/OR.763

International Atomic Energy Agency (IAEA) (1992a) Record of GOV/OR Meeting 783, GOV/OR.783

International Atomic Energy Agency (IAEA) (1992b) Record of GOV/OR Meeting 776, GOV/OR.776

International Atomic Energy Agency (IAEA) (1992c) Excerpts from Statements Made by the Director General under the Agenda Item "Strengthening of Agency Safeguards" at the Board's December 1991 Meetings, GOV/INF/646, Attachment 1

International Atomic Energy Agency (IAEA) (1992d) Record of GOV/OR Meeting 768, GOV/OR.768

International Atomic Energy Agency (IAEA) (1993a) Report on the Implementation of the Agreement Between the Agency and the Democratic People's Republic of Korea for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, GOV/2636

International Atomic Energy Agency (IAEA) (1993b) Report by the Director General on the Implementation of the Resolution Adopted by the Board on 25 February 1993 (Gov/2636) and of the Agreement Between the Agency and the Democratic People's Republic of Korea for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/403), GOV/2645

International Atomic Energy Agency (IAEA) (1993c). Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System, GC(XXXVII)/RES/619

International Atomic Energy Agency (IAEA) (1995) Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards: Report by the Director General to the General Conference, GC(39)/17

International Atomic Energy Agency (IAEA) (1997) Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected)

International Atomic Energy Agency (IAEA) (2003a) Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran, GOV/2003/69

International Atomic Energy Agency (IAEA) (2003b) Implementation of the NPT Safeguards agreement in the Islamic Republic of Iran: Report by the Director General, GOV/2003/40

International Atomic Energy Agency (IAEA) (2014) Committee of the Whole: Record of the Seventh Meeting, GC(57)/COM.5/OR.7

International Energy Associates Ltd (1984) Review of the Negotiating History of the IAEA Safeguards Document, INFCIRC/153. US Arms Control and Disarmament Agency

Rockwood L (2014) The IAEA's State-Level Concept and the Law of Unintended Consequences. Arms Control Today 44:25–30

Rockwood L, Johnson L (2015) Verification of Correctness and Completeness in the Implementation of IAEA Safeguards: The Law and Practice. In: Black-Branch J, Fleck D (eds) Nuclear Non-Proliferation in International Law, Volume II: Verification and Compliance. Springer/TM Asser Press, Heidelberg/New York

United Nations Security Council (2003) Letter Dated 19 March 2003 from the Secretary-General Addressed to the President of the Security Council, S/2003/342

Chapter 11
Safeguards for the Future

Trevor Findlay

Contents

Abstract Safeguards have evolved as a result of new circumstances, institutions, technologies and practices, including cultural phenomena. This chapter examines safeguards from a historical perspective as the product of a political process that resulted in the negotiation of safeguards instruments. In particular, the chapter addresses the IAEA safeguards from the perspective that adaptation of the legal framework for safeguards is necessary and often difficult. Major change will only occur through a political process, not a legal one, involving Member States of the IAEA. The change will be facilitated through the IAEA Secretariat's role in strengthening safeguards implementation using the power and responsibilities afforded to it; the advancement of technology and techniques as a vital element of this process; and the non-technological aspects of safeguards, particularly the human element.

Keywords Treaty on the Non-Proliferation of Nuclear Weapons (NPT) · IAEA safeguards system · IAEA statute · Comprehensive safeguards agreements · Small quantities protocol · Additional protocol · Safeguards training

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11.1 Introduction

The nuclear safeguards system operated by the International Atomic Energy Agency (IAEA) counts as one of the crowning achievements of international law. Designed to deter through early detection the diversion of nuclear materials from peaceful to military purposes, nuclear safeguards are an unprecedented attempt to prevent the proliferation of nuclear weapons to States which do not have them. With its safeguards system the IAEA has pioneered intrusive international on-site inspection, monitoring and reporting that have since been replicated in other fields.

Safeguards are, naturally, the product of a political process that results in the negotiation of treaty law, with all the imperfections that compromises, creative ambiguity and material constraints produce. Nuclear safeguards also suffer, like most legal arrangements, from the passage of time. New circumstances, institutions, technologies and practices, including cultural phenomena, arise that were not foreseen. Adaptation is necessary and often difficult. This chapter examines IAEA nuclear safeguards from this perspective, bearing in mind that major change will only occur through a political process, not a legal one, involving Member States of the IAEA. In the meantime, the IAEA Secretariat can and should strengthen safeguards implementation using the complete range of power and responsibilities afforded to it. While the advancement of technology and techniques is a vital element of this process, this chapter focuses on the non-technological aspects of safeguards, particularly the human element.

11.2 The Current Status of IAEA Safeguards

Nuclear safeguards are based on two primary international legal foundations, the 1957 IAEA Statute and the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT).[1] The Statute mandates the IAEA to "establish and administer safeguards designed to ensure that fissionable and other materials, services, equipment, facilities, and information" are not used "to further any military purpose".[2] Safeguards may be applied either to the IAEA's materials and activities or to bilateral or multilateral arrangements at the request of the parties. Pursuant to Article III of the NPT, IAEA Member States agreed to a system of mandatory, legally binding, comprehensive safeguards agreements (CSAs) applicable to non-nuclear weapon States (NNWSs) that are party to the treaty.[3] Prior to the NPT, only item specific safeguards had been applied, voluntarily, to discrete amounts of nuclear material or facilities.[4] CSAs would now cover all of a State's declared nuclear material and facilities. To help

[1] IAEA 1989; Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968, entered into force 5 March 1970 (NPT).

[2] IAEA 1989, Article III.5.

[3] IAEA 1972.

[4] IAEA 1965 (as provisionally extended in 1966 and 1968).

assuage concerns that nuclear weapon States (NWSs) party to the NPT would not be subject to any constraints on their peaceful nuclear industries, voluntary offer agreements (VOAs) were negotiated that impose limited safeguards on each of them.[5] In addition, a series of regional nuclear-weapon-free zone treaties has been negotiated which oblige States Parties to adopt IAEA nuclear safeguards. For NNWSs with no or little nuclear material, a small quantities protocol (SQP) to CSAs was adopted in 1971, allowing them to indefinitely suspend most of their safeguards obligations.[6]

The discovery in 1991 of Iraq's violation of its safeguards agreement and the NPT—an undeclared nuclear establishment had been built parallel to its declared one—resulted in a 'revolution' in IAEA safeguards that is still playing out today. It led the IAEA to reform the system through two legal processes: identifying and utilizing legal authorities that it already possessed, but which remained underutilized; and negotiating a voluntary addendum to CSAs that came to be known as the Additional Protocol (AP).[7] The AP, which States began adopting in 1997, obliges them to provide greatly expanded information on their nuclear activities and holdings. It also gives the IAEA greater data gathering and inspection powers, notably complementary access to locations of concern.

11.3 The Quest for Universality

From a legal perspective one of the continuing challenges is to induce all NNWSs parties to the NPT to bring a CSA into force. None of the current holdouts have known nuclear capabilities or ambitions and, except for Somalia, are small developing countries.[8] But they remain non-compliant with the NPT. Many States with little or no nuclear activity, while acquiring a CSA, also adopted an SQP, which holds in abeyance most of the reporting and verification requirements of the CSA. This is now regarded as little better than having no CSA at all.

In 2005, an amended SQP was introduced that increases the number of safeguards obligations that an SQP State is obliged to fulfil, even if it has not yet acquired significant nuclear capabilities.[9] This includes regular reporting, early notification of the intention to build a nuclear facility (rather than 180 days of notice before nuclear material is introduced into a facility) and the possibility of ad hoc and special inspections. The new SQP is a significant closing of a legal lacuna, since under the old agreement quite advanced States could avoid safeguards until they were well on the way to acquiring large amounts of nuclear material and had built a nuclear facility. SQP States have increasingly adopted the new version. But among the 31 still holding

[5] https://www.iaea.org/topics/safeguards-legal-framework/more-on-safeguards-agreements. Accessed 30 September 2021.

[6] Ibid.

[7] IAEA 1997.

[8] IAEA 2021a.

[9] IAEA 2006.

out are the not inconsequential States of Kyrgyzstan, Mongolia, Myanmar, Namibia, Saudi Arabia, Sierra Leone, Suriname and Zambia.[10] IAEA Director General Rafael Mariano Grossi wrote to all 31 States in September 2020 asking them to adopt an amended SQP and warning that the IAEA's ability to draw a credible and soundly based annual safeguards conclusion for those States was becoming "increasingly challenging".[11] So far Maldives and Sudan are the only two to have heeded his call.[12] But in addition, three States, Lithuania, the Syrian Arab Republic and the United Arab Emirates, have indicated they wish to rescind their SQPs altogether.

An even more daunting challenge is achieving universality of the AP. There has been a continuous slow uptake of APs since 1997, with 137 States, plus EURATOM, with an AP in force. Yet almost a quarter of a century after it was inaugurated and despite talk of the AP becoming the safeguards 'gold standard', there are still several significant outliers, with either existing nuclear infrastructure (Argentina, Brazil, Democratic People's Republic of Korea (DPRK) and the Syrian Arab Republic) or plans to acquire it (Egypt, Malaysia and Saudi Arabia).[13] The Islamic Republic of Iran is a special case, having agreed voluntarily to implement its AP without formally adopting it (although currently not fully complying with all aspects).[14] Argentina and Brazil, which have a bilateral safeguards arrangement and a dedicated verification body, the Argentine–Brazil Agency for Accountancy and Control (ABACC),[15] plead special circumstances. But this does not relieve them of their obligation as responsible members of the international community to lead by example.

An action plan to persuade more States to assume their safeguards obligations was adopted by the Secretariat in 2001 and has been periodically renewed, most recently in 2018.[16] The IAEA's External Auditor in 2019 commended the Secretariat on the significant progress made and the intensifying outreach efforts, but could offer no suggestions on how to proceed other than to 'carry on'.[17] Non-IAEA Member States, where there are no working level relations with IAEA staff and little or no experience with the IAEA's mandated activities, represented a special challenge. In the past, regional workshops have been successful in convincing some States to act, but as the numbers dwindle such events may be too humiliating for the holdouts (often a lack of understanding or capacity is the problem) and a more tailored, albeit resource intensive, approach involving personal contact with relevant national authorities is needed. The IAEA Secretariat's leverage is of course limited. Committed Member

[10] IAEA 2021a.

[11] https://www.iaea.org/newscenter/pressreleases/iaea-director-general-steps-up-efforts-to-strengthen-safeguards-implementation. Accessed 30 September 2021.

[12] IAEA 2021b.

[13] IAEA 2021c.

[14] https://www.iaea.org/iaea-director-generals-introductory-statement-to-the-board-of-governors-7-june-2021. Accessed 15 June 2021.

[15] Agencia Brasileño–Argentina de Contabilidad y Control de Materiales Nucleares Verificando el uso pacífico de la energía nuclear en Argentina y Brasil (ABACC).

[16] IAEA 2020a.

[17] IAEA 2020b.

States, the United Nations Security Council and the Nuclear Suppliers Group (NSG) should add their weight to the campaign.

11.4 Further Strengthening of Safeguards

The safeguards system has been a work-in-progress since its inception, not only through the adoption of new legal instruments, but also through modification of processes and practices by the IAEA Secretariat. Some of these have been specifically approved or acquiesced to by the Board of Governors, while others fell under the Secretariat's mandate to establish and run the safeguards system. Various factors combine to press the IAEA to improve the effectiveness and efficiency of safeguards. One is the generic characteristic of all arms control and disarmament verification regimes: 100% verification of compliance is unachievable without a degree of intrusiveness and expense that all States would find unacceptable. Instead, within such constraints, verification must produce an acceptable level of assurance and confidence that compliance is occurring and that violations will be caught early enough to permit international action to deal with them.

A second factor, which especially drives the quest for greater efficiency, is the increasing number of States under safeguards and the growth in the amount of nuclear material and number of facilities to which safeguards are applied—all at a time of continuing budgetary constraints that show no sign of abating. In addition, new types of facilities require safeguarding: new nuclear power generation technologies (such as small and medium reactors, floating reactors, fast breeder reactors and fusion reactors); high level radioactive waste and spent fuel storage facilities; decommissioned plants; and potentially new enrichment and reprocessing technologies (such as laser and pyro-processing). The IAEA is also periodically (and randomly) requested to take on additional significant verification tasks for ad hoc agreements, as in the cases of Iraq, the DPRK and the Islamic Republic of Iran. These episodes divert key personnel and resources away from their normal purposes, sometimes without adequate compensatory funding.

A third factor is pressure on the Secretariat from Member States facing financial difficulties, as in all organizations in the United Nations family, to adopt best management practices, including strategic planning and enhanced recruitment, training, budget and finance. These apply as much to the Department of Safeguards as to any other part of the IAEA.

While the constant drive to strengthen safeguards implementation implies gradually tightening constraints on Member States, in reality some improvements to safeguards result in decreasing the safeguards burden for fully compliant States. This has been the experience with 'integrated safeguards', adopted since the advent of the AP. For a fully compliant State this rationalizes duplicative safeguards activities imposed over the years, resulting in a streamlined, targeted and more effective and efficient safeguards arrangement with the IAEA. It is in this spirit that further improvements to safeguards should be pursued in order to bring all Member States on board.

Periodically, there have been calls for the negotiation of additional legal documents to enhance safeguards, sometimes referred to as 'AP Plus'. The last effort in the Board of Governors, the Committee on Safeguards and Verification (Committee 25), established in 2004, achieved little in this direction (or any other) and was wound up in 2007. Members of Committee 25 were not only divided over whether new measures were warranted, but even States keen on such measures failed to produce workable ideas. After almost a decade and a half since, it could be argued that it is time to revisit the effort. However, one of the issues that derailed the committee, the non-compliance case of the Islamic Republic of Iran, is still alive and would presumably scuttle a new Board initiative, at least until the fate of the 2015 Joint Comprehensive Plan of Action (JCPOA) is settled.

The Standing Advisory Group on Safeguards Implementation (SAGSI), established in 1975, has made considerable contributions to safeguards reform. However, SAGSI's recommendations only go to the Director General, its members (appointed by the Director General) have been drawn from a limited number of Member States (mostly retired ambassadors or senior safeguards personnel) and it does not operate transparently. Its reports are not made public and even its agenda is unpublished. It has, arguably, not made cutting-edge recommendations since contributing to the conceptualization of the AP. SAGSI could be transformed into a more dynamic, creative and open body by broadening its membership, seeking input from external contributors and publishing its results.

During meetings of Committee 25, the Secretariat proposed numerous ideas to strengthen existing safeguards operations, rather than pushing for new authorities, which suggests that it saw sufficient possibilities for improvements short of legal remedies.[18] Since then, the Department of Safeguards has moved ahead on its own initiative, in seeking greater effectiveness and efficiency where such measures lie within its authority, notably in strategic planning, management, technology (especially IT) and personnel development.

11.5 Management of Safeguards

The Department of Safeguards is embedded in a United Nations-style international organization that determines its bureaucratic hierarchy and procedures, staff recruitment and appointment rules, funding arrangements and, not least, organizational culture. Nonetheless, within these constraints the Department has made valiant efforts in recent years to improve the management of safeguards. Gone are the days when inspectors' reports were written on scraps of paper that may or may not have been read and were indifferently filed. Also gone are the days when Member States nominated candidates for automatic recruitment and training was minimal. Even more

[18] Boureston and Ferguson 2005.

significantly, gone is the accountancy mentality and focus on declared materials and facilities that pervaded early safeguards culture.

Today, the Department is better managed than ever before. This is partly due to IAEA-wide reforms, such as a results-based management approach to programme planning, monitoring, and reporting. The Agency-wide Information System for Programme Support (AIPS) reportedly continues to produce efficiencies through automation of processes more than a decade after it was introduced.[19] Financial management has improved with adoption in 2011 of the United Nations-wide International Public Sector Accounting Standards (IPSAS), which "provide[s] greater insight into the actual assets, liabilities, revenues and expenses of the Agency."[20] Both AIPS and IPSAS, the Secretariat reports, "continue to require fine-tuning, adjustments, improvements and enhancements."[21] An accountability framework is currently being 'operationalized' across the Agency.[22]

The Department of Safeguards, in addition, has taken its own steps towards greater effectiveness and efficiency. A pathbreaking initiative, not only organizationally but substantively, is its Long-Term Strategic Plan (2012–2023), the only one of its kind at the Agency.[23] Drafted in-house after consultations with staff, this plan sets out a vision for the Department and systematically attempts to identify future non-proliferation challenges. Although only available publicly in summary form, the document is revealing. It says the IAEA should aspire to be the "pre-eminent international nuclear verification agency" and achieve the "confidence and support of the international community".[24] It also emphasizes the need for continuous improvement in safeguards and for effectiveness and efficiency. On the substantive side is its novel admonition that it is "vital …to detect and report early any *potential* [emphasis added] misuse of nuclear material and activities".[25] Traditionally, safeguards were premised on the idea that they could only detect activities of concern after the event.

The Long-Term Strategic Plan is meant to be a living document that is reviewed and updated every two years. This occurred most recently in 2018. A public version of the revised document, even in summary form, is unfortunately not available. The Department should ensure that at least a summary is available publicly to provide continuing reassurance about its strategic direction. As part of its strategic planning, the Department also develops a biennial Development and Implementation Support (D&IS) Programme for Nuclear Verification and has formulated a Long-Term R&D Plan, 2012–2023, both of which are publicly available.[26]

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[19] IAEA 2019b.

[20] IAEA 2020b, p. 141.

[21] IAEA 2019b, p. 142.

[22] IAEA 2020c, p. 19.

[23] IAEA 2011, p. 2.

[24] This is not as ambitious as it sounds since there is only one other at present, the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) and it is still in preparatory mode.

[25] IAEA 2011, p. 4.

[26] IAEA 2020d, 2013.

Another welcome trend in improving the management of safeguards is the Department's quality management system (QMS) that has been operating since 2004.[27] In August 2018, the Deputy Director General (DDG) for Safeguards, Massimo Aparo, issued the latest iteration of the Department's quality policy, first issued in 2004, including the following admonition: "Quality is about building trust and confidence in our safeguards conclusions."[28] The Department's quality management principles, essentially the same ones identified in 2004, are: leadership; engagement of people; process approach; evidence based decision making; improvement (although for some reason no longer 'continuous' as in the 2004 version); customer focus; and relationship management. Two quality objectives were specified in support of the policy: "Promoting a quality culture and encouraging ownership of quality responsibilities and accountabilities" and "Implementing our quality policy and following our quality management principles in the way we work."

Despite these worthwhile aspirations, the Department has struggled with implementing the QMS, as evidenced by the Director General's annual account of efforts to improve it.[29] To be fair, this is because, by its very nature, quality management involves a never ending process of review, evaluation and reform. Member States recognize the continuing challenges, as indicated by their Support Programme for 2020–2021. It includes a project to "strengthen and mature the Department's Quality Management System and monitor and report on its effectiveness", drawing on a 2017 internal self-assessment of its 'maturity'.[30]

More specific to safeguards, the Department has also initiated State-level Effectiveness Evaluation Reviews (SEER), carried out by a dedicated departmental State-level Effectiveness Evaluation Reviews Team (SEERT). Bringing together cross-cutting Departmental expertise, SEERT reviews the planning, development, implementation and conclusion of safeguards activities. It aims to give the DDG an additional level of assurance on the correctness of safeguards conclusions.[31] In 2019, the external auditor undertook a special assessment of the extent to which the Department had truly established "an Effective Quality Control to support the Implementation of SG [safeguards]".[32] It observed various responses to the SEERT among Departmental staff: "Some support it and consider it an important aspect of effectiveness evaluation, and some others find it as a duplication of work and an extra burden to their current job, particularly when it comes to the resources."[33] The auditor criticized the lack of proper action plans that would capture key activities, dates and milestones in implementing SEERT recommendations.[34] The IAEA agreed with the auditor's recommendations.

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[27] IAEA 2019b, p. 130.

[28] IAEA 2020d, p. 96.

[29] Ibid., pp. 43–48.

[30] Ibid., pp. 90–96.

[31] IAEA 2020b, p. 180.

[32] Ibid., p. 179.

[33] Ibid., p. 181.

[34] Ibid., p. 180.

A somewhat different approach to safeguards quality control has been suggested by Australian safeguards expert John Carlson. He proposes a safeguards audit, conducted by a small group of trusted experts, presumably external to the Department, reporting to the Director General, who could review safeguards decisions and, where appropriate, make recommendations on process.[35] Carlson understands that such an arrangement operated in the 1980s and says, "it could have a useful role today where states are looking for assurance on the directions in which safeguards practice is evolving."

As for technological improvements for safeguards, a €41 million Modernization of Safeguards Information Technology (MOSAIC) project, launched in 2015 was completed in 2018. Employing 150 in-house professionals, the project developed more than 20 unique software applications designed to make safeguards more effective, efficient and secure. The Department recently established a Collaborative Analysis Platform (CAP) that integrates big data collection and analysis tools into safeguards work. Also contributing greatly to safeguards effectiveness has been the Enhancing Capabilities of the Safeguards Analytical Services (ECAS) project, a multi-year endeavour to design and construct new laboratory facilities for the Safeguards Analytical Laboratories at Seibersdorf, comprising the Nuclear Material Laboratory (NML) and the Environmental Sample Laboratory (ESL).[36] The redesigned NML, described as the 'workhorse' of the IAEA's sample analysis, increased capacity by over 50%. The project, funded by voluntary Member State contributions, was completed in 2015 within budget and on schedule. Such is the constant advance of science and technology, however, that the IAEA will need to continuously ensure that its laboratories remain state of the art if they are to meet future nuclear proliferation challenges.

A recent new focus of Departmental concern has been organizational resilience, particularly due to the COVID-19 pandemic, which threatened to have a significant impact on safeguards implementation. Not only did Headquarters staff need to adjust to working from home, with particular complications owing to the confidentiality of safeguards derived information, but inspectors had to go to extraordinary lengths to carry out their on-site activities and maintain the continuity of verification. Director General Grossi declared that "Safeguards implementation did not stop for a single minute."[37] Creative ways were found to enable both Headquarters and in-field tasks to continue unabated, despite travel and quarantine restrictions. Thanks to Member State support, the IAEA was able, for the first time, to hire dedicated aircraft when necessary to transport inspectors to their destinations. Overall, the IAEA has, to date, demonstrated a reassuring degree of organizational robustness in coping with the effects of COVID-19. To identify vulnerabilities to safeguards operations from

[35] Carlson 2018.

[36] https://www.iaea.org/newscenter/news/iaea-safeguards-labs-more-efficient-and-accurate-thanks-to-recent-upgrades. Accessed 12 July 2021.

[37] https://www.iaea.org/newscenter/news/iaea-nuclear-verification-continued-during-the-covid-19-pandemic-safeguards-statement-2020. Accessed 30 September 2021.

future global emergencies the IAEA completed a Business Impact Analysis (BIA).[38] The risk management approach to IAEA operations is to be applauded.

11.6 Transparency and Openness

Debates about the lack of transparency at the IAEA often conflate three different challenges: internal transparency within the Secretariat; transparency between the Secretariat and Member States; and public-facing transparency. Each requires different approaches. During his tenure, Director General Mohamed ElBaradei launched his 'One House' campaign to break down the internal informational stovepipes for which the Secretariat was notorious and to induce all departments of the Agency to pull in the same direction. In 2020, Director General Grossi, in introducing the Policy, Management and Administration part of his first Programme and Budget, was still contending that achieving the objectives of Member States required "effective coordination to ensure a one house approach".[39] He then listed almost all of the IAEA's activities as needing this approach, including "the management of information within the Secretariat, between the Secretariat and Member States, and for the benefit of the general public and the media." All these aspects are relevant to safeguards implementation.

Yet, as the repository of most of the confidential information held by the IAEA, the Department of Safeguards has over the years understandably struggled with embracing the one house ideal more than other departments. Indeed, the confidentiality principle set out in safeguards agreements is explicitly designed to guard against information sharing by the Department. The confidentiality mantra, unusual for an international organization, is now so firmly embedded in IAEA safeguards culture that it has contributed to a general culture of opacity about all safeguards matters and a lack of transparency at the IAEA generally.

Transparency within the Department of Safeguards has in recent years improved as a by-product of the State-level concept (SLC), which demands intensive collaboration between managers, analysts and inspectors in State Evaluation Groups (SEG) to draw up safeguards conclusions for each State, based on multiple sources of information. Nonetheless, this has clearly not been sufficient as efforts are continuing, with Member State support, to implement the Department's 2013 Strategic Internal Communication Plan to "enhance senior leadership and departmental staff member communication capabilities."[40]

As for transparency between the Secretariat and Member States, there have long been calls for a better explanation of evolving safeguards approaches by the Safeguards Department. A particular issue arose in 2012 when some Member States criticized the lack of information and analysis from officials about the State-level concept. Although some of the reaction was political point-scoring, there was

[38] IAEA 2020e, p. 15.

[39] IAEA 2019b, p. 141.

[40] IAEA 2020d, pp. 16–17, 43–48.

also genuine concern among some Member States about this latest example of safeguards obtuseness.[41]

A longer-running debate has ensued over the impenetrability of the annual Safeguards Implementation Report (SIR). Since its introduction in 1977, it has become, in Roger Howsley's memorable words "data rich and information poor".[42] For example, the 2019 Safeguards Statement, the public, bowdlerized version of the SIR, revealed, helpfully, that one State had lost its broader conclusion. In typical fashion, however, it was not announced directly and the State concerned, Libya, was not named. This was only apparent from the drop in the number of States with the broader conclusion from 71 to 70. This was the perfect opportunity to nudge the SIR towards increased transparency, as Libya was mired in a civil war and could hardly be blamed for its safeguards lapse. Similar safeguards challenges occurred after the accident at the Fukushima Daiichi nuclear power plant and due to the inability of the Agency to access certain locations in Ukraine. In all these cases, the reissuing of the broader conclusion "did not reflect the technical facts on the ground".[43] As Australia remarked to the Board, "the SIR should contain enough detail to enable Member States to understand the operation of the Agency's safeguards system and assess the effectiveness of safeguards implementation."[44]

Others have argued that the SIR should "identify when problems are attributable to the IAEA, whether due to equipment failures, staff issues or administrative challenges."[45] At present, Member States and the public are left guessing, which contributes to amnesia about the problems facing safeguards: no one appears responsible. The External Auditor recommended in 2020 that the late submission of State declarations and its impact on drawing safeguards conclusions should be highlighted in the SIR, including information on utilization (or not) of the State Declarations Portal (SDP), a secure, web-based application that supports data exchange between the IAEA and Member States.[46] Former DDG for Safeguards Olli Heinonen argues that the SIR should also highlight emerging problems in safeguards, which should also be covered in technical briefings to the Board of Governors.[47] He has also suggested that the Secretariat should issue stand-alone reports on problematic countries, presumably not just after they have been revealed to have been in non-compliance, as is currently the practice.

The 2020 SIR had some welcome new elements. The 2020 Annual Meeting of the Institute of Nuclear Materials Management (INMM) and the European Safeguards Research and Development Association (ESARDA) heard that there was "a lot more, meaningful rich data in the SIR" (Carrie Mathews, Chair), including new trends and new graphics, and "a new fancy cover" (DDG Aparo). Aparo also announced the

[41] Mayhew 2020.

[42] Howsley 2011.

[43] Otto 2021.

[44] https://austria.embassy.gov.au/vien/AEIASIRJune2021.html. Accessed 30 September 2021.

[45] Rockwood et al. 2019, p. 29.

[46] IAEA 2020b, pp. 177–178.

[47] Heinonen 2013.

Director General's intention to provide additional information to Member States on "how we are doing our business", including data derived from the SLA, but cautioned against rendering the SIR "unreadable".[48]

As for external or public-facing transparency, this can likely only be changed with an organization-wide cultural shift. Greater openness by the IAEA about its strategic goals, budget and finance, organizational restructuring, and performance measurement would embolden the Safeguards Department to be more open about the effectiveness of safeguards, emerging proliferation challenges, and generic concerns about non-compliance by Member States. As a start, Heinonen advocates making the entire SIR public, to highlight implementation and compliance problems to all stakeholders, including researchers and whistle-blowers, who could use it to publicize and help further expose State malfeasance.[49] The Secretariat itself has supported such a move, but is inhibited by some Member States' qualms.

A further difficulty is the Secretariat's reluctance to publicly answer the IAEA's critics, leaving the Safeguards Department undefended and vulnerable to misunderstanding and further criticism. The previous Director General, Yukiya Amano, noting that it was sometimes difficult for Member States and the public to understand what the IAEA was doing, conceded that "It can also be frustrating for us when we see inaccurate information under discussion in the public domain."[50] The answer is plainly greater transparency. Writing for the Vienna Center for Disarmament and Non-Proliferation (VCDNP), Laura Rockwood and her colleagues have recommended that "False assertions regarding the IAEA's legal authority should be challenged by Member States and by the Secretariat."[51] They suggest that "Challenges to the IAEA's authority stemming from States' mistrust of the Secretariat can be ameliorated with transparency, consultations and messaging that underscores a safeguards relationship characterized by partnership rather than contestation." They also propose giving SAGSI a public-facing role to help challenge false statements about safeguards and to offer independent opinions on safeguards issues to the public and to the Board of Governors.

The non-proliferation community is largely supportive of the IAEA and its mission and should be regarded as 'force multipliers' in spreading the word about its accomplishments and challenges, especially given the doleful lack of support from some Member States. Director General Grossi appears more open to sharing information and is more outspoken in his public pronouncements, including making spontaneous rather than scripted responses. But he also needs to repair the IAEA's relationships with the media, academia and civil society, which have become frayed in recent years. Encouragingly, since becoming Director General, he has argued that forging inclusive partnerships—not only with Member States but also by reaching out to

[48] Mathews and Aparo 2020.

[49] Heinonen 2013, p. 5.

[50] https://www.iaea.org/newscenter/statements/challenges-in-nuclear-verification. Accessed 30 September 2021.

[51] Rockwood et al. 2019, p. 26.

non-governmental and international organizations, industry and civil society—can help the IAEA maximize its ability to ensure a better future for all.[52]

11.7 Safeguards Training

The Safeguards Department has taken significant steps to improve training in recent years. Its Training Section (CTR) is responsible for designing and delivering safeguards training for both IAEA personnel and those from State or regional authorities (SRAs).[53] The latter role helps impart IAEA safeguards practice and culture to national nuclear authorities, in addition to allowing the Secretariat to detect dysfunctional safeguards practice and cultures in such institutions.

Training for new inspectors begins with an Introductory Course on Agency Safeguards (ICAS) lasting three to four months. Modules cover the necessary technical topics, including non-destructive assay techniques, containment and surveillance, radiation protection and design information verification. Training increasingly also involves soft skills, including observation, negotiation, communication and interviewing techniques. Trainees are familiarized with the history of safeguards, including past non-compliance cases, and the background to safeguards treaties and agreements. The introductory course concludes with a comprehensive inspection exercise at a light water reactor and presentation of a case study.

The new ‘completeness and correctness’ mantra embodied in the strengthened safeguards system since the Iraq case is now being embedded in the culture through training. Inspectors are being trained to be more inquisitive, more investigatory, more questioning of their facility or government hosts, and more willing to take initiative in the field rather than automatically requesting authorization from Vienna. An experienced inspector who conducts part of the introductory training course has claimed that the new approach is working: “But in addition to measuring nuclear material, reviewing accountancy and auditing the books, we’re always looking for signs or indications of potentially undeclared nuclear materials and activities”.[54] The aim is to teach inspectors to think not as physicists, chemists or engineers, which the majority are, but as investigators.[55] Essentially, inspectors must learn to be whistle-blowers. This involves not just being prepared to uncover evidence of non-compliance, but also being confident enough to make the case for a violation to a potentially sceptical senior IAEA supervisor.

In addition to training new staff, the CTR also offers courses for continuing safeguards staff, covering the range of safeguards activities at facilities and Headquarters

[52] Grossi 2021, pp. 13–14.

[53] IAEA 2020d, p. 97.

[54] https://www.iaea.org/newscenter/news/training-iaea-inspectors. Accessed 10 February 2015.

[55] https://www.iaea.org/newscenter/news/a-day-in-the-life-of-a-safeguards-inspector. Accessed 30 September 2021.

and aiming to develop both 'technical and behavioural skills'.[56] Quality management training for all safeguards staff, including inspectors, has recently intensified.[57] Given the prominence of the State-level approach, it is especially important that all safeguards personnel be trained in the systematic use of new analytical techniques, including critical thinking and 'structure analysis'.[58] Analytical skills training is designed to help analysts and inspectors avoid 'group think'; employ competing hypothesis analysis, which can reportedly be remarkably effective; and remove individual bias as much as possible. Participants are taught that there are three levels of analysis: objective analysis, with which they are all comfortable; subjective analysis, where some degree of subjectivity is required to draw a conclusion on the evidence; and the political level, where they should not venture. The CTR is conducting a series of one-day workshops to teach participants in State Evaluation Groups how to work as teams.[59]

Although training is seeking to change safeguards culture to accommodate the new espoused values of strengthened safeguards, there is no conscious mention of safeguards culture in safeguards training documentation or plans. This contrasts sharply with global practice in nuclear safety and security, where no respectable introductory course would be complete without reference to culture and at least a class on what it is and how to enhance it. This lacuna should be rectified. It is increasingly being recognized that there is a need to transmit 'tacit knowledge' which is not in handbooks or instructions, but which is in large part cultural. Senior inspectors are key to mentoring new staff and passing on safeguards culture, especially in helping them know how far they can go in being proactive and assertive. The IAEA has undertaken knowledge management efforts since 2007 to support supervisors in identifying the retention of critical job-related knowledge from staff members retiring or otherwise leaving the Department.[60]

As to preparing for future non-proliferation challenges, the IAEA claims that it now continuously updates its training programme to match the evolution of safeguards implementation.[61] For instance, additional training was provided at short notice to address verification challenges at the Fukushima Daiichi site in Japan after the 2011 accident and after 2015 to support verification in the Islamic Republic of Iran after the conclusion of the JCPOA.[62] Training is also continuing for possible resumption of inspections in the DPRK.[63] The CTR is also cognizant of the need for training for the arrival of new technologies, whether verification technologies employed by the IAEA itself or new technologies in the nuclear industry.[64]

[56] https://www.iaea.org/newscenter/news/training-iaea-inspectors. Accessed 10 February 2015.

[57] IAEA 2007, p. 6.

[58] IAEA 2020d, p. 104.

[59] Ibid., p. 107.

[60] IAEA 2007.

[61] IAEA 2014a.

[62] IAEA 2017.

[63] Project SGCP-102, see IAEA 2020d, p. 98.

[64] Ibid., pp. 100–101.

The most recent challenge to effective safeguards training has been the COVID-19 pandemic. In-person learning has been largely replaced by e-learning, requiring the re-imagining of teaching techniques and expected outcomes. CTR believes the experience may have long-lasting effects on training, shifting the emphasis from traditional instruction methods (lectures and Q&A) to 'student centred learning', with enhanced interactivity, instant student feedback, a greater focus on goals and methods to achieve pedagogical objectives and the use of simultaneous translation for trainees who do not speak English.[65] Safeguards training in a multicultural environment has always faced challenges and the pandemic may have hastened the consideration of significant reforms.

Obviously, no training programme can be perfect. A 2019 report commissioned by the Swedish Radiation Safety Authority pointed to alarming examples of inspectors "who are unaware of or non-compliant with the requirements of safety and security in a facility, who are not fully informed of the legal framework (including constraints on the IAEA) or who simply misbehave or engage in combative behaviour with the operator or the State."[66] It concluded that while "luckily, the examples are few", they "warrant attention." The Organisation for Economic Co-operation and Development (OECD) suggests that regulatory-type organizations follow the International Organization for Standardization (ISO) standards for inspections and seek accreditation.[67] The IAEA has already done this for its Safeguards Analytical Laboratory. Given the IAEA's perception that its safeguards system is unique, it may be unwilling to subject itself to such an accreditation process, although it could learn from the widely accepted standards themselves.

The CTR concedes that its work is complicated by budget constraints, staff turnover, reliance on external trainers (60%), increased restrictions on facility access for on-site training, and the need to update management and training tools.[68] Extra-budgetary support from Member States (mostly Western) is required for most training courses and course travel, as well as for cost-free experts to teach some courses.[69] Reliance on voluntary funding not only complicates planning but unfortunately perpetuates the misleading idea that nuclear safeguards are a Western project far removed from the priorities of the developing world. Ideally, the sources of funding and cost-free training staff should be broadened to signal that safeguards are a universal concern, although this is challenging given current financial constraints. This may be an area where public–private partnerships are possible.

65 Stevens et al. 2021.

66 Rockwood et al. 2019, p. 29.

67 OECD 2014; ISO 2017.

68 Project SGCP-102, see IAEA 2020d.

69 Ibid.

11.8 Further Enhancing the Safeguards Workforce

A safeguards workforce that is highly motivated, dedicated, adaptable and ready to meet current and future verification challenges should be a high priority for the IAEA. Despite laudable efforts to improve recruitment and training, the organization faces institutional legacies that stand in the way of optimal outcomes. One is the United Nations staff 'rotation' system that the IAEA employs. Designed to preclude the emergence of a permanent Secretariat career, it subjects inspectors and other professional safeguards staff to a maximum tenure of seven years (usually an initial three year contract followed by two extensions of two years each). After seven years most are required to leave but may reapply for rehiring after a year's absence. At the Director General's discretion, a contract can be extended indefinitely, considering the limited availability of candidates with safeguards expertise, the need to maximize the IAEA's return on investment in inspector training (up to €240,000 over five years per individual) and the increasingly sophisticated and specialized technical requirements of safeguards. Currently, about 30% of IAEA professional staff are on long term contracts, most of them in the Safeguards Department.[70]

The advantage of the rotation system is that it gives the nationals of more Member States an opportunity to work at the IAEA, which developing countries are constantly advocating. It also permits 'fresh blood', with new ideas and skills, to be regularly injected into the system. Less widely recognized, it also enables the Secretariat to send experienced safeguards staff back to their home countries where they may propagate safeguards best practice and culture in their national safeguards authorities. Finally, the rotation policy enables the IAEA to relieve itself of underperforming staff.

However, the disadvantages are considerable. 'Rotation' is a misnomer, as it suggests that staff rotate in and out of the Agency in an orderly fashion. In fact, many highly rated inspectors never return or return so late that they require retraining. The constant churn of personnel results in a loss of expertise and institutional memory and the chance to embed a strong safeguards culture in the workforce. Repatriation costs for terminated staff are considerable. In recruiting new staff, the IAEA cannot offer a guaranteed professional career path. The system also helps managers avoid what should be a standard staff assessment process, documenting both good and bad performance by staff, "which, by most accounts, is not a prevailing culture at the IAEA."[71] These are practices that no modern corporation would tolerate. Meanwhile, the IAEA struggles to recruit qualified staff from all geographical areas, as its Statute requires, particularly as specialized qualification requirements rise. In offering limited term contracts with no career path, the IAEA cannot compete. Large nuclear projects in several countries (including Bangladesh, Egypt, India, Turkey and United Arab Emirates) are drawing potential talent away—despite the lure of Vienna. A particular challenge is the recruitment of analysts, including those skilled in satellite imagery and social media analysis (where the IAEA has only just scratched the surface).

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[70] IAEA 2020b, p. 182.

[71] Rockwood et al. 2019, p. 31.

Although the IAEA Statute requires that "its permanent staff shall be kept to a minimum,"[72] former IAEA legal adviser Laura Rockwood claims that there is no legal bar to modifying the rotation policy with immediate effect (ideally with Board approval or acquiescence).[73] In the meantime, several steps could be taken to replicate by other means the advantages of the rotation system. Rotation within the Department should be systematized, as recommended by the External Auditor (and agreed by the Department). Instead of rotating staff out of the IAEA, sabbaticals, exchange programmes and secondments could be used to refresh staff qualifications and experiences. National nuclear agencies or nuclear related organizations, including EURATOM, ABACC, the Comprehensive Nuclear-Test-Ban Treaty Organization, the World Nuclear University and the OECD's Nuclear Energy Agency, could be potential collaborators. In any event a thorough study of IAEA staffing practices, perhaps by an external consultant, appears warranted.

Despite calls for revamping safeguards culture following the Iraq case in the early 1990s, and unlike the fields of safety and security, cultural change has not been widely recognized as part of the response to sustaining the effectiveness of IAEA safeguards.[74] The Secretariat has not adopted a deliberate cultural change strategy, nor for the most part has it used the language of culture. Yet revolutionary changes in the safeguards system since the Iraq case have inevitably produced changes in safeguards culture in the three areas identified by organizational theorists as key: artefacts, espoused values and underlying assumptions.[75]

The greatest changes in espoused values have concerned correctness and completeness, the need for a more investigatory approach by inspectors, and the value of a more collaborative approach by all staff. The Department of Safeguards has made changes that have been culturally sensitive, such as the consultations that produced the Strategic Plan and its updates, improvements in recruitment and training, and reforms resulting from the quality management process. Staff turnover and generational change will help ensure that a new culture becomes widespread over time, and it also means that the culture may change in unexpected ways, especially as the proportion of women and personnel from under-represented countries increases. The Department also faces the continuing challenge of integrating or at least reconciling several subcultures, especially the bureaucratic and scientific ones, as well as the inspector and analyst subcultures.

Cultural change takes time, however, and such changes may not yet be fully reflected in underlying assumptions held by safeguards personnel. Scepticism about the value of the cultural approach still abounds within the Department, presumably due to a lack of understanding about the insights it can provide and perhaps fear of what it might reveal. This is despite the IAEA routinely urging its Member States

[72] IAEA 1989, Article VII.C.

[73] Rockwood et al. 2019, p. 31.

[74] For a comprehensive study of IAEA safeguards culture, see Findlay 2022 (forthcoming).

[75] Schein 2004, Schein and Schein 2017.

to attend to cultural aspects, not just in the areas of safety and security, but also in strengthening their national nuclear organizations.[76]

The elements of an optimal safeguards culture should be apparent. Some of these are boilerplate aspirations that all organizations should aspire to: organizational excellence; a sense of service and loyalty; and a commitment to effectiveness and efficiency. Other values are specific to the IAEA as an international organization dedicated to a higher cause than its own well-being, notably international peace and security. An optimal safeguards culture should embody a strong commitment by the entire IAEA to the non-proliferation regime. Despite its best intentions, the Department of Safeguards alone is unable to change Agency-wide cultural norms, much less those of the United Nations system, that deeply affect safeguards culture—the most prominent being those related to leadership, management style, recruitment and promotion. Such change requires action from the highest levels of the IAEA, the Director General, and senior staff, as well as the Board of Governors and general membership.

As to safeguards culture specifically, the Secretariat should engage the entire safeguards community, including Member States, to reach an agreed definition of safeguards culture and identify the elements that constitute an optimal culture, just as the nuclear safety and security communities have done. While such an exercise will not automatically lead to cultural change, it can serve as a guide and inspiration to the Secretariat, Member States and other stakeholders. Furthermore, the IAEA should commission a survey and study of its organizational culture by qualified management experts, with a focus on safeguards and related staff. This should include reflections on the impact on safeguards culture of the staff rotation policy, recruitment and training practices, staff assessment counselling, and the reward system. It should also seek lessons from other organizations with regulatory functions. When contemplating major organizational change, the IAEA should from the outset include consideration of the likely cultural impact and put in place measures to achieve the desired cultural shift. Appointing an officer in charge of cultural change management would facilitate this process.

11.9 Future Verification Challenges

One of the challenges for safeguards planning is the periodic, unexpected demand for ad hoc verification services resulting from international agreements reached without the IAEA's direct involvement. The most prominent cases so far have been Iraq, the DPRK and the Islamic Republic of Iran. After years of zero real growth budgets, there is no 'fat' in the IAEA's system to provide for the costs (financial, technical, human resource and management) associated with such episodes. This forces the IAEA to rely on voluntary contributions from Member States. While these usually do arrive, sometimes just in time, the disruption to the IAEA's normal operations can

[76] IAEA 2008a, b, 2014b.

be considerable. It is not just the lack of available funds but the diversion of key staff away from their day-to-day functions. This occurred in the case of the Iraq Action Team and again in the case of the Iran Task Force and later the Office for Verification in Iran. One way of coping with such cases in future would be for the IAEA to establish a special emergency fund. This could be used not just for non-compliance cases but also for nuclear accidents, such as at the Fukushima Daiichi nuclear power plant, when the Secretariat must scramble to mount a crisis response.

On the other hand, the IAEA should seek to derive benefit from the novel verification challenges that invariably arise from ad hoc arrangements. In the Iraq case, collaboration with the UN Special Commission (UNSCOM) and the UN Monitoring, Verification and Inspection Commission (UNMOVIC) exposed the IAEA, for better or for worse, to different approaches to verification, including documentary searches and interviews with key personnel, as well as new techniques such as environmental sampling. In the Islamic Republic of Iran, the IAEA has undoubtedly learned several lessons and gained invaluable experience from maintaining a 24-hour monitoring presence at some facilities and from, as the JCPOA coyly puts it, the "use of modern monitoring technology".[77] Although the JCPOA states explicitly that its provisions and measures "should not be considered as setting precedents",[78] the knowledge and experience gained by the IAEA from the Iran experience will be impossible to firewall from its verification corpus and toolbox. The Secretariat should ensure that lessons learned are properly documented, catalogued and studied. Although some may regard the Secretariat's continuing preparations for re-entry into the DPRK as a waste of resources, the maintenance of this capability enhances the IAEA's overall capabilities, as well as removing verification unpreparedness as an obstacle to the DPRK's swift return to safeguards or to its acceptance of additional monitoring measures.

In addition to these unforeseen one-off verification exercises, there has long been debate about the role of the IAEA in verifying future multilateral or bilateral agreements. The fissile material cut-off treaty (FMCT) has for decades been cited as the next key multilateral step on the road to nuclear disarmament with a potential IAEA verification role. Proposals have also been made for the IAEA to verify surplus nuclear material resulting from nuclear disarmament by the NWSs, especially the Russian Federation and the United States of America. The Trilateral Initiative of the 1990s and early 2000s was meant to pave the way for such involvement.[79] Finally, the 2017 Treaty on the Prohibition of Nuclear Weapons calls for multilateral verification of complete nuclear disarmament, although it does not take advantage of the existence of an experienced body like the IAEA to carry out the task. Nonetheless, at least since the tenure of Mohamed ElBaradei ended, the IAEA has been remarkably shy about putting its case for assuming any of these future roles. The IAEA's Statute has proved extraordinarily flexible over the past 60 years in accommodating new

[77] Joint Comprehensive Plan of Action 2015, Annex 1, para 67.

[78] Ibid., Preamble and general provisions, xi.

[79] Shea and Rockwood 2015.

tasks and there would seem to be no insuperable barrier to taking on any and all of these functions if requested by Member States.

Technological advancements pose continuing challenges to the effectiveness of safeguards, not just in terms of the IAEA ensuring that it has state of the art verification technologies and techniques, but also that it adapts its verification processes to new types of nuclear facilities and technologies of the Member States. The IAEA only has a small budget for research and development activities and relies on Member State support programmes to help drive its technical modernization. Modern information management processes are especially critical as the Secretariat copes with mountains of new data each year, struggles with the perpetual 'signal to noise' challenge and confronts the need to integrate all available information into the State-level approach.[80] The Department's projects on Statistical Evaluation Platform for Safeguards (STEPS), State-Level Approach Implementation Planning (SLAIP) and Environmental Sampling Environment Enhancement (ESEE) are attempts to deal with such challenges. Meanwhile, the proliferation of microsatellites with advanced capabilities promises continuous improvements in remote monitoring from space that the Department must be prepared to exploit. Advanced social media monitoring, big data mining, and distributed ledger and block-chain techniques also remain to be fully exploited by the Safeguards Department. Funding and personnel constraints are constant. The use of artificial intelligence capabilities during on-site inspections, through handheld devices that inspectors can interrogate, is one promising idea that can save inspector time better utilized for other tasks.[81]

11.10 More Regional Offices?

For years, the IAEA has had two regional offices, in Tokyo and Toronto, to facilitate the large safeguards workload in Japan and Canada, respectively. During the COVID-19 pandemic, the two offices have proved especially useful in permitting on-site activity to continue with fewer interruptions from lockdowns and travel bans. DDG Aparo has floated the idea of additional regional offices to provide resiliency to the safeguards system in the event of future crises.[82]

Additional offices may be useful not only for such purposes but also to establish an IAEA presence in regions that feel remote from Vienna and that could benefit from constant interaction with IAEA officials on safeguards issues. Such offices could also manage capacity building for SRAs, SSACs and RSACs, support safeguards training, enhance technical cooperation (TC) projects and further other aspects of the IAEA's mandate, notably nuclear security. There would be cost implications, but one could envisage the IAEA sharing offices and collaborating with existing in-country UN offices such as the United Nations Development Programme (UNDP),

[80] Baute 2021.
[81] Smartt 2021.
[82] Aparo 2020.

which often acts as the focal point for UN activities in developing countries. Choosing each location would be a political challenge. Perhaps the least controversial approach would be to co-locate new IAEA regional offices with the existing regional centres of the UN Department for Disarmament Affairs (Lima, Peru, for Latin America; Lomé, Togo, for Africa; and Kathmandu, Nepal, for Asia and the Pacific). Moving some staff from costly Vienna to cheaper locales may turn out to be cost-neutral. The idea is worth investigating.

11.11 Safeguards Funding

Funding for safeguards has for decades been squeezed between increasing demand for safeguards, zero real growth budgets and linkage with funding for TC. There is a yawning gap between what the Department of Safeguards could do to maximize the effectiveness of safeguards and what it is funded to do through the regular annual budget. For the 2020–2021 biennium, the estimated cost of unfunded projects in the Department's 'wish list' amounted to approximately €33 million, compared with approximately €149 million in the regular budget.[83] Although the regular budget for safeguards has increased each year, it is insufficient to cope with increased demands arising from what the Secretariat calls its 'main challenges'. In addition to those discussed in detail in this chapter, these include planning for and conducting verification activities in a challenging security environment, which may require additional measures to ensure the physical safety of staff operating in the field and to ensure information security.

Despite the election of a US administration, led by President Joe Biden, that is more supportive of international organizations than its predecessor, it is unlikely to lead a major campaign to increase the safeguards budget, although voluntary US funding may increase. In any event, the 25% share of the IAEA budget borne by the United States of America is unhealthy for any international body, much less one as important to international peace and security as the IAEA. In the case of safeguards, it only reinforces the notion that safeguards are principally a 'first world' concern. Funding of safeguards is becoming more equitable through the end of the 'shielding' system, originally designed to protect developing countries from the rising costs of safeguards.[84] Category 3 States, which remarkably include China and India, are due to lose their shielding in 2024, followed by Category 4, comprising least developed countries, in 2032 (they already get a discount in overall regular budget assessments). It has always seemed inequitable that a country like China, that has been rapidly emerging as an economic powerhouse, should not provide a greater share of safeguards financing. Given the strength of the Chinese economy, it is hard to see why it should not contribute a similar amount as the United States of America to the safeguards budget. India's separation of its civilian nuclear facilities from its military

[83] IAEA 2019b, pp. 139–140.
[84] IAEA 2019a.

ones for safeguards purposes and its conclusion of a bespoke Additional Protocol has added considerably to the safeguards budget. Like VOAs, this arrangement is more symbolic than real since India already has nuclear weapons, but it benefits the country by allowing it greater access to peaceful nuclear technology. India should be prepared to at least offset the safeguards costs. Along with increasingly prosperous European States like Bulgaria, Estonia, Latvia, Lithuania, Poland and Turkey, both China and India should voluntarily remove themselves from the shielding system before 2024.

In theory, an additional way to increase the safeguards budget would be to detach it from the perpetual TC linkage.[85] This author has previously proposed a 'grand bargain' that would see TC included in the regular budget in return for including nuclear security (a developed country priority). The annual budget negotiations would then at least start from the premise that all main programmes of the Agency deserve regular budgetary funding. Another possibility is further pursuit of public–private partnerships. These work well in the case of technology, for supporting the IAEA's laboratories and for inspection equipment, but are less likely, and may be too politically sensitive, for other safeguards activities. The establishment of an emergency verification fund, as proposed, could be partially funded from non-governmental sources. The IAEA has already pioneered such a funding model with the major contribution of the Nuclear Threat Initiative (NTI) to the IAEA Low Enriched Uranium (LEU) Bank.

11.12 Conclusion

The IAEA safeguards framework has truly undergone a revolution since the Iraq case in the early 1990s. The strengthened safeguards system is functioning well. The IAEA is now fully cognizant of the threat from undeclared nuclear materials and activities. The Safeguards Department has adopted strategic planning, improved its management and budgeting, and transformed recruitment and training. It has adopted modern technology, including IT, where it is likely to be effective and affordable.

But the IAEA is also aware of the continuing weaknesses of safeguards and the challenges involved in dealing with current and future non-compliance cases, advances in nuclear technology and external threats such as cyberattacks, and, latterly, pandemics. The long drawn-out case in the Islamic Republic of Iran threatens the integrity of safeguards because it challenges key elements of the strengthened safeguards system, including the implementation of elements of the Additional Protocol and the reaching of the broader conclusion. The Secretariat is also conscious that even strengthened safeguards may not be guaranteed to detect evolving and increasingly sophisticated non-compliance efforts. Enhanced technical capabilities such as wide-area sampling (currently prohibitively expensive) and new techniques such as data mining will be required, along with the continuing provision by States of appropriate

[85] Findlay 2016.

intelligence information when necessary. Member States must also do their part by striving for the universality of safeguards agreements and robust national safeguards authorities. They and the international community generally need to provide the level of support—political, financial and technological—that is commensurate with the challenges that the IAEA's safeguards system faces. As many have pointed out, the IAEA is an international security bargain.

References

Aparo M (2020) 61st Annual Meeting of INMM & ESARDA. Journal of Nuclear Materials Management XLVIII, 3/4:21–26

Baute J (2021) Information Management for Nuclear Verification: An Update, Concurrent Session VII-A, The State of Information Management for Safeguards, INMM & ESARDA Virtual Annual Meeting 2021

Boureston J, Ferguson C D (2005) Strengthening Nuclear Safeguards: Special Committee to the Rescue? Arms Control Today 35

Carlson J (2018) Future Directions in IAEA Safeguards, Project on Managing the Atom. https://www.belfercenter.org/publication/future-directions-iaea-safeguards. Accessed 30 September 2021

Findlay T (2016) What Price Nuclear Governance? Funding the International Atomic Energy Agency. https://www.belfercenter.org/publication/what-price-nuclear-governance-funding-international-atomic-energy-agency. Accessed 30 September 2021

Findlay T (2022) Transforming Safeguards Culture: The IAEA, Iraq, and the Future of Non-Proliferation. MIT Press, Cambridge, MA (Forthcoming)

Grossi R M (2021) Emerging Roles, Challenges, and Prospects for the Future, in Pilat J (ed) International Atomic Energy Agency: Historical Reflections, Current Challenges and Future Prospects. Routledge, London and New York

Heinonen O (2013) IAEA Safeguards—Evolving its 40-Year Old Obligations to Meet Today's Verification Challenges, https://www.belfercenter.org/publication/iaea-safeguards-evolving-meet-todays-verification-undertakings. Accessed 30 September 2021

Howsley R (2011) The Safeguards Implementation Report: Time for Transparency? SAGSI, IAEA, Vienna

International Atomic Energy Agency (IAEA) (1965) The Agency's Safeguards System (1965), INFCIRC/66. https://www.iaea.org/publications/documents/infcircs/agencys-safeguards-system-1965. Accessed 30 September 2021

International Atomic Energy Agency (IAEA) (1972) The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected). https://www.iaea.org/sites/default/files/publications/documents/infcircs/1972/infcirc153.pdf. Accessed 30 September 2021

International Atomic Energy Agency (IAEA) (1989) Statute as Amended up to 28 December 2019. IAEA, Vienna

International Atomic Energy Agency (IAEA) (1997) Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540. https://www.iaea.org/publications/documents/infcircs/model-protocol-additional-agreements-between-states-and-international-atomic-energy-agency-application-safeguards. Accessed 30 September 2021

International Atomic Energy Agency (IAEA) (2006) Revision of the Standard Text of the Small Quantities Protocol, GOV/INF/276.Mod.1

International Atomic Energy Agency (IAEA) (2007) Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System Including Implementation of Additional Protocols: Report by the Director General, GC(51)/8
International Atomic Energy Agency (IAEA) (2008a) A Harmonized Safety Culture Model, IAEA Working Document (Last Revised 5 May 2020). https://www.iaea.org/sites/default/files/20/05/harmonization_05_05_2020-final_002.pdf. Accessed 30 September 2021
International Atomic Energy Agency (IAEA) (2008b) Nuclear Security Culture Implementing Guide, IAEA Nuclear Security Series No. 7. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2011) Department of Safeguards Long-Term Strategic Plan (2012–2023) Summary, 2011. www.iaea.org/safeguards/documents/LongTerm_Strategic_Plan_%2820122023%29-Summary.pdf. Accessed 30 September 2021
International Atomic Energy Agency (IAEA) (2013) Department of Safeguards Long-Term R&D Plan, 2012–2023, STR-375. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2014a) Annual Report 2013. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2014b) Managing Organizational Change in Nuclear Organizations, IAEA Nuclear Energy Series No. NG-T-1.1. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2017) Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards: Report of the Director General, GC(61)/16
International Atomic Energy Agency (IAEA) (2019a) Scale of Assessment of Member States' Contribution Towards the Regular Budget for 2020, GC(63)/12
International Atomic Energy Agency (IAEA) (2019b) The Agency's Programme and Budget 2020–2021, GC(63)/2
International Atomic Energy Agency (IAEA) (2020a) Plan of Action to Promote the Conclusion of Safeguards Agreements and Additional Protocols, https://www.iaea.org/sites/default/files/20/09/sg-plan-of-action-2019-2020.pdf. Accessed 30 September 2021
International Atomic Energy Agency (IAEA) (2020b) The Agency's Financial Statements for 2019, GC(64)/4
International Atomic Energy Agency (IAEA) (2020c) Annual Report 2019, GC(64)/3
International Atomic Energy Agency (IAEA) (2020d) Development and Implementation Support Programme for Nuclear Verification 2020–2021, STR-393. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2020e) Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards: Report by the Director General, GC(64)/13
International Atomic Energy Agency (IAEA) (2021a) Status List, Conclusion of Safeguards Agreements, Additional Protocols and Small Quantities Protocols Status as of 1 June 2021. https://www.iaea.org/sites/default/files/20/01/sg-agreements-comprehensive-status.pdf. Accessed 10 June 2021
International Atomic Energy Agency (IAEA) (2021b) Status List, Amendment to Small Quantities Protocols Status as of 1 June 2021. https://www.iaea.org/sites/default/files/20/01/sg-sqp-status.pdf. Accessed 15 July 2021
International Atomic Energy Agency (IAEA) (2021c) Status List, Conclusion of Safeguards Agreements, Additional Protocols and Small Quantities Protocols Status as of 1 June 2021. https://www.iaea.org/sites/default/files/20/01/sg-agreements-comprehensive-status.pdf. Accessed 10 June 2021
International Organization for Standardization (ISO) (2017) ISO/IEC/17020, Conformity Assessment—Requirements for the Operation of Various Types of Bodies Performing Inspection (Revised and Confirmed in 2017). https://www.iso.org/obp/ui/#iso:std:iso-iec:17020:ed-2:v1:en:en. Accessed 30 September 2021
Matthews C, Aparo M (2020) Plenary Meeting, 61st Annual Meeting of INMM, 12–16 July 2020. Journal of Nuclear Materials Manage XLVIII(3/4):21–26
Mayhew N (2020) A Lexical History of the State-Level Concept and Issues for Today, Occasional Paper. Vienna Center for Disarmament and Non-Proliferation, Vienna
Organisation for Economic Co-operation and Development (OECD) (2014) OECD Best Practice Principles for Regulatory Policy: Regulatory Enforcement and Inspections. OECD, Paris

Otto T et al. (2021) Reimaging the Broader Conclusion, Proceedings of the INMM & ESARDA Joint Virtual Annual Meeting, August 23–26 and August 30–1 September 2021 (forthcoming)
Rockwood L, Mayhew N, Lazarev A, Pfneisl M (2019) IAEA Safeguards: Staying Ahead of the Game. https://www.stralsakerhetsmyndigheten.se/contentassets/dbd8127f5cc44dadba96d4f20f6e530f/201914-iaea-safeguards-staying-ahead-of-the-game. Accessed 30 September 2021
Schein E H (2004) Organizational Culture and Leadership, 3rd ed. Jossey-Bass, San Francisco
Schein E H, Schein P (2017) Organizational Culture and Leadership. John Wiley and Sons, Hoboken
Shea T E, Rockwood L (2015) IAEA Verification of Fissile Material in Support of Nuclear Disarmament. Belfer Center for Science and International Affairs, Harvard Kennedy School, Cambridge, MA
Smartt H et al. (2021) Hey Inspecta! Proceedings of the INMM & ESARDA Joint Virtual Annual Meeting 2021 (forthcoming)
Stevens R et al. (2021) Lessons Learned From a Year of Online Training and Engagement in Safeguards, Concurrent Session VII-H, Going Virtual with E-Learning, INMM–ESARDA Virtual Annual Conference (forthcoming)

Chapter 12
Nuclear Liability and Post-Fukushima Developments

Steven McIntosh

Contents

Abstract The international community has developed a series of conventions on civil liability for nuclear damage, which aim to ensure compensation is available for damage, including transboundary damage, caused by a nuclear incident. Those conventions have struggled to gain universal adherence, and the “global regime” called for in 2011 is at best a patchwork quilt, with a number of treaties with differing memberships, and many States (including States with large and growing nuclear

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sectors) not party to any convention. However, the principles of the conventions are reflected in national laws in most States which operate nuclear power reactors and associated facilities. This chapter assesses the current global nuclear liability regime and discusses a series of recommendations made by the International Expert Group on Nuclear Liability (INLEX) to allow the international community to respond to the continued evolution of the nuclear industry.

Keywords Nuclear liability · Civil liability for nuclear damage · Global nuclear liability regime · International Expert Group on Nuclear Liability (INLEX) · Fukushima · Convention on Supplementary Compensation (CSC) · Paris convention · Vienna convention · Joint protocol · Nuclear incident · Radioactive sources · Transportable nuclear power plants (TNPPs) · Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency · Decommissioning · Waste disposal · Nuclear fusion · Small modular reactors (SMRs) · Nuclear-powered ships

12.1 Introduction

The issue of nuclear liability may appear somewhat arcane, but it is vital to the future of the nuclear industry. Unless there is public confidence that innocent victims will be properly compensated in the unlikely event of a nuclear incident, the nuclear industry will struggle to gain the social licence it needs—both at the national level and internationally. The international community has developed a series of conventions which reflect common principles in relation to strict liability, the liable entity, the court in which claims would be heard, the amount of money which must be available, and the protection of victims located in a country different from the one in which the liable entity is located. Although those conventions have struggled to gain universal adherence, their principles are reflected in national laws in most States which operate nuclear power reactors and associated facilities. The International Expert Group on Nuclear Liability (INLEX) provides advice to the Director General of the International Atomic Energy Agency (IAEA) on the implementation of the conventions and on their application to the evolving nuclear landscape.

12.2 International Expert Group on Nuclear Liability

The Director General of the IAEA established INLEX in 2003. INLEX serves three major functions:

(a) Creating a forum of expertise to explore and advise on issues related to nuclear liability;
(b) Enhancing global adherence to an effective nuclear liability regime; and

(c) Assisting in the development and strengthening of the national nuclear liability legal frameworks in IAEA Member States.[1]

Since its establishment, the Group has held regular annual meetings where it has explored and advised on issues regarding the existing international liability regime for nuclear damage. In this context, INLEX finalized explanatory texts on the nuclear liability instruments adopted under Agency auspices in 1997[2] and on the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention of 1988.[3]

12.3 Actions Taken in Direct Response to the Accident

In September 2011, six months after the accident at the Fukushima Daiichi nuclear power plant, the IAEA Board of Governors approved an Action Plan on Nuclear Safety, which was also endorsed by the IAEA General Conference.[4] In respect of nuclear liability, the plan called on:

> Member States to work towards establishing a global nuclear liability regime that addresses the concerns of all States that might be affected by a nuclear accident with a view to providing appropriate compensation for nuclear damage. The IAEA International Expert Group on Nuclear Liability (INLEX) to recommend actions to facilitate achievement of such a global regime. Member States to give due consideration to the possibility of joining the international nuclear liability instruments as a step toward achieving such a global regime.[5]

In response to the second sentence of that action, INLEX reviewed the actions taken by Japan under its national nuclear liability law to provide compensation to those affected by the accident in order to identify whether there were any instances where victims were not properly compensated because of a gap in that law. Whilst Japan was not party to any of the international conventions at the time of the accident, its national law generally reflected their content; the detail, amendments to and operation of that law after that accident have been expounded in great detail elsewhere,[6] and I will not attempt to summarize them here.

That review found no such gaps. What was obvious, however, was that the lack of treaty relations would have been the cause of significant disputes between States

[1] https://www.iaea.org/about/organizational-structure/offices-reporting-to-the-director-general/office-of-legal-affairs/international-expert-group-on-nuclear-liability-inlex. Accessed 13 July 2021.

[2] IAEA 2017.

[3] Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, opened for signature 21 September 1988, entered into force 27 April 1992 (Joint Protocol); IAEA 2013.

[4] https://www.iaea.org/topics/nuclear-safety-action-plan. Accessed 13 July 2021; see IAEA 2011a.

[5] IAEA 2011b.

[6] OECD/NEA 2012.

had damage spread beyond Japan,[7] and that the amount of damage caused by the Fukushima Daiichi accident had demonstrated the inadequacy of the minimum amounts specified in the conventions (the 1960s conventions, the amending protocols adopted in 1997 and 2004, and the Convention on Supplementary Compensation (CSC))[8] in the event of a major nuclear incident.[9] Consequently, INLEX made a number of recommendations[10] directed at developing a global nuclear liability regime and at increasing the amounts of compensation available at the national level.

12.3.1 Strengthening the Global Nuclear Liability Regime

The recommendations directed at strengthening the regime were, as is always the case with nuclear liability, a political compromise:

1. All Member States with nuclear installations should adhere to one or more of the relevant international nuclear liability instruments that contain commonly shared international principles reflecting the enhancements developed under the auspices of the IAEA during the 1990s. In addition, all Member States with nuclear installations should adopt national laws that are consistent with the principles in those instruments and that incorporate the best practices identified below.
2. All Member States with nuclear installations should strive to establish treaty relations with as many States as practical with a view to ultimately achieving universal participation in a global nuclear liability regime that establishes treaty relations among all States. The INLEX experts note that the CSC establishes treaty relations among States that belong to the Paris Convention, the Vienna Convention[11] or neither, while leaving intact the Joint Protocol[12] that establishes treaty relations among States that belong to the Paris Convention or the Vienna Convention. In addition to providing treaty relations, the CSC mandates the adoption of the enhancements developed under the auspices of the IAEA and contains features to promote appropriate compensation, including an international fund to supplement the amount of compensation available for nuclear damage.
3. Member States with no nuclear installations should give serious consideration to adhering to a global regime, taking into account the benefits which such a regime can offer for victims once it achieves adherence by a significant number of States with nuclear installations.

[7] Even though damage was confined to Japan, that did not prevent multiple court cases being brought in the United States of America; see later discussion.

[8] Convention on Supplementary Compensation for Nuclear Damage, opened for signature 29 September 1997, entered into force 15 April 2015 (CSC).

[9] Noting that Japan's domestic law did not have a cap on liability and that the Japanese government had put in place a legislated scheme to ensure that all claims were paid in full.

[10] IAEA 2012.

[11] Paris Convention on Third Party Liability in the Field of Nuclear Energy, opened for signature 29 July 1960, entered into force 1 April 1968 (Paris Convention); Vienna Convention on Civil Liability for Nuclear Damage, opened for signature 21 May 1963, entered into force 12 November 1977 (Vienna Convention); additional protocols amending both conventions have come into force since their original adoption.

[12] Joint Protocol, above n. 3.

Unfortunately, these recommendations have largely been ignored by the international community. In the decade since 2011, the number of States Parties to the 1997 Vienna Convention[13] has only increased from six to fifteen; of those nine additional States Parties, only the United Arab Emirates has nuclear power reactors in operation.[14] The CSC[15] has fared only slightly better: prior to March 2011, only four States[16] had ratified the convention; since then, another seven have, including nuclear power States Canada, India, Japan and the United Arab Emirates. The CSC now covers around 40% of the world's operable power reactors.

One promising recent event has been the announcement that the 2004 protocols to the Paris Convention[17] and to the Brussels Supplementary Convention to the Paris Convention (BSC)[18] will enter into force on 1 January 2022. The delay in entry into force was largely attributable to a stipulation from the European Commission that all European Union (EU) Member States party to the Paris Convention[19] could only ratify the protocols simultaneously, which meant in practice that their entry into force was held hostage to the Member State with the slowest legislative process.[20] Fortunately, there have been no nuclear incidents in the territory of any of the parties to the Paris Convention in the intervening years. Whilst the entry into force of the protocols is certainly welcome, the States Parties to that convention represent only 23% of the world's operable power reactors, a share that will continue to decline as a result of political decisions to phase out nuclear power in some EU Member States and increasing new build in developing countries.

What all this means is that there is not a global nuclear liability regime at present. Instead, we have:

- The 1960 Paris Convention as amended by the Additional Protocol of 28 January 1964, by the Protocol of 16 November 1982 and by the Protocol of 12 February 2004,[21] which after 1 January 2022 will provide for significantly higher minimum limits of liability (and thus greater amounts of compensation)[22] than any other

[13] Vienna Convention on Civil Liability for Nuclear Damage of 21 May 1963, as amended by the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage of 29 September 1997, entered into force 4 October 2003 (1997 Vienna Convention).

[14] Noting that of the pre-March 2011 parties Argentina, Belarus and Romania have power reactors.

[15] CSC, above n. 8.

[16] Including Argentina, Romania and the United States of America.

[17] Protocol to Amend the Paris Convention on Nuclear Third Party Liability, opened for signature 12 February 2004, not yet in force (2004 Paris Protocol).

[18] Protocol to Amend the Brussels Supplementary Convention to the Paris Convention, opened for signature 12 February 2004, not yet in force (2004 BSC Protocol).

[19] Paris Convention, above n. 11.

[20] Which turned out to be Italy.

[21] 2004 BSC Protocol, above n. 18.

[22] Particularly when backed up by the 2004 BSC Protocol, above n. 18.

convention. However, the geographical scope of the Paris Convention is restricted to a region with a declining nuclear power industry.[23]

- The 1963 Vienna Convention,[24] which covers a number of States operating nuclear power reactors in eastern Europe and elsewhere, but was implicitly found in the 1990s to offer inadequate protection to victims.
- The 1997 Vienna Convention,[25] which has few States Parties (and very few with nuclear power reactors).
- The Joint Protocol,[26] which creates treaty relations between most States party to the Paris Convention and a number of States party to the 1963 Vienna Convention and the 1997 Vienna Convention. However, the disparity in the minimum limits of liability between the parties to the Paris Convention[27] and the parties to the 1963 Vienna Convention has caused some disquiet among the parties to the Paris Convention; when approving the Joint Protocol in 2014, France made a reservation effectively imposing a reciprocity requirement on parties to the Vienna Convention.[28]
- The CSC,[29] which only has a small number of States Parties (albeit including some important nuclear States), none of which are party to the Paris Convention.

All this means that the "global regime" called for in 2011 is at best a patchwork quilt, with a number of treaties with differing memberships, and many States (including States with large and growing nuclear sectors) not party to any convention. Whilst the consequences of most nuclear incidents will be restricted to the territory of the incident State,[30] and most nuclear power States have domestic legislation that reflects the principles of the conventions, the five Fukushima-related lawsuits brought in US federal courts in California, the District of Columbia and Massachusetts following the Fukushima Daiichi accident illustrate the perils of a lack of treaty relations.[31]

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[23] Noting that Turkey is an exception to that general statement, being both a party to the Paris Convention and a State with an active new build programme; however, as of the date of writing this paper, Turkey had yet to ratify the 2004 Paris Protocol.

[24] Vienna Convention, above n. 11.

[25] 1997 Vienna Convention, above n. 13.

[26] Joint Protocol, above n. 3.

[27] Particularly as amended by the 2004 Paris Protocol, above n. 17.

[28] "France makes a reservation regarding subpara 2 of Article IV, specifying that, for States which limit the amount of the liability of the operator and which are Parties to the Vienna Convention and the Joint Protocol, France reserves the right to provide, in case of nuclear accident in its territory, that the operator responsible shall be liable for the nuclear damage caused in the territory of one or several of these States up to the amount provided for by the national law of these States at the time of the accident for reparation of nuclear damage caused in French territory."

[29] CSC, above n. 8.

[30] The Chernobyl accident appears to be an outlier in many ways.

[31] For the discussion following, I am indebted to Omer Brown for access to his unpublished presentation to the OECD NEA Nuclear Law Committee in June 2021.

Plaintiffs favour US courts, especially given the lower nuclear liability limits of many other countries, the more generous attitudes of US juries, the potential availability of punitive damages, liberal discovery, contingency fees and large damage awards. Additionally, non-governmental entities typically make attractive targets for plaintiffs' lawyers, because, for example, they are more likely subject to jury trials, have fewer defences against executions of judgements and lack sovereign immunity.

Because there were no treaty relations in respect of nuclear liability between the United States of America and Japan at the time of the accident, US courts were under no obligation to defer to the jurisdiction of Japanese courts and were not bound by rules regarding the channelling of liability exclusively to the operator. Consequently, the defendants in the US cases included not only the operator of the Fukushima Daiichi plant, the Tokyo Electric Power Company (TEPCO), but also a number of suppliers. The plaintiffs included not only US citizens but also Japanese citizens with no connection to the United States of America.

Even though Japan's nuclear liability law channels liability for nuclear damage exclusively to nuclear operators, and provides for unlimited liability (with the Japanese Government committing more than US$76 billion to resolve Fukushima-related claims as of February 2021), the last two of the five US lawsuits were not dismissed until 20 May 2021, following consideration of the cases by three US district courts, two US courts of appeals, and the US Supreme Court. There appears little doubt that a critical factor in the eventual decisions to dismiss the various cases was the absence of any cap on liability in Japanese law, which meant that the defendants were ultimately able to successfully argue that Japanese courts offered the most convenient venue in which claims could be heard.

12.3.2 Increasing the Amounts of Compensation

In making recommendations to increase available amounts of compensation at the national level, INLEX implicitly recognized the impracticality of either amending the conventions to increase the minimum liability limits prescribed therein, or of utilizing the complex mechanisms set out in the conventions to increase those limits.[32] Those recommendations are:

> All IAEA Member States with nuclear installations should ensure that there are adequate funds available to compensate all victims of a nuclear incident, without discrimination. Therefore, such Member States should in particular:
>
> a. Establish compensation and financial security amounts significantly higher than the minimum amounts envisaged under the existing instruments;
>
> b. Undertake regular reviews of the adequacy of compensation amounts in order to ensure that their value is maintained and that they reflect developments in the understanding of the possible impact of incidents involving the installations on their territory, noting that there is a trend towards establishing unlimited liability of the operator;

[32] 1997 Vienna Convention, above n. 13, Article V D; CSC, above n. 8, Article XXV.

c. Undertake regular reviews of the adequacy of financial security amounts in order to ensure that those amounts reflect available capacity in insurance markets, as well as other sources of financial security;
d. Be prepared to set up appropriate funding mechanisms in cases where the amount of damage to be compensated exceeds the available compensation and financial security amounts;
e. Provide compensation for latent injuries, noting that the revised Vienna and Paris Conventions set a 30 year time limit for filing claims for personal injury; and
f. Ensure that compensation is available in the case of an incident directly due to a grave natural disaster of an exceptional character."

It would be valuable to survey IAEA Member States (not just parties to the conventions) to measure the extent to which those recommendations have been actioned.[33] The author is aware that:

(a) Canada increased its national nuclear liability limit to 1 billion Canadian dollars[34] as part of the legislative package adopted to allow for ratification of the CSC.[35] In 2021, the Canadian Government undertook a review of the 1 billion Canadian dollar limit, pursuant to a requirement in the national law that requires the responsible minister to review the liability limit at least once every five years.[36]
(b) The United States of America has continued, in accordance with the legislative scheme known as the Price–Anderson Act, to index the amount payable by each operator in the United States of America[37] in the event of a grave nuclear disaster, thereby increasing the total amount of the pool that would be used to compensate victims in such an event. The amount for which each plant has to be insured has also been increased. As a result of both these steps, the total amount of money available to pay compensation in the event of a grave nuclear disaster[38] is now US $13,522,836,000.[39]
(c) The amount of money available in the global nuclear insurance market has continued to increase over the years and is now well in excess of the amounts set out in the conventions.

[33] Noting that in the case of Japan a number of those recommendations had been actioned either prior to the accident or in the immediate aftermath.

[34] Approximately 560 million Special Drawing Rights (as of 7 September 2021).

[35] CSC, above n. 8.

[36] The review was ongoing at the time of writing this paper.

[37] Noting that when a plant is permanently shut down, the former operator of the plant is no longer bound to pay a deferred premium following a nuclear incident, meaning that the total compensation amount available shrinks.

[38] Leaving aside both moneys payable by other States Parties under the CSC and the possibility foreseen under the Price–Anderson Act that Congress could vote for additional moneys to be provided by government.

[39] Approximately 9.5 billion Special Drawing Rights (as of 9 September 2021).

12.3.3 Other Recommendations

The remaining recommendations from INLEX were that:

All Member States should:

a. Ensure that all claims arising from a nuclear accident are dealt with in a single forum in a prompt, equitable and non-discriminatory manner with minimal litigation, which could include a claims handling system (which may be set up in close cooperation with insurers or other financial guarantors) in order to deal equitably and expeditiously with all claims;
b. Use the model legislation developed by the IAEA as a guide, as appropriate, when drafting or revising national nuclear liability legislation.

The experience of Japan in using a claims handling system to address the great majority of compensation claims has encouraged a number of other States to make provision for the rapid creation of a similar system in the event of a major nuclear incident.

12.4 Other Issues Considered by INLEX Since 2012, Largely Responding to Developments and Innovations in the Global Nuclear Industry

The global nuclear industry is not static, but rather in constant change. In particular, the recent changes in the broader energy generation landscape driven by climate change concerns have caused the industry to question whether the long-standing model of very large water cooled reactors constructed on-site is the only viable model for nuclear power, or whether advanced designs, transportable reactors and/or smaller reactors might be more flexible[40] and more predictable in build cost. Just as international and national safety standards have to be updated to address these developments, consideration also needs to be given to whether the existing nuclear liability regime adequately addresses any new risks which arise, or any changes in expert assessment of the magnitude of existing risks. In addition, radiological risks which fall outside the scope of the existing conventions should be taken account of by INLEX.

In considering these issues, INLEX needs to be conscious that the nuclear liability principles are detailed in international treaties, which are very difficult to change. This is in contrast to the safety landscape, where the conventions are written in general terms and the detailed safety rules are contained in non-binding safety standards which are subject to regular review and update. For that reason, INLEX has developed a practice of making recommendations to States that sometimes go beyond the letter

[40] Both in terms of where they can be sited and in terms of their ability to operate alongside intermittent renewable energy sources.

of the conventions. Those recommendations are made from a perspective that the nuclear liability principles generally offer superior protection and greater certainty to victims than does normal tort law.

12.4.1 The Establishment of Maximum Limits for the Exclusion of Small Quantities of Nuclear Material from the Application of the Vienna Conventions on Nuclear Liability

In 2013, INLEX decided that a recent revision of the IAEA transport regulations, specifically as it related to fissile materials, required a minor consequential change in the 2007 decision of the Board of Governors regarding the Exclusion of Small Quantities of Nuclear Material from the Application of the Vienna Conventions on Nuclear Liability.[41] A draft decision amending that earlier Board decision was approved by INLEX in 2014, and, following approval by the relevant safety standards committees, adopted by the Board of Governors in November 2014.[42]

12.4.2 Radioactive Sources

Radioactive sources—whether sealed or unsealed—are excluded from the scope of all the liability conventions (see, for example, Article I(g) of the 1997 Vienna Convention),[43] given that they are generally under the control of persons who are not operators of nuclear facilities.[44] Implicitly, materials that have reached such stage of fabrication are covered by general tort law, including any applicable environmental law. To quote the IAEA:

> Radioactive sources are used extensively throughout the world for a wide range of beneficial purposes, particularly in medicine, general industry, agricultural research and educational applications. The need to ensure the safety and security of these sources has been recognized for many years, and many Member States established regulatory infrastructures for that purpose. Even so, the occurrence of a number of serious accidents in the 1980s and 1990s

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[41] Replacing the words "paragraph 672 of the 2005 Edition of the Agency's Transport Regulations" with "paragraphs 417, 674 and 675 of the 2012 Edition of the Agency's Transport Regulations".

[42] IAEA 2014.

[43] "'Radioactive products or waste' means any radioactive material produced in, or any material made radioactive by exposure to the radiation incidental to, the production or utilization of nuclear fuel, *but does not include radioisotopes which have reached the final stage of fabrication so as to be usable for any scientific, medical, agricultural, commercial or industrial purpose"* (emphasis added), 1997 Vienna Convention, above n. 13.

[44] Where a radioactive source is used in a nuclear installation, damage arising may be compensable under the liability conventions; see 1997 Vienna Convention, above n. 13, Article IV(4) and similar provisions in the other conventions.

> led the international community to question the effectiveness of these controls. … [There was a] growing realization that inadequate controls over radioactive sources had led to some significant radiological accidents, some of which had caused serious injuries, even death, and/or severe economic disruption. These accidents had their origins in a breakdown or absence of proper regulatory control and were not a result of malicious intent. After 2001, concerns regarding the possible use of radioactive sources for malicious purposes led the international community to broaden the focus of discussions to consider also the need to strengthen controls over the security of radioactive sources.[45]

In recognition of those hazards, in the early 2000s the IAEA adopted a Code of Conduct on the Safety and Security of Radioactive Sources.[46] That Code contains comprehensive advice to States as to the regulatory structures they should put in place to ensure the safety and security of the sealed sources under their jurisdiction, whether in use or in storage. However, it does not contain any provisions concerning third party liability. In 2013, a major international conference suggested that INLEX might consider the issue.[47]

When INLEX considered the issue, the general view was that the possible scope of damage—particularly transboundary damage—was not so great as to demand a special international regime. However, it recommended that States should require, as a condition for the licensing of an activity involving a high activity radioactive source, that the licensee take out a specified amount of insurance[48] to cover its potential third party liability. Some States already have such a requirement in place, and the advice from the insurers was that such insurance is readily available.[49] Consequently, the group encouraged the IAEA Secretariat to convey the importance of insurance provision covering radioactive sources to Member States in the context of its legislative assistance activities.

INLEX noted that facilities where bulk material irradiated in a reactor is processed into its final form, and the transport of such bulk material, do not fall within the exception. For example, rods of cobalt-60 are generally transported in bulk form from a nuclear installation to a manufacturer of radioactive sources. Another example is the case of molybdenum-99, a form of nuclear medicine, which is created in reactors and then often shipped in bulk to another site where it is dispensed into 'generators' for the use of hospitals and medical clinics. In those circumstances, the exclusion would not apply because the material being transported would not qualify as radioisotopes "which have reached the final stage of fabrication". Facilities where the materials are transformed into their final form are "nuclear installations" under the conventions.[50]

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[45] IAEA 2015, pp. 707–708.

[46] IAEA 2004.

[47] IAEA 2015, p. 720.

[48] That amount might be specified in the regulations or in the licence associated with a particular source.

[49] For facilities such as hospitals, their general insurance policies would generally cover the relatively minor risks arising from radioactive sources they might hold.

[50] Noting that "the Installation State may determine that several nuclear installations of one operator which are located at the same site shall be considered as a single nuclear installation", 1997 Vienna

12.4.3 Transportable Nuclear Power Plants

The issue of whether transportable nuclear power plants (TNPPs) are covered by the conventions was the subject of discussions by INLEX spread over many years. The issue turns around the definition of "nuclear installation" in the convention, in particular the exclusion of a nuclear reactor "with which a means of sea or air transport is equipped for use as a source of power, whether for propulsion thereof or for any other purpose".[51] There was broad agreement that, although the nuclear liability regime does not apply to reactors with which a means of sea or air transport (or, in the case of the Paris Convention,[52] any means of transport) is equipped for its own operational purposes, TNPPs to be used only for the external production of nuclear energy would be covered by the regime when in operation. INLEX considered that the term "as a source of power" necessarily implied that the power was used in connection with the operation of the means of sea or air transport.[53] This conclusion is consistent with the clear intention of the original drafters of the Vienna Convention[54] to include in the definition of "nuclear installation" "low and medium power mobile power plants" transported by truck or railroad (while excluding reactors used to propel means of transport by sea or air or in outer space) while the mobile reactors were in a stationary position and operation.[55]

Once it is determined that TNPPs are, in principle, within the scope of the definition of "nuclear installation", the question turns to which State would be the Installation State for the purpose of the conventions. All current proposals for TNPPs envisage that the reactors would only be operable when in a fixed position, very likely within the territory[56] of a State (which would be the Installation State). In the unlikely event that a TNPP would be operated outside the territory or territorial sea of any State, from artificial islands, installations or other structures in the exclusive economic zone or the continental shelf, jurisdictional rules under the Law of the Sea relating to the exclusive economic zone and the continental shelf could be used, in principle, to identify the Installation State. Uncertainties arise if that State is not party to the international conventions, but those uncertainties are no different in principle to those that arise in the case of land-based reactors located in such States.

Convention, above n. 13, Article I(1)(j); CSC, above n. 8, Annex, Article 1(1)(b); the definition in the Paris Convention is worded differently but ultimately means the same.

[51] 1997 Vienna Convention, above n. 13, Article I(1)(j)(i); CSC, above n. 8, Annex, Article 1(1)(b)(i); the definition in the Paris Convention is worded differently but ultimately means the same.

[52] Paris Convention, above n. 11.

[53] This conclusion cannot apply in circumstances where the reactor is used for the propulsion of the vessel. During the movement of such a vessel, it would fall outside the definition of "nuclear installation" contained in all conventions.

[54] Vienna Convention, above n. 11.

[55] IAEA 1964.

[56] "Territory" includes territorial sea.

Whilst the determination of the Installation State is therefore straightforward for TNPPs when in operation, the mobile nature of TNPPs means that liability for a nuclear incident in the course of transport of the reactor also needs to be considered. While in transport from the site of manufacture to the deployment site, the TNPP might contain fresh fuel, or it might not. In the former case, it would be treated as a transport of nuclear material for liability purposes. In the latter case, the liability conventions would not apply. While in return transport from the deployment site to the site of manufacture, the TNPP might contain spent fuel, or the spent fuel might have been unloaded (although the TNPP would inevitably still be radioactive, given activation of structural materials). In either case, it would again be a transport of nuclear material for liability purposes.

However, if the host State is not a party to the same convention as the sending State, or is not party to any convention, there may not be a "receiving operator" as envisaged under the conventions. If the conventions are interpreted literally, the "sending operator" might remain as the liable operator for the entire duration of the deployment; under that interpretation, the State of origin would remain as the Installation State. In particular, where the sending operator is in a Contracting Party to, for example, the Vienna Convention and the reactor is being sent to a person in a non-Contracting State, Article II.1(b)(iv) of the Vienna Convention[57] provides that the sending operator is liable for damage caused by a nuclear incident occurring before the nuclear material "has been unloaded from the means of transport by which it has arrived in the territory of that non-Contracting State". Similar language occurs in all the conventions. This language was considered ill-suited to the case of a TNPP because it would entail that, there being no unloading of nuclear material from the means of transport by which the TNPP had reached the State of destination, the sending operator would remain liable indefinitely, irrespective of whether the TNPP would thereafter be operated by another operator, and regulated by a regulatory body, in the State of destination. Following a broad discussion, the group considered that the Vienna Convention and the CSC[58] should be interpreted to mean that, in the particular case of the transportation of a floating nuclear power plant when no unloading of fuel from the vessel occurs before its operation, the sending operator would cease to be liable when the TNPP is taken charge of by the authorized person in the State of destination. At some future point of time when the original sending operator took responsibility for the TNPP in order to return it to the sending State, that operator would again assume liability. Although this appears complex, in reality it is inevitable that the deployment and operation of any TNPP in a State other than the State of origin will be the subject of an intergovernmental agreement between the two States involved. Such an agreement would determine, inter alia, regulatory responsibility for the facility and, in the absence of any existing liability convention to which both States are party, the liability rules which would apply.[59]

57 Vienna Convention, above n. 11 and 1997 Vienna Convention, above n. 13.

58 CSC, above n. 8.

59 However, such an agreement could not derogate from the rights of other States under any applicable liability convention.

12.4.4 The Interaction, If Any, Between the Liability Conventions and the Assistance Convention

In 2014, INLEX considered the interaction, if any, between the liability conventions and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Assistance Convention),[60] in particular Article 10 thereof. Article 10 provides that the State requesting assistance shall, in respect of death or injury to persons, damage to or loss of property, or damage to the environment caused within its territory or other area under its jurisdiction or control in the course of providing the assistance requested: (a) refrain from bringing legal proceedings against the assisting party or persons and entities acting on its behalf; (b) assume responsibility for dealing with such legal proceedings that may be brought by third parties; (c) hold the assisting party or persons and entities acting on its behalf harmless in respect of any such legal proceedings; and (d) compensate the assisting party or persons and entities acting on its behalf for damage suffered as a result of providing assistance.

INLEX noted that Article 10 of the Assistance Convention[61] could only apply if the convention applied, and that in each case it should be clear whether it had been invoked. INLEX also noted that a significant number of States Parties to the Assistance Convention had made reservations to Article 10, and that the existence of such a reservation might impact on the willingness of other States Parties to provide assistance. The group observed that, if there were treaty relations under one of the international liability conventions, Article 10 would be of little practical relevance to incidents falling within the scope of the applicable liability convention, given that the channelling of liability to the operator would effectively exempt the assisting party or persons and entities acting on its behalf from liability in any case. However, the scope of the Assistance Convention is much wider than that of the liability conventions, in that it extends to all radiological incidents, including those involving radioactive sources, and Article 10 also applies to damage other than nuclear damage. Article 10 of the Assistance Convention may also be relevant where claims are made in a State other than the State requesting assistance in circumstances where there are no treaty relations under one of the nuclear liability conventions between those two States.

12.4.5 Installations Undergoing Decommissioning

In principle, there is no difficulty in deciding whether reactors or other nuclear facilities undergoing decommissioning are subject to the conventions. Whilst they may no longer "contain nuclear fuel in such an arrangement that a self-sustaining chain process of nuclear fission can occur therein without an additional source of

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[60] Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, opened for 26 September 1986 (Vienna) and 6 October 1986 (New York), entered into force 26 February 1987 (Assistance Convention).

[61] Assistance Convention, above n. 60.

neutrons", they are nevertheless facilities "where nuclear material (radioactive waste) is stored". Only when the site is fully released from regulatory control as a nuclear facility will it fall outside the conventions.

The difficulty is that when a reactor, for example, is in operation it is subject to very high liability limits and particularly insurance amounts. At what stage in the decommissioning process is the hazard of that reactor reduced so much that it no longer needs to be insured for that amount—or indeed at all? This issue is particularly acute under the 2004 Paris Convention, given that the minimum amount of liability and insurance for lower-risk installations is €70 million.[62] If there is a wish on the part of government to further reduce the burden on the 'operator' of an installation in the late stages of decommissioning, the only option is for the installation to be excluded from the scope of the convention altogether, pursuant to Article 1(b) of the Convention.[63] The OECD Steering Committee on Nuclear Energy has set criteria for the exclusion of certain installations under that provision. Similar considerations apply to installations used for the disposal of certain types of low level radioactive waste.

In 2017, INLEX considered whether there was a need for similar action to be taken by the IAEA Board of Governors.[64] However, it was noted that both the 1997 Vienna Convention (Article V(2)) and the CSC (Article 4(2) of the Convention on Supplementary Compensation Annex) allow the Installation State to establish a lower amount of liability (5 million Special Drawing Rights) of the operator having regard to the nature of the nuclear installation or the nuclear substances involved and to the likely consequences of an incident originating from such installations. Taking this into account, and also noting the view that the exclusion of some installations from the scope of the Vienna Convention and the CSC may act as a disincentive for companies considering involvement in decommissioning activities, INLEX concluded that there was no need to exclude any installations being decommissioned or low level waste disposal facilities from the scope of the 1997 Vienna Convention and the CSC.

12.4.6 Waste Disposal Facilities

In 2016–2018, INLEX considered the application of the conventions to facilities for the disposal of radioactive waste. The conventions adopted under the auspices of the IAEA only expressly include facilities for the "storage" of nuclear material, which includes radioactive waste.[65] INLEX considered three distinct periods during the lifetime of such a facility:

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[62] 2004 Paris Protocol, above n. 17, Articles 7(b) and 10(a).

[63] Paris Convention, above n. 11.

[64] Vienna Convention, above n. 11 and 1997 Vienna Convention, above n. 13, Article I(2); CSC, above n. 8, Annex, Article 1(2).

[65] The 2004 Paris Protocol, above n. 17, expressly includes "installations for the disposal of nuclear substances" in the definition of "nuclear installation".

(a) The period when the facility is being actively utilized, with wastes being emplaced by a licensed operator;
(b) The period immediately following closure of the facility,[66] when institutional controls will remain active and the facility will continue to be under regulatory control with a licensed operator;
(c) The period after the end of institutional control,[67] when the operating licence will be surrendered or otherwise cease.

INLEX noted there would be an interest to maintain these installations within the scope of the conventions as much as possible, as it would otherwise mean that other legislation or general tort law would be applicable in case of an incident at such an installation. This would in particular be a concern in situations where the radioactive waste remains the property of the waste producer.

For periods (a) and (b), INLEX concluded that during the period where institutional controls remain active (the duration of which will differ from country to country and with different classes of waste), there will still be an operator and the waste can be regarded as being in storage. Therefore, the nuclear liability conventions would continue to apply during the period of institutional control.

Following the cessation of institutional control over the site (period (c)), the group noted that in the absence of an operator, the nuclear liability conventions cannot be applied, and therefore the State which has agreed to the cessation of institutional control would implicitly be expected to assume the responsibility in case of any nuclear incident. In such a case, the State would compensate for any nuclear damage caused by the nuclear incident, implicitly assuming the nuclear liability.

12.5 Current and Future Areas of Discussion

As will be apparent, INLEX is observing the current wave of innovation in the nuclear industry with interest, and is considering the implications for nuclear liability. We have commenced consideration of nuclear fusion and will soon turn our attention to small modular reactors (SMRs) and to marine reactors.

12.5.1 Nuclear Fusion Installations

Although the most well known fusion reactor project is the ITER project in France, there are currently multiple projects in multiple countries developing multiple designs of fusion facilities. Most of the new concepts are much smaller than ITER, but their

[66] Such a period could last for up to 300 years.

[67] Although the risks involved in this period would probably be very limited and would most probably not trigger transboundary damage, the conventions also act to harmonise national law on liability issues.

developers are looking at much shorter timelines to commercial deployment. Fusion is now progressing from the academic ambit to a much more technological approach, and the quantities of radioactive substances generated by more advanced facilities will be much higher than those currently generated by existing experimental facilities. Moreover, private entities are entering as a new player in the development of future fusion facilities and, as a result, a stronger regulatory framework may be needed and is in fact already being considered, in the United States of America, the United Kingdom[68] and elsewhere.

The technical consensus is that a catastrophic accident scenario is not credible, and the radioactive inventory of fusion reactors (primarily tritium) is much smaller than that of commercial fission-based facilities. However, the future operation of fusion facilities will result in the generation of significant amounts of low–intermediate level radioactive waste, both in terms of tritium and in terms of material activated by the operation of the reactor.

Nuclear fusion facilities fall outside the definition of "nuclear installation" in all of the conventions,[69] and any radioactive materials generated during their operation similarly fall outside the definition of "nuclear material". Liability arrangements for such facilities are therefore currently covered only by national law.

INLEX has discussed whether it would be desirable to include nuclear fusion installations within the scope of the 1997 Vienna Convention[70] or to adopt a specific regime, either at the international or at the national level, to deal with liability for damage caused by nuclear fusion facilities and related activities. That discussion has not yet come to a finalized position. On the one hand, the hazard posed by fusion facilities is of a different magnitude than that posed by large fission reactors, more akin to that posed by a large chemical plant or uranium mining and milling operations, which fall outside the scope of the conventions. On that view, the inclusion of fusion facilities within the scope of the existing nuclear liability conventions might lead the public to believe that they posed hazards of a similar nature to large fission reactors. On the other hand, the existing conventions capture facilities of a similar level of hazard, in the shape of research reactors and radioactive waste storage facilities, and the nuclear liability system offers greater protection to victims than does normal tort law. Discussion will continue at the 22nd session of INLEX in 2022.

[68] Department for Business, Energy & Industrial Strategy (2021) Towards Fusion Energy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1022286/towards-fusion-energy-uk-government-proposals-regulatory-framework-fusion-energy.pdf. Accessed 12 October 2021. The paper includes specific discussion of third party liability on pp 50–54.

[69] The definitions of "nuclear reactor" and "nuclear fuel" explicitly refer to fission.

[70] 1997 Vienna Convention, above n. 13, by way of a decision by the Board of Governors under Article I(1)(j)(iv) thereof. Such a decision could have no effect under the 1963 Vienna Convention, above n. 11, or the CSC, above n. 8, given that they lack a corresponding provision.

12.5.2 Small Modular Reactors

At its 2021 meeting, INLEX decided to discuss liability issues concerning small modular reactors (SMRs) in 2022. In principle, SMRs raise no new issues for the nuclear liability regime; whilst they may well pose a lesser hazard than large power reactors because of their smaller radioactive inventory,[71] so do research reactors, which have been covered by the regime since its inception. What may be worthy of discussion is whether INLEX has a view on the advisability of States reducing the liability limit and/or the financial security amount of the operator as foreseen in Articles V and VII of the 1997 Vienna Convention[72] and similar provisions in the other conventions. It will be instructive to hear from experts in government, industry and the insurers as to their experience of situations where States have taken advantage of these provisions in respect of other low hazard facilities and activities.

12.5.3 Nuclear-Powered Ships

INLEX will probably also commence consideration of liability issues around nuclear-powered vessels in 2022. There have been recent reports in the nuclear press[73] regarding plans by both operators and regulators to prepare for the introduction of nuclear-powered civilian vessels. Increasing concerns about the greenhouse gas emissions of diesel-fuelled vessels have led to proposals for the use of nuclear power, either to generate hydrogen or ammonia to replace the diesel in internal combustion engines, or directly as the power source for the vessel. Whilst the former option raises no new issues for nuclear liability, the latter is worthy of discussion. Whilst barge-mounted reactors are best viewed as covered by the conventions (see Sect. 12.4.3), nuclear-powered vessels clearly fall outside the definition of "nuclear installation" in the Vienna Convention,[74] the CSC[75] and the Paris Convention.[76] This potential gap in coverage was recognized in the early 1960s; in response the 1962 Brussels

[71] Noting also the claimed increased safety margins of next generation SMRs such as molten salt reactors and pebble bed reactors.

[72] "[T]he Installation State, having regard to the nature of the nuclear installation or the nuclear substances involved and to the likely consequences of an incident originating therefrom, may establish a lower amount of liability of the operator, provided that in no event shall any amount so established be less than 5 million SDRs, and provided that the Installation State ensures that public funds shall be made available up to the amount established pursuant to paragraph 1." 1997 Vienna Convention, above n. 13.

[73] https://www.world-nuclear-news.org/Articles/Q-A-Core-Power-Chairman-and-CEO-Mikal-B%C3%B8e. Accessed 13 September 2021; https://www.world-nuclear-news.org/Articles/UK-introducing-regulation-for-nuclear-shipping. Accessed 13 September 2021.

[74] Vienna Convention, above n. 11.

[75] CSC, above n. 8.

[76] Paris Convention, above n. 11.

Convention on the Liability of Operators of Nuclear Ships[77] was adopted by the Eleventh Session of the Diplomatic Conference on Maritime Law held under the sponsorship of the Belgian Government and of the IAEA in Brussels from 17 to 29 April 1961. However, that convention has never entered into force. The reasons for that have been explored in detail;[78] I will not repeat them here. At the time of the discussions to revise the Vienna Convention in the Standing Committee on Nuclear Liability in the 1990s, scepticism about the prospects for civilian nuclear-powered vessels meant that there was little interest in a late proposal to include them in the scope of the revised conventions.[79] And there was certainly no prospect of including military nuclear-powered vessels within the scope, given the decision to remove the possible ambiguity surrounding the inclusion of military installations generally.[80]

If it considers that action to address this potential future gap in liability coverage is desirable, INLEX may consider a number of issues:

- The chances of the 1962 Brussels Convention[81] entering into force, noting that not only is there the problem of military vessels, the limit on liability has been overtaken by the 1990s conventions, and the convention foresees jurisdiction possibly lying with the courts of multiple States Parties.
- The possibility of amendments to the 1962 Brussels Convention, noting that the depositary is not the IAEA but rather the Government of Belgium.
- The possibility of an amendment to the modernized liability conventions to remove the exception in the definition of "nuclear installation", noting the glacial pace of ratification of the 1990s conventions.
- Whether there is scope for the IAEA Board of Governors to add nuclear-powered vessels to the scope of the 1997 Vienna Convention[82] by way of a decision under Article I(1)(j)(iv) thereof.[83] It is noted that such a decision could have no effect under the 1963 Vienna Convention[84] or the CSC,[85] given that they lack a corresponding provision.
- Whether the issue can be addressed by way of bilateral arrangements between the flag State of the vessel and the State(s) where ports of call are located, as has

[77] Convention on the Liability of Operators of Nuclear Ships and Additional Protocol, opened for signature 25 May 1962, not yet in force (Liability Nuclear Ships 1962).

[78] Handrlica 2009.

[79] IAEA 2017, Footnote 73.

[80] Ibid., p. 28.

[81] Liability Nuclear Ships 1962, above n. 77.

[82] 1997 Vienna Convention, above n. 13.

[83] Under the Paris Convention, the OECD Steering Committee for Nuclear Energy has a similar power.

[84] Vienna Convention, above n. 11.

[85] CSC, above n. 8.

been suggested,[86] noting that such a solution would not address the concerns[87] of transit States.[88]

12.6 Conclusion

The nuclear industry continues to evolve, often in ways that could not be foreseen by those who developed the nuclear liability principles in the early 1960s.[89] The recommendations made by INLEX allow the international liability regime to respond to that evolution in a way which remains faithful to those principles.

References

Handrlica J (2009) Facing Plans for Multiplying Nuclear-Powered Vessels: Lessons Gained from the Brussels Convention on the Liability of Operators of Nuclear Ships of 1962. International Journal of Nuclear Law 2:313–333

International Atomic Energy Agency (IAEA) (1964) Civil Liability for Nuclear Damage, Official Records. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub54web.pdf. Accessed 13 September 2021

International Atomic Energy Agency (IAEA) (2004) Code of Conduct on the Safety and Security of Radioactive Sources. https://www.iaea.org/publications/6956/code-of-conduct-on-the-safety-and-security-of-radioactive-sources. Accessed 13 September 2021

International Atomic Energy Agency (IAEA) (2011a) Measures to strengthen international cooperation in nuclear, radiation, transport and waste safety, GC(55)/RES/9

International Atomic Energy Agency (IAEA) (2011b) IAEA Action Plan on Nuclear Safety. https://www.iaea.org/sites/default/files/actionplanns.pdf. Accessed 13 September 2021

International Atomic Energy Agency (IAEA) (2012) IAEA Action Plan on Nuclear Safety – Nuclear Liability. https://www.iaea.org/sites/default/files/17/11/actionplan-nuclear-liability.pdf. Accessed 13 September 2021

International Atomic Energy Agency (IAEA) (2013) The 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention — Explanatory Text. IAEA International Law Series No. 5. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2014) The Establishment of Maximum Limits for the Exclusion of Small Quantities of Nuclear Material from the Application of the Vienna Conventions on Nuclear Liability: Resolution adopted by the Board of Governors on 20 November 2014, GOV/2014/63

International Atomic Energy Agency (IAEA) (2015) Safety and Security of Radioactive Sources: Maintaining Continuous Global Control of Sources throughout Their Life Cycle, Proceedings of an International Conference Held in Abu Dhabi. IAEA, Vienna

[86] Handrlica 2009.

[87] I make no judgement as to whether such concerns would be technically justified, but they will exist.

[88] Including states whose exclusive economic zones might be transited.

[89] Although it is interesting to read the *travaux préparatoires* for the 1963 Vienna Convention, above n. 11, and see how they discuss issues such as TNPPs which took decades to come to fruition.

International Atomic Energy Agency (IAEA) (2017) The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage — Explanatory Texts. IAEA International Law Series No. 3 (Revised). IAEA, Vienna

OECD Nuclear Energy Agency (OECD/NEA) (2012) Japan's Compensation System for Nuclear Damage. https://www.oecd-nea.org/jcms/pl_14806/japan-s-compensation-system-for-nuclear-damage. Accessed 13 September 2021

Chapter 13
The Humanitarian Atom: The Role of Nuclear Power in Addressing the United Nations Sustainable Development Goals

Sama Bilbao y Leòn and John C. H. Lindberg

Contents

Abstract After decades of mostly rhetoric on climate change, robust and urgent actions must be taken to avoid its worst effects. However, the energy transition discourse reflects an anti-humanitarian philosophy that will undermine any serious efforts of achieving decarbonisation, as well as merely entrenching already-existing global inequalities. The potential of nuclear power for radically reducing greenhouse gas emissions has been well-explored. However, to date, few attempts have been made to fully discern the broader positive impacts nuclear technology can have on

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achieving sustainable and equitable development. Nuclear science and technology have broad applications and should be placed at the centre of policies aimed at combatting energy poverty, reducing air pollution, providing clean water, addressing food insecurity, or fulfilling any other of the United Nations' 17 SDGs. This chapter explores the centrality of energy in ensuring sustainable development, a just energy transition, and the importance of nuclear energy, which goes far beyond simply delivering low-carbon electricity.

Keywords Climate change · Sustainable development goals · Nuclear energy · Low-carbon energy · Nuclear technology · Cancer · Clean water · Hunger · Clean air · Biodiversity · Environment · Net zero · Energy transition

13.1 Introduction

The coronavirus pandemic has added to the many challenges that humanity faces, ranging from the effects of climate change and air pollution to chronic malnutrition, water scarcity, forced displacement and growing inequality. Even before the pandemic, a major step change was required to meet the United Nations (UN) Sustainable Development Goals (SDGs) by the 2030 deadline.[1] Whilst the pandemic has highlighted the many global inequalities that still exist, the immense progress in human development that has taken place since the end of the Second World War must not be diminished. Standards of living across the world have increased: in 1950, 55% of the global population lived in extreme poverty, with 72% living in poverty,[2] while in 2017 the same figures were 9.3% and 40%, respectively.[3] In 1950, 24.7% of all children died before the age of five, while in 2018, the same figure was 3.9%.[4] In less than 50 years, the number of people suffering from starvation or undernourishment has decreased by 17%,[5] while in less than 20 years, the amount of people with access to electricity has increased, from 72.8% in 2000 to 90% in 2019.[6]

Most of this astounding progress in human living standards has been powered by fossil fuels. For the next chapter of human progress, the challenge is to find ways of safeguarding the progress already made, while ensuring that humanity's use of resources and the environment is sustainable. Human activities have had a considerable impact on the Earth system and urgent actions are required to avoid further

[1] UN 2021.

[2] Bourguignon and Morrisson 2002.

[3] https://data.worldbank.org/topic/poverty. Accessed 1 July 2021; https://www.worldbank.org/en/news/press-release/2020/10/07/covid-19-to-add-as-many-as-150-million-extreme-poor-by-2021. Accessed 1 July 2021.

[4] https://www.gapminder.org/data/documentation/gd005/. Accessed 1 July 2021.

[5] Rosling et al. 2018.

[6] https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity. Accessed 1 June 2021.

destabilization of the planet's habitability.[7] A major driver is the unsustainability of the current developmental trajectory, with anthropogenic climate change being one of the symptomatic challenges, which the United Nations has called "the defining issue of our time".[8] In order to keep global warming below 1.5 ºC, anthropogenic greenhouse gas emissions must decline rapidly, with net zero emissions being reached around 2050.[9] However, despite several decades of political platitudes, and with climate change mitigation consistently being cited as a key political aim, between 1985 and 2018 the use of fossil fuels increased both in absolute and relative terms.[10] This has resulted in annual global greenhouse gas emissions continuing to increase, from 20.5 billion tonnes of CO_2 in 1990 to 33.3 billion tonnes of CO_2 in 2019.[11] A similarly fossil-fuelled development journey for low and middle income countries—including the 770 million people without even rudimentary electricity access[12]—would render any efforts to keep global average temperatures below 2 °C futile. It is therefore evident that the status quo, insofar as emission reductions are concerned, is far from sufficient. A radical departure from conventional responses will be required to address climate change, to build a global community that is, at the same time, more prosperous, more equitable and more sustainable.

However, much of the discourse pertaining to the energy transition betrays an intellectual adherence to a pessimistic 'zero-sum' mentality that threatens to weaken global efforts to decarbonize the world economy in an equitable fashion. This scarcity mindset has resulted in a widespread narrative that contends that it is necessary to take away privileges from those living in high income countries and to limit the growth for those living in low and middle income countries. Historically, this has been reflected in the debate, with arguments being levied against population growth or economic growth on the grounds of environmental protection. This, however, is misguided. Depriving people of a better standard of living will invariably result in public discontent and non-adherence to policies aimed at resolving the challenge at hand. At the core of building a sustainable global community is the provision of a genuinely affordable, clean and on-demand energy system that has as small a footprint (ecological, economic, social) as possible. Nuclear power is at the heart of this new energy system.

Since the first civilian reactors came online in the 1950s, nuclear power has played an important role in providing low carbon, affordable and reliable electricity to communities across the world. Thanks to its low lifecycle emissions,[13] it is estimated that the use of nuclear power has prevented the emission of 68 billion metric tons of greenhouse gases by displacing mainly coal fired power plants in the period

[7] Rockström et al. 2009; Steffen et al. 2015.

[8] https://www.un.org/en/sections/issues-depth/climate-change/. Accessed 1 January 2021.

[9] IPCC 2018.

[10] BP 2020; Ember 2020.

[11] Schlömer et al. 2014.

[12] IEA 2021a, b.

[13] Schlömer et al. 2014.

1970–2015,[14] and the potential role for nuclear in mitigating climate change has been widely recognized.[15] The International Energy Agency (IEA) has noted that "[w]ithout action to provide more support for nuclear power, global efforts to transition to a cleaner energy system will become drastically harder and more costly".[16] However, the potential of nuclear technology goes far beyond climate change mitigation. Thanks to its unique characteristics and broad applications, it should be placed at the centre of policies aimed at combating energy poverty, reducing air pollution, providing clean water, addressing food insecurity, or fulfilling other United Nations SDGs. However, to date, few attempts have been made to fully discern the positive impacts that nuclear technology can have on sustainable development.[17] This chapter will be exploring the centrality of energy in ensuring sustainable development, and the importance of nuclear energy, which goes beyond simply delivering low carbon electricity. The chapter will be structured thematically, highlighting how nuclear technology provides better health, a better environment and a more just world.

13.2 The Centrality of (Clean) Energy to Sustainable Development and the Role of Nuclear Energy

Energy is central to all aspects of life, and many of the most fundamental changes to human lives throughout history have been closely related to breakthroughs in our relationship with energy. These revolutions, whether it is the conquering of fire, the invention of the steam engine, or the advent of electricity, have been associated with major improvements in living standards for many. Despite its undisputed centrality to modern life, energy policymaking is often neglected, and is frequently conducted in a disjointed, crisis-driven and myopic fashion. It is often dictated by short political timeframes (a few years) rather than the generational infrastructure timeframes (30+ years) that are usually required. While being only one of 17 SDGs, the seventh United Nations Sustainable Development Goal—Affordable and Clean Energy—underpins most, if not all, SDGs.

Among energy forms, electricity is perhaps the most impactful. Without electricity, it is not possible to genuinely empower people or protect the environment. Without electricity, there cannot be a modern healthcare system, nor universal access to clean water or sanitation, or quality education. There is a clear relationship between

[14] IAEA 2018.

[15] Brook 2012; Baek and Pride 2014; Hong et al. 2015; Liddle and Sadorsky 2017; MIT Energy Initiative 2018, 2012; OECD/NEA 2019.

[16] International Energy Agency 2019.

[17] Lindberg (in press).

electricity access and human development, with increasing use of electricity facilitating better quality of life,[18] and access to low cost clean electricity being essential to reducing socioeconomic inequalities.[19] There is also solid evidence of the strong connection between electricity access and poverty reduction,[20] and in particular the positive effects on women's empowerment and welfare.[21] Electricity breaks the link between daylight and productive time, allowing women to spend less time on domestic chores, making them more likely to get remunerated work, and facilitating higher educational attainment.[22]

Energy is responsible for 73.2% of global greenhouse gas emissions, of which heat and electricity account for about one third.[23] In terms of total energy production (electricity, heat, transport), fossil fuels are completely dominant, accounting for 84.3% of all energy.[24] Fossil fuels also generate some 63.3% of global electricity, with low carbon sources accounting for the remainder. As highlighted in a recent IEA report on the global electricity market, the considerable growth in renewable electricity generation has been outpaced by a bigger and faster increase in electricity demand, with the difference (approximately 90%) being fulfilled by coal fired power plants.[25] The urgency and the scale of the challenge is striking, especially as in order to limit warming to 1.5 °C, "a virtually full decarbonization of the power sector around mid-century" is required.[26] Instead, global carbon emissions have increased year by year, only shrinking during times of crisis (e.g. the global recessions of the 1930s, early 1980s and 2008–2009; the end of the Second World War; the collapse of the Soviet Union; and the COVID-19 pandemic).[27]

The enormity of the challenge becomes more dramatic when considering that some 770 million people, predominantly in sub-Saharan Africa, still lack access to electricity,[28] and that raising the global population's electricity consumption to the European Union average (700 W/person/year), assuming that the global population stagnated, would require an estimated 5000 GW of additional capacity, on top of the existing 2500 GW.[29] Given the likely increase in electricity demand resulting from the widespread electrification of the economy, it is likely that demand will grow even further.

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[18] Niu et al. 2013.

[19] UNECE 2021.

[20] Khandker et al. 2014; Dinkelman 2011; Rao and Pachauri 2017; Karekezi et al. 2012.

[21] Winther et al. 2017.

[22] Khandker et al. 2014.

[23] https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors. Accessed 1 January 2021.

[24] BP 2020.

[25] International Energy Agency 2021a, b.

[26] Rogelj et al. 2018.

[27] https://www.wri.org/insights/history-carbon-dioxide-emissions. Accessed 1 July 2021.

[28] https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity. Accessed June 2021.

[29] Devanney 2021.

Too often, policy discourse focuses almost exclusively on decarbonization and is marked by the notion of 'energy as a constraint'. This misguided notion manifests itself in a multitude of ways, most notably the perceived need to reduce energy consumption due to its unsustainability. In many ways, energy should rather be seen as a driver to affect socioeconomic change, given its importance in all facets of modern life. In addressing climate change, there is a window of opportunity to decarbonize the global economy, and at the same time create a more sustainable and equitable global society. While intermittent electricity access (e.g. through off-the-grid solar panels) represents a step in the right direction, it is more than evident that it is not sufficient to power a modern economy.[30] For the transition to a low carbon global society to be considered equitable, it is crucial that reliable, around-the-clock, non-polluting energy portfolios are developed to match the needs and the natural endowments of each nation.

Nuclear energy provides low and middle income countries an opportunity to fundamentally transform their energy systems in a sustainable fashion, leapfrogging the carbon intensive pathways travelled historically by developed countries. Nuclear energy has proven that it is possible to disassociate economic growth and greenhouse gas emissions, as highlighted by Sweden[31] and France[32]. Indeed, the rapid expansion of nuclear power in both Sweden and France from 1960 onwards showcased that it is possible to rapidly transform the electricity systems of developed industrial economies from being largely reliant on fossil fuels to becoming some of the lowest emitting in the world within 20 years[33]—similar to the timeframes set by the 2015 Paris Agreement to avoid the worst effects of climate change. Modelling concludes that a global expansion of nuclear power at these historic rates would see fossil fuels displaced from the global electricity system within the required timeframes.[34]

Nuclear energy is the only low carbon energy source that can produce not only electricity but also heat. This brings enormous opportunities to decarbonize other hard-to-abate sectors of the economy. While climate change may result in warmer winters in many parts of the world, heating for buildings will remain crucial, and surplus heat from nuclear power plants is already used across the world, for instance in Switzerland, the Russian Federation and China,[35] to provide district heating in nearby cities. Additionally, there are efforts in China and Finland to explore the possibility of building small reactors specifically for the purposes of generating heat for building conditioning.[36] Nuclear energy can also be used to generate the heat that is indispensable for many industrial processes, such as the production of

[30] Clack et al. 2017; Heard et al. 2017.

[31] Lindberg 2017.

[32] World Nuclear Association 2019.

[33] Cao et al. 2016.

[34] Qvist and Brook 2015.

[35] Csik and Kupitz 1997; Jasserand and Devezeaux de Lavergne 2016; https://www.world-nuclear-news.org/Articles/Haiyang-begins-commercial-scale-district-heat-supp. Accessed 1 July 2021.

[36] Värri and Syri 2019.

concrete, steel and paper, as well as in the chemical industry,[37] and the production of hydrogen and synthetic fuels[38] for shipping and transport. Specifically built reactors that operate at higher temperatures, or retrofitting nuclear reactors into existing coal fired power plants to reuse existing infrastructure, have been suggested as potential ways to decarbonize these other sectors of the economy.[39]

Beyond providing zero-carbon electricity and heat for clean affordable energy, nuclear technologies directly contribute in a myriad of ways towards the global efforts to reach many of the SDGs, including Goals 2 (zero hunger), 3 (good health and well-being), and 6 (clean water and sanitation) to ensure a healthier world.

13.3 Nuclear Technology for Better Health

One of the most fundamental requirements for realizing human potential is good health, and access to efficient and affordable healthcare is critical to this. The global coronavirus pandemic has focused attention on public health in an unprecedented fashion, and it has in very stark terms highlighted the vast health inequalities that exist globally, as well as within individual countries. Access to reliable, around-the-clock and clean electricity plays an important role in strengthening public health both directly and indirectly. The provision of good public health goes beyond powering medical facilities, and includes protecting children's lungs from the known dangers of air pollution, fighting communicable diseases such as sleeping sickness and non-communicable diseases such as cancer, the provision of safe drinking water, and combating starvation and food insecurity. Nuclear technology has for decades played a major role within all of these areas, and it is a role that should be greatly expanded to improve the health of every man, woman and child across the world, irrespective of their location.

13.3.1 Cleaner Air with Nuclear Power

Air pollution is a major public health issue afflicting communities across the world, playing a major role in the development of illnesses such as chronic pulmonary disease, ischaemic heart disease, haemorrhagic and ischaemic strokes, and lower respiratory infections. Air pollution is often associated with polluting energy sources, be it dirty cooking fuels or the use of polluting fuels for electricity generation, as well as combustion engines. The Global Burden of Diseases, Injuries, and Risk Factors Study 2015 ranks air pollution (indoor and ambient) as a leading cause of

[37] Royal Society 2020.

[38] Ingersoll and Gogan 2020.

[39] Qvist et al. 2021.

illness,[40] with some 91% of the global population being exposed to air that exceeds the World Health Organization's (WHO) air quality guidelines.[41] This has detrimental impacts on public health globally, with air pollution contributing to approximately 9% of all deaths worldwide, with low and middle income countries—especially in South and East Asia—being worse affected.[42] The WHO estimates that ambient air pollution significantly contributes to 4.2 million premature deaths per year, with some 3.8 million premature deaths resulting from indoor air pollution,[43] while some studies estimate that the use of fossil fuels contributed to some 8.7 million premature deaths in 2018 alone.[44]

Much of the indoor air pollution can be eliminated if solid fuels (e.g. wood, dung, charcoal) and kerosene were replaced with electricity for cooking, and if that electricity came from low carbon power sources, a considerable amount of the ambient air pollution would be avoided too. Air pollution is currently especially prevalent in low and middle income countries,[45] which is also where most of the growth in electricity demand is expected to occur. Currently, over 2.6 billion people across the world do not have access to clean cooking facilities (with only 17% of the population in sub-Saharan Africa having access,[46] relying on biomass, coal or kerosene). Thus, transitioning to a clean electric system offers an important opportunity to not only prevent many millions of premature fatalities, but also to safeguard local forests.

Nuclear power has played an important role in protecting local communities from the known dangers of air pollution for decades, owing to the fact that nuclear power plants do not emit any air pollution. A study conducted by Kharecha and Hansen in 2013 estimated that the use of nuclear energy between 1971 and 2009 had prevented some 1.8 million air pollution related deaths,[47] either by replacing more polluting energy sources, or rendering such sources unnecessary. The impacts of nuclear energy on air pollution can also be seen in places where nuclear power plants have been prematurely closed for political reasons, as was the case in Germany following the accident at the Fukushima Daiichi nuclear power plant in 2011. It has been estimated that between 2010 and 2017, the German nuclear phaseout resulted in an additional 1,100 air pollution related deaths annually, driven largely by the fact that nuclear power was to a significant degree replaced by coal.[48] Therefore, it is crucial that existing reactors continue to operate for as long as they are capable of doing so, and

[40] Cohen et al. 2017.

[41] https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health. Accessed 12 June 2021.

[42] https://ourworldindata.org/air-pollution#air-pollution-is-one-of-the-world-s-leading-risk-factors-for-death. Accessed 1 July 2021.

[43] https://www.who.int/health-topics/air-pollution#tab=tab_1. Accessed 12 June 2021.

[44] https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking. Accessed 15 June 2021.

[45] https://ourworldindata.org/air-pollution#air-pollution-is-one-of-the-world-s-leading-risk-factors-for-death. Accessed 1 July 2021.

[46] Kharecha and Hansen 2013.

[47] Jarvis et al. 2019.

[48] Vohra et al. 2021.

that nuclear power is expanded to low and middle income countries to displace fossil fuel-fired electricity generation.

13.3.2 Combating Cancer and Other Diseases

Radiation has been used in modern medicine for many decades for the diagnosis and treatment of many conditions, but it is most intimately associated with the treatment of cancer. Few, if any, diseases hold as emotive a place in human society as cancer. The earliest mention of cancers can be found in papyruses that are more than 5000 years old, and the term was initially coined by Hippocrates (460–370 BC).[49] Cancer is one of the most common diseases, with more than 14 million new cases diagnosed each year.[50] Approximately 20% of all men and 17% of all women are diagnosed with cancer during their lifespan,[51] but these figures vary country to country. However, as life expectancy rises, so does the risk of cancer[52]—with, for example, a 40% lifetime risk in the United States of America[53] and a risk of approximately 50% in the United Kingdom.[54]

Radiation plays a tremendously important role in combating cancers around the world. Radiotherapy—often using radioactive elements produced in reactors—can be used in approximately 50% of all cancer cases, for curative or palliative purposes.[55] Some radiotherapy techniques allow addressing conditions difficult to handle in any other way, such as the Leksell Gamma Knife that can destroy cancers in places difficult to reach surgically, such as the brain, by concentrating a large number of small external radiation beams into the target tumour. Early imaging techniques such as X rays revolutionized medicine, but current nuclear imaging techniques, such as computed tomography (CT or CAT), single photon emission computed tomography (SPECT) or positron emission tomography (PET), which provide 3-D images and allow doctors to see bones and tissues and assess organ functionality, represent a step change in our ability to diagnose and cure disease. Additional diagnostic methods include real-time RT–PCR, which is a nuclear derived diagnosis method that detects potential pathogens in a few hours, as opposed to days, including viruses such as COVID-19 or Ebola. More than 40 million nuclear medicine procedures are performed each year, and demand for radioisotopes is increasing at up to 5% annually.

Another important application of nuclear technology for delivering better human health globally is the Sterile Insect Technique (SIT). Some 17% of all infectious

[49] American Cancer Society 2014.

[50] Jaffray and Gospodarowicz 2015.

[51] WHO 2018.

[52] International Agency for Research on Cancer 2020.

[53] American Cancer Society 2020.

[54] Smittenaar et al. 2016.

[55] Jaffray and Gospodarowicz 2015.

diseases globally are vector-borne, including malaria, yellow fever, dengue fever and Zika.[56] Owing to climate change, it is likely that vector-borne and zoonotic diseases will spread beyond their current ranges; indeed, there is evidence of this already taking place.[57] This problem may be exacerbated as mosquitoes and other vectors build resistance against most commonly used insecticides.[58] SIT uses radiation from radioactive sources, such as Cobalt-60 or Caesium-137, to sterilize a large number of male target pests (e.g. Tsetse flies or Anopheles mosquitoes) that are subsequently released into the environment. As these males will not be able to successfully breed, the pest population will be radically reduced or eradicated, and by extension the risk of human infection of any vector-borne diseases will be significantly decreased.[59] SIT has been used successfully around the world to control pests that act as vectors for a large number of diseases[60]—including myiasis (caused by Screwworm flies) and African trypanosomiasis (caused by Tsetse flies)—and could play a major role in combating mosquito-borne diseases such as malaria and dengue fever.[61] SIT also replaces or reduces the need for pesticides, which often have additional health and environmental consequences.

13.3.3 Providing Fresh and Clean Water with Nuclear Technology

Water is the key to virtually all life on the planet, and the crucial role of water for humanity cannot be overstated. The global demand for water has grown steadily, whereas existing reserves of fresh water have shrunk,[62] and it is expected that climate change will have negative impacts on water resources globally, exacerbating water scarcity.[63] Water is an unevenly distributed resource and two thirds of the global population already experience severe water scarcity for at least one month every year,[64] and more than 1.4 billion people (of which 450 million are children) live in areas with high or extremely high water vulnerability.[65] This is also compounded by the lack of safe drinking water, which was responsible for an estimated 1.2 million fatalities in 2017,[66] with diarrhoeal diseases such as cholera and dysentery killing

[56] WHO and IAEA 2020.
[57] Higgs 2018, p. 285.
[58] Bouyer et al. 2020.
[59] Klassen and Vreysen 2021.
[60] Klassen et al. 2021.
[61] Klassen 2009.
[62] Boretti and Rosa 2019.
[63] Jiménez Cisneros et al. 2014.
[64] Mekonnen and Hoekstra 2016.
[65] UNICEF 2021.
[66] https://ourworldindata.org/water-access#unsafe-water-is-a-leading-risk-factor-for-death. Accessed 1 July 2021.

almost 500,000 people annually.[67] Unfortunately, UN-Water recently concluded that not enough progress has been made towards meeting SDG 6 (clean water and sanitation), with water sources drying up and/or becoming even more polluted.[68] Nuclear radiotracers are an essential tool for the surveying of groundwater resources, to identify and map their origin, distribution, quantity and quality, and to develop sensible and sustainable plans for their exploitation and management. These same nuclear techniques are used to assess and manage seawater leaks into freshwater aquifers, to study ecosystem dynamics, to track pollutants in water streams and to analyse the effectiveness of pollution control and remediation techniques.[69]

An important tool for ensuring a steady supply of potable water for homes and industry alike is desalination of seawater. There are currently some 16,000 desalination facilities worldwide, with the majority of them located in the Middle East. Desalination requires considerable amounts of energy to operate, and when reliant on fossil energy sources (which often is the case), it results in a considerable emissions footprint.[70] Unless the cost of fresh water from desalination facilities can be made comparable to the cost of water from traditional sources,[71] many of the world's most climate-vulnerable communities, some 700 million people, will be forced to relocate by 2030.[72] Increasing water demands in combination with the need for decarbonization mean that nuclear energy presents a suitable alternative to fossil fuels to power desalination facilities.[73] This could be done either by coupling large power reactors with desalination plants as an additional application, or using reactors dedicated to desalination.[74] Nuclear desalination is by no means a novel application, with some 200 reactor years' worth of experience amassed, mostly on a smaller scale, especially in Japan, India and Kazakhstan.[75] It is also a concept that has been widely researched, and the combination of empirical testing and feasibility studies has proven that nuclear desalination is both technically and economically achievable.[76] For instance, scientific studies suggest that a nuclear desalination programme in China—which already suffers from water scarcity[77]—would be able to significantly increase water resources in areas of scarcity, and at affordable levels.[78]

[67] https://www.who.int/news-room/fact-sheets/detail/drinking-water. Accessed 1 July 2021.

[68] UN-Water 2021.

[69] IAEA 2015.

[70] Jones et al. 2019; Darre and Toor 2018.

[71] Ziolkowska 2015.

[72] https://www.unicef.org/wash/water-scarcity. Accessed 25 June 2021.

[73] Ingersoll et al. 2014a.

[74] Ingersoll et al. 2014b.

[75] https://www.iaea.org/topics/non-electric-applications/nuclear-desalination. Accessed 1 January 2021.

[76] Belessiotis et al. 2010.

[77] Jiang 2009.

[78] Avrin et al. 2015, 2018.

13.3.4 Combating Hunger with Nuclear Technology

Some 768 million people (2020) suffer from hunger,[79] and every year, undernutrition is either the direct or underlying cause of 45% of all deaths among children.[80] Additionally, more than one in five children under the age of five (some 144 million children) are stunted, and while the pandemic has resulted in increased levels of food insecurity, the pre-pandemic trend already saw a food insecurity increase of 3.2% between 2014 and 2018.[81] At the same time, approximately 1.3 billion tonnes of food are wasted every year, either by consumers or retailers, or become spoiled as a result of poor storage, transportation or harvesting practices.[82]

Electricity is a vital component in eliminating world hunger, helping to increase food production, decrease post-harvest losses, and enable better storage of food (including refrigeration).[83] Empirical studies have concluded that access to electricity has an immediate positive effect on food security, especially in terms of food production, conservation and preparation.[84] Nuclear power already plays a major role in providing pollution-free electricity, and in combination with other nuclear technologies, can play a crucial role in combating hunger worldwide, thus meeting the second of the SDGs.

Nuclear techniques can be used to promote more efficient use of water and nutrients by crops, ensuring increased agricultural yields, leaving more space for nature. One such nuclear technology is food irradiation, where foodstuffs are exposed to carefully controlled amounts of radiation, often using Cobalt-60 manufactured in nuclear reactors, to kill disease causing fungi, parasites and bacteria. The process significantly increases the shelf-life of food, helping to avoid wastage.[85] Equally important from a public health perspective, food irradiation can also play a large role in tackling food-borne diseases, which cause more than 420,000 deaths annually—deaths that disproportionately impact children under the age of five. Additionally, food-borne diseases can cause long lasting health detriments, and cost low and middle income countries US$110 billion in lost productivity and medical expenses each year.[86] Food irradiation has been approved by the WHO, the Food and Agricultural Organization, and the United States Food and Drug Administration[87] and

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[79] FAO et al. 2021.

[80] Mark et al. 2020.

[81] https://sdgs.un.org/goals/goal2. Accessed 1 July 2021.

[82] UNEP 2020.

[83] Willcox et al. 2015.

[84] Candelise et al. 2021.

[85] Verma and Gautam 2015; Thayer 1993.

[86] https://www.who.int/NEWS-ROOM/FACT-SHEETS/DETAIL/FOOD-SAFETY. Accessed 1 July 2021.

[87] WHO 1994; WHO 1988; https://www.fda.gov/food/buy-store-serve-safe-food/food-irradiation-what-you-need-know. Accessed 1 July 2021.

although it is currently employed in more than 60 countries around the world,[88] there are enormous opportunities to increase its use.

A further application of nuclear technology to reduce food insecurity and hunger is the aforementioned SIT. Some 20–40% of crop yields are lost every year because of different pests and diseases.[89] Such losses are likely to be exacerbated by climate change[90] at a time when food production will need to increase by almost 50% to meet growing demand.[91] SIT programmes around the world have demonstrated the value of the technique in terms of controlling pests (e.g. fruit flies) and preventing their spread to new areas. The technique is cost effective and environmentally friendly as it helps to reduce pesticide and fertilizer use, both of which are associated with health and environmental risks.[92]

13.4 Protecting the Environment with Nuclear Energy

13.4.1 Habitat Destruction and Biodiversity Loss

One consequence of our developmental journey is the largely unprecedented loss of biodiversity that has taken place over the past 500 years, with the rate of extinction being almost 100 times higher than expected.[93] There is now little doubt that both extinction of entire species and population declines are largely anthropologically driven, and their magnitude and rate are comparable to the previous five major extinction events that have taken place in the past 450 million years.[94] Between 1970 and 2016, there was a 68% average decline in population sizes amongst mammals, fish, reptiles, amphibians and birds,[95] and this trend was seen amongst both 'traditionally' vulnerable species (e.g. apex predators) as well as species of low concern.[96] This decline has been largely driven by changes to, or outright destruction of, natural habitats, with 75% of the planet's ice-free surface having been significantly altered by human action[97] directly through overexploitation and indirectly through the effects of climate change.[98] The loss of biodiversity threatens to have considerable consequences on the long term stability and dynamics of ecosystems which, in turn, could

88 https://www.iaea.org/topics/food-irradiation. Accessed 1 July 2021.
89 http://www.fao.org/news/story/en/item/1187738/icode/. Accessed 1 July 2021.
90 IPPC Secretariat 2021.
91 FAO 2017.
92 Enkerlin 2005.
93 Ceballos and Ehrlich 2018.
94 Dirzo et al. 2014.
95 WWF 2020.
96 Ceballos et al. 2017.
97 WWF 2020.
98 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services 2019.

result in secondary impacts such as disruptions to food production (as a result of increased pest density or decrease in pollinators)[99] and environmental degradation (in turn associated with forced migration and increased emergence of infectious diseases, for example).[100]

A crucial step to stop biodiversity loss is to alleviate the pressures posed by habitat destruction, climate change and unsustainable exploitation on local environments and species.[101] Energy, both in terms of access and source, plays a crucial role in causing these pressures. For instance, there is a direct relationship between forest degradation (and deforestation) and energy access. Where people either entirely lack access to electricity—or do not have enough of it—they often rely on biomass (often collected from local forests) for fuel. This not only damages local habitats and contributes to decreasing biodiversity, but is also a major source of household air pollution. An extensive analysis of some 158 countries looking at deforestation and rural access to electricity found that rural electrification plays a very significant role in reducing deforestation as electricity replaces biomass.[102] This again highlights not only the scale of the challenge or the many benefits of ensuring rural electrification, but also the great increase in electricity demand that will be an inevitable consequence of replacing biomass with electricity.

13.4.2 More Space for Nature

Meeting this energy demand will require all available low carbon energy sources, but from an environmental conservation viewpoint, nuclear energy is the most benign. The key to nuclear power's conservation value is its very small physical footprint. By virtue of the energy density inherent to nuclear fuel, nuclear power plants have much smaller physical footprints than all other low carbon energy sources. Indeed, a single uranium fuel pellet (weighing roughly 10 g) contains the equivalent energy of three barrels of oil (149 gallons), one tonne of coal or 481 m^2 of fossil gas.[103] The energy density of nuclear fuels, and the extremely high capacity factor of nuclear reactors (global average 82.5% in 2019, with many individual reactors at over 90%) in comparison to other energy sources (solar photovoltaic (PV) 18% in 2019, onshore wind 35% in 2019, offshore wind 43.5% in 2019, coal 49% in 2019, fossil gas 29–63% in 2018) means that a nuclear centric energy system would require significantly less land than any energy system that is highly—or entirely—reliant upon intermittent renewables.[104] An average sized (1000 MWe) nuclear reactor, capable of

[99] Tscharntke et al. 2012.

[100] Schmeller et al. 2020.

[101] Ceballos et al. 2015.

[102] Tanner and Johnston 2017.

[103] https://www.nei.org/fundamentals/nuclear-fuel. Accessed 1 July 2021.

[104] World Nuclear Association 2020; https://www.energy.gov/ne/articles/what-generation-capacity. Accessed 1 July 2021; https://www.irena.org/Statistics/View-Data-by-Topic/Costs/Global-Trends.

powering over two million homes in Europe, occupies approximately 3.4 km^2 and is able to generate electricity 90–95% of the time. In contrast, a solar farm with the same installed capacity (1000 MWe) would occupy 194 km^2, with the equivalent wind farms occupying between 673 and 963 km^2.[105] Given that renewable power sources generate electricity only part of the time, and also require backup generation, the physical footprint of an energy system highly or entirely dependent on intermittent renewables could contribute considerably to both environmental degradation and habitat loss. With a larger physical footprint, there is an increased risk of interference with the natural environment. Indeed, it is well established that these installations can have a detrimental impact on local wildlife, in terms of direct mortality (e.g. impact trauma, entrapment, burning), indirect mortality (e.g. predation due to habitat changes, increased competition), and habitat degradation or loss.[106] The IEA highlighted in their recent Net Zero by 2050 report that in order to meet the stated policy goals by 2050, an unprecedented expansion of both solar and wind will be required; by 2030, some 630 GW of solar PV and 390 GW of wind would have to be installed annually—four times above the levels in 2020.[107] For solar PV, this would require installing the equivalent of the world's largest solar farm every single day. As of July 2021, the world's largest commissioned solar farm—the Bhadla Solar Park in Rajasthan, India—occupies an area of 14,000 acres (~57 km^2).[108] This would mean that in the next ten years, solar farms with a cumulative size slightly larger than the country of Belarus, approximately 208,000 km^2, would have to be constructed.

Nuclear power plants not only occupy considerably less space than any other low carbon energy sources, but also use the materials needed in a very resource efficient manner, thanks in part to the longevity of the reactors (80 years+)[109] in comparison to wind turbines (20 years)[110] and solar panels (depending on type, 5–35 years).[111] Invariably, the construction of any energy infrastructure requires materials—from concrete to an array of different metals and minerals—and these materials have an environmental footprint that needs to be taken into account. Nuclear reactors use about ten times less critical minerals than solar/TWh, and between 10–15 times less than wind power/TWh.[112] The type of materials used plays a major contributory role in determining the potential environmental (and health) impacts. Wind turbines and solar panels require considerable amounts of rare earth elements and heavy

Accessed 1 July 2021; International Energy Agency 2020; https://www.iea.org/data-and-statistics/charts/average-annual-capacity-factors-by-technology-2018. Accessed 1 July 2021.

[105] https://www.nei.org/news/2015/land-needs-for-wind-solar-dwarf-nuclear-plants. Accessed 1 July 2021; Stevens 2017.

[106] Chock et al. 2021.

[107] International Energy Agency 2021a, b.

[108] https://www.nsenergybusiness.com/features/largest-solar-power-plants/. Accessed 1 July 2021.

[109] https://www.energy.gov/ne/articles/whats-lifespan-nuclear-reactor-much-longer-you-might-think. Accessed 1 July 2021.

[110] Ziegler et al. 2018.

[111] http://solarenergyforus.com/solar-panel-efficiency-lifespan/. Accessed 1 July 2021.

[112] International Energy Agency (2021) and International Energy Agency (2021).

metals mostly (90%) produced in China,[113] and these mining operations have well established and considerable negative environmental and public health impacts.[114]

Furthermore, the unprecedented expansion of renewable energy capacity that would be required—and the considerable amount of physical space needed—faces a major challenge and potential barrier: public acceptance. While public opinion polls at the national level generally find high levels of support,[115] the picture is often very different at the local level. There are already signs of growing opposition among potential host communities, both in terms of hosting renewable installations and the transmission infrastructure that invariably will be required. Such local opposition is often on the grounds of visual impact, (perceived or actual) inequitable distribution of costs and benefits, fears relating to adverse effects on the local economy, impacts on wildlife, or issues related to its footprint (land use).[116]

One of the fundamental principles of ensuring a just energy transition is the safeguarding of self-determination of local communities, with guarantees that only willing communities would act as hosts of any energy infrastructure. The sheer scale of the renewables expansion required, and the fact that public opposition is already rising, are concerns that must be taken into account when designing energy policies for the future. Utilizing a sizeable nuclear component in any future energy system would significantly limit the impact of energy infrastructure on local communities. The key factor is energy density, with nuclear power plants being capable of generating vast amounts of electricity with a footprint of an order of magnitude similar to, or smaller than all other low carbon energy sources.

13.5 Ensuring a Just Energy Transition

It is essential that transitions to clean energy systems are done in a way that means no one is left behind, both on an individual level, on a sector level, as well as on a country level. Indeed, the provision of robust energy infrastructure is essential to ensuring that countries thrive, rather than simply subsist. The energy transition does provide a great opportunity to create wealth and prosperity for everyone on the planet, but thought leadership and an abundance mindset will be needed to make the most of this opportunity. Nuclear energy has a central role to play in ensuring a just energy transition, and it is essential that no unreasonable constraints—political, legislative, financial or otherwise—are placed on the expansion of nuclear technologies to low and middle income countries that wish to incorporate this technology in their energy mix.

[113] Van Gosen et al. 2017.

[114] Lee and Wen 2017; Arshi et al. 2018.

[115] Tyson et al. 2021; Department for Business, Energy, and Industrial Strategy 2021; https://ec.europa.eu/clima/citizens/support_en. Accessed 1 July 2021.

[116] Gross 2020; Goyal et al. 2021; O'Neil 2021; https://www.cleanenergywire.org/factsheets/fighting-windmills-when-growth-hits-resistance. Accessed 1 July 2021.

13.5.1 Nuclear Energy Strengthening Energy Independence

Since energy and electricity are fundamental to every facet of modern life, securing supplies that are secure and resilient to external pressures should be a priority for governments. Indeed, throughout history there is ample evidence to suggest that States use energy as a political tool (e.g. the 1973 Oil Crisis) to maintain, exert and expand their spheres of influence.[117] Such actions can have, and have had, considerable political, socioeconomic and humanitarian consequences. In transitioning to clean energy systems, it is crucial that these new systems promote social, economic and political stability, and ensure a large degree of national independence and resiliency. A diversified energy mix that includes nuclear energy helps to ensure self-reliance.

Nuclear energy does not use large amounts of strategic raw materials and its fuel, uranium, can be found in many parts of the world.[118] Furthermore, the prospects of refining naturally occurring uranium from seawater[119] or using abundant thorium as fuel[120] are being explored. Uranium is not only a relatively abundant material (it is the 48th most common element on Earth, approximately 1000 times more common than gold), it is also found in many countries around the world. The pervasive nature of nuclear fuel deposits—unlike fossil gas or rare earth elements that are only found in a small number of countries—means that the geopolitical risks of the nuclear fuel supply chain are considerably lower than energy systems reliant on fossil gas[121] or renewable energy.[122] The cost of uranium has been historically low, partly driven by its relative abundance and partly driven by the few competing uses of uranium. Additionally, the cost of nuclear electricity is relatively insensitive to the price of uranium (a doubling of uranium prices would result in a 10% increase in electricity price).[123]

[117] Directorate-General for External Policies of the Union (European Parliament) 2018.

[118] https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx. Accessed 1 July 2021.

[119] https://www.scientificamerican.com/article/uranium-extraction-from-seawater-takes-a-major-step-forward/. Accessed 1 July 2021.

[120] https://world-nuclear.org/information-library/current-and-future-generation/thorium.aspx. Accessed 1 July 2021.

[121] https://world-nuclear.org/information-library/economic-aspects/energy-security.aspx. Accessed 1 July 2021.

[122] Habib et al. 2016; Stegen 2015.

[123] https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx. Accessed 1 July 2021.

13.5.2 Minimizing the Legacy for Future Generations

Every industrial process invariably generates some form of waste. Indeed, some of the greatest challenges that humanity faces, such as climate change, are caused by waste management failures. Central to ensuring a just clean energy transition is minimizing its legacy footprint, both in the amount and longevity of waste. Such a holistic approach is crucial to ensuring that potentially short sighted policies aimed at resolving today's problems do not create potentially greater harms for future generations. Among low carbon energy sources, nuclear energy is the only industry that since its inception has strived to manage its waste streams throughout its lifecycle and internalize all costs in the price of nuclear electricity. Nuclear power plants have amongst the smallest raw material requirements per unit of electricity generated, which results in the smallest waste footprint. An average sized (1000 MWe) nuclear reactor discharges approximately 25–30 metric tonnes of used nuclear fuel each year,[124] and since the first nuclear unit came online in the late 1950s, the entire industry has discharged an estimated total 400,000 tonnes of used nuclear fuel, with approximately 30% of this material having been recycled for reuse in reactors.[125] The equivalent coal fired power plant generates on average 275,000 tonnes of toxic ash per year (containing, for example, mercury, arsenic and beryllium), on top of more than 3 tonnes of carbon dioxide. Similarly, it is estimated that by 2050 some 60–78 million tonnes of electronic waste will have been generated by the use of solar PV,[126] with analysis suggesting that the actual figure might be considerably higher as solar panels are prematurely replaced.[127] Solar waste often contains toxic materials such as cadmium, antimony and lead, and the glass that makes up the majority of the panel can rarely be recycled due to impurities, meaning that panels often end up in landfills, or are exported to low and middle income countries as electronic waste. If the panels break, toxic materials can leach into the local environment, with potentially detrimental health impacts.[128] In contrast, most nuclear waste can be recycled, including the used nuclear fuel. Recycling of nuclear materials is common practice in the nuclear industry, and extensive efforts are currently underway to further reduce nuclear power's already small waste footprint. The main thrust in this field is research and commercialization of so-called 'burner reactors' which are capable of being powered by used fuel from the current nuclear reactor fleet, thus reducing the overall amount of nuclear waste by 97%.

Its small waste legacy and effective use of natural resources makes nuclear power an integral tool in ensuring that a just energy transition can take place. Indeed, civil

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[124] https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-and-realities.aspx. Accessed 1 July 2021.

[125] IAEA 2020.

[126] International Renewable Energy Agency, International Energy Agency Photovoltaic Power Systems 2016.

[127] https://hbr.org/2021/06/the-dark-side-of-solar-power. Accessed 1 July 2021.

[128] https://www.discovermagazine.com/environment/solar-panel-waste-the-dark-side-of-clean-energy. Accessed 1 July 2021.

nuclear waste is managed to the highest standards and has not caused any harm to people or the environment. With nuclear waste repositories now being constructed, the nuclear industry can demonstrate that long term management solutions are readily available.

13.5.3 An Affordable and Value-Creating Transition with Nuclear Energy

The question of cost-effectiveness is integral to ensuring a just energy transition. The design of the energy systems of the future must optimize the use of available resources—financial, human and material—to deliver reliable, around-the-clock, affordable and clean energy to all sectors of the economy. Any solutions must represent genuine value for money, be long lasting, and result in socioeconomic spillovers for the local, national and regional economies.[129] For example, studies from the IEA, the MIT Energy Initiative, the OECD's Nuclear Energy Agency and others have found that achieving the same low carbon emissions with a larger contribution of nuclear generation makes the total cost of electricity for the end consumer or the taxpayer more affordable compared with a generation mix that relies on a large share of variable renewable energy.[130]

The low carbon energy sector, and nuclear energy in particular, can play a major role in terms of job creation and leading the efforts towards building a more sustainable and resilient future. Investment in the nuclear sector has a proven track record of contributing to socially sustainable and equitable economic development, while helping to create reliable low carbon modern energy systems that offer resilience with regards to weather fluctuations or future geopolitical and economic shocks. The development of nuclear power has historically proven to be a catalyst for industrial and economic growth and prosperity across the world. Countries with limited domestic energy resources such as France, Japan and Republic of Korea are excellent examples of how nuclear energy delivers widespread growth along with energy independence, security of supply and resilience against geopolitical shocks.

Nuclear energy generates a significant amount of highly skilled, highly paid, and mostly local jobs for an extended period of time, often for 80–100 years when including construction, operations and decommissioning. Putting nuclear energy at the heart of a modern industrial strategy will provide support for skills development, R&D, and trade and investment. Analysis of the European nuclear industry has found that every direct job created by the nuclear industry generates work for an additional 3.2 people.[131] It is estimated that every euro spent in the European

[129] Batini et al. 2021.

[130] MIT Energy Initiative 2018; OECD/NEA 2012, 2019; International Energy Agency 2019; Zappa et al. 2019.

[131] https://www.foratom.org/downloads/nuclear-energy-powering-the-economy-full-study/?wpdmdl=42758&refresh=5f61d7fee0ce71600247806. Accessed 1 July 2021.

nuclear industry generates an additional four euros in the European economy.[132] Similarly, every dollar spent by an American nuclear power plant during the year will generate an additional four dollars for the local economy.[133] As a result, nuclear energy investments provide not only a reliable and affordable source of electricity, but also considerable socioeconomic benefits, reinforcing the importance and benefit of placing nuclear power projects at the heart of any just energy transition policy.

13.6 Conclusion

The global coronavirus pandemic that is currently gripping the world has in many ways highlighted the considerable inequities that exist between, and within, different countries. It has also shown that when humanity comes together to resolve an emergency, it is possible to achieve monumental outcomes. The development of safe and effective COVID-19 vaccines in less than a year is a case in point, especially considering that the previous vaccine development record was more than four years.[134] After decades of mostly rhetoric on climate change, the same sense of urgency must be used to take robust action to avoid the worst effects of climate change.

However, modern political discourse relating to the clean energy transition, and economic development more broadly, carries the characteristics of a 'zero-sum' mindset, positing that the populations of high income countries must accept lowering their standards of living to allow low and middle income countries to become more high powered, while limiting the level of developments these countries can expect. This is an anti-humanitarian philosophy that will undermine any serious efforts of achieving decarbonization, as well as merely entrenching already existing global inequalities. While it is conceivable that the world's wealthiest countries will undergo a major behavioural transformation and will consent to energy-restricted lifestyles, it is extremely unlikely that the same will apply to the world's low and middle income countries, which are home to more than 85% of the global population.[135]

These countries need more reliable, around-the-clock energy to ensure a higher standard of living for their populations, and it is within their right to strive for the same high powered lifestyles that high income countries have been enjoying for several generations. The key question at hand is whether these low and middle income countries will commit to the same high carbon, high pollution journey as others have in the past, or whether they will have access to the required skills, financing and technologies to leapfrog straight away to an energy system that is affordable, low carbon and reliable.

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[132] Ibid.

[133] Nuclear Energy Institute 2012.

[134] https://www.nationalgeographic.com/science/article/why-coronavirus-vaccine-could-take-way-longer-than-a-year. Accessed 1 July 2021.

[135] https://www.gapminder.org/fw/income-mountains/. Accessed 1 July 2021.

Nuclear technologies hold immense potential to fundamentally alter life prospects around the world, be it by providing abundant, sustainable and reliable electricity or combating hunger and diseases using various radioisotopes. Nuclear power provides a golden opportunity to embrace an abundance mindset once and for all, and it is the only technology that has a track record to prove not only that it can achieve deep decarbonization at the speed required, but also that it can help to bring vast quantities of electricity to populations across the world. Nuclear power has broken the correlation between economic growth and growing emissions, showing that it is possible to decarbonize the electricity systems of advanced economies within the timeframes necessary to avert the worst effects of climate change, whilst allowing high powered but sustainable lifestyles.

George Santayana's aphorism "those who cannot remember the past are condemned to repeat it"[136] offers some guidance relevant to the energy transition that humanity is embarking upon. It is clear that communities around the world have to wean themselves off their long standing addiction to fossil fuels, and that access to more electricity and a better quality of life will trump concerns about greenhouse gas emissions. With nuclear power, no such trade-off has to take place. A crucial first step towards this is for policymakers at all levels, be it local, national or international, to dare to challenge preconceived notions about nuclear technologies and stand for the opportunity they provide. Just as crucial is the leadership from the world's high-income countries- because of the legacy of past emissions, they have a responsibility to help low- and middle- income countries to leapfrog the fossil-powered development phase. This can be achieved by encouraging multilateral banks to support all low-carbon technologies, including nuclear, and promoting technical cooperation and knowledge transfer. If they do, the momentous task of building truly equitable, sustainable and aspirational societies around the world becomes considerably easier.

References

American Cancer Society (2014) The History of Cancer. https://www.cancer.org/content/dam/CRC/PDF/Public/6055.00.pdf. Accessed 1 July 2021

American Cancer Society (2020) Lifetime Risk of Developing or Dying From Cancer. https://www.cancer.org/content/dam/CRC/PDF/Public/509.00.pdf. Accessed 1 July 2021

Arshi P S, Vahidi E, Zhao F (2018) Behind the Scenes of Clean Energy: The Environmental Footprint of Rare Earth Products. ACS Sustainable Chemistry & Engineering 6:3311–3320

Avrin A-P, He G, Kammen D M (2015) Assessing the impacts of nuclear desalination and geoengineering to address China's water shortages. Desalination 360:1–7

Avrin A-P, He G, Kammen D M (2018) Chapter 7—Relevance of Nuclear Desalination as an Alternative to Water Transfer Geoengineering Projects: Example of China. In: Renewable Energy Powered Desalination Handbook. Butterworth-Heinemann, Oxford, pp 265–286

Baek J and Pride D (2014) On the income–nuclear energy–CO2 emissions nexus revisited. Energy Economics 43:6–10

[136] Santayana 1905.

Batini N, Di Serio M, Fragetta M, Melina G, Waldron A (2021) Building Back Better: How Big Are Green Spending Multipliers? https://www.imf.org/-/media/Files/Publications/WP/2021/English/wpiea2021087-print-pdf.ashx. Accessed 1 July 2021

Belessiotis V, Papanicolaou E, Delyannis E (2010) Nuclear desalination: A review on past and present. Desalination and Water Treatment 20:45–50

Boretti A, Rosa L (2019) Reassessing the projections of the World Water Development Report. npj Clean Water 2

Bourguignon F, Morrisson C (2002) Inequality among World Citizens: 1820–1992. The American Economic Review 92:727–744

Bouyer J, Culbert N J, Dicko A H, Gomez Pacheco M, Virginio J, Pedrosa M C, Garziera L, Macedo Pinto A T, Klaptocz A, Germann J, Wallner T, Salvador-Herranz R, Argiles Herrero R, Yamada H, Balestrino F, Vreysen M J B (2020) Field performance of sterile male mosquitoes released from an uncrewed aerial vehicle. Science Robotics 5

BP (2020) BP Statistical Review of World Energy. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf. Accessed 1 July 2021

Brook B W (2012) Could nuclear fission energy, etc., solve the greenhouse problem? The affirmative case. Energy Policy 42:4–8

Candelise C, Saccone D, Vallino E (2021) An empirical assessment of the effects of electricity access on food security. World Development 141

Cao J, Cohen A, Hansen J, Lester R, Peterson P, Xu H (2016) China-U.S. cooperation to advance nuclear power. Science 353:547–548

Ceballos G and Ehrlich P R (2018) The misunderstood sixth mass extinction. Science 360:1080–1081

Ceballos G, Ehrlich P R, Barnosky A D, García A, Pringle R M, Palmer T M (2015) Accelerated modern human–induced species losses: Entering the sixth mass extinction. Science Advances DOI:https://doi.org/10.1126/sciadv.1400253

Ceballos G, Ehrlich P R, Dirzo R (2017) Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. Proceedings of the National Academy of Sciences of the United States of America 114:6089–6096

Chock R Y, Clucas B, Peterson E K, Blackwell B F, Blumstein D T, Church K, Fernández-Juricic E, Francescoli G, Greggor A L, Kemp P, Pinho G M, Sanzenbacher P M, Schulte B A, Toni P (2021) Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. Conservation Science and Practice 3:319–328

Clack C T M, Qvist S A, Apt J, Bazilian M, Brandt A R, Caldeira K, David S J, Diakov V, Handschy M A, et al. (2017) Evaluation of a proposal for reliable low-cost grid power with100% wind, water, and solar. Proceedings of the National Academy of Sciences 114:6722–6727

Cohen A J, Brauer M, Burnett R, Anderson H R, Frostad J, Estep K, Balakrishnan K, Brunekreef B,et al. (2017) Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. The Lancet 389 10082:1907–1918

Csik B J, Kupitz J (1997) Nuclear power applications: Supplying heat for homes and industries. IAEA Bulletin 39:21–25

Darre N C, Toor G S (2018) Desalination of Water: a Review. Current Pollution Reports 4:104–111

Deloitte (2019) Economic and Social Impact Report FORATOM. https://www.foratom.org/downloads/nuclear-energy-powering-the-economy-full-study/?wpdmdl=42758&refresh=5f61d7fee0ce71600247806. Accessed 1 July 2021

Department for Business, Energy, and Industrial Strategy (2021) BEIS Public Attitudes Tracker (March 2021, Wave 37, UK) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/985092/BEIS_PAT_W37_-_Key_Findings.pdf. Accessed 1 July 2021

Devanney J (2021) Why Nuclear Power has been a Flop. The CTX Press, Stevenson, WA

Dinkelman T (2011) The Effects of Rural Electrification on Employment: New Evidence from South Africa. American Economic Review 101:3078–3108
Directorate-General for External Policies of the Union (European Parliament) (2018) Energy as a tool of foreign policy of authoritarian states, in particular Russia. https://op.europa.eu/en/publication-detail/-/publication/1c80b8c6-58b6-11e8-ab41-01aa75ed71a1/language-en. Accessed 1 July 2021
Dirzo R, Young H S, Galetti M, Caballos G, Isaac N J B, Collen B (2014) Defaunation in the Anthropocene. Science 345:401–406
Ember (2020) Global Electricity Review. Ember, London https://ember-climate.org/wp-content/uploads/2020/03/Ember-2020GlobalElectricityReview-Web.pdf. Accessed 1 July 2021
Enkerlin W R (2005) Impact of Fruit Fly Control Programmes Using the Sterile Insect Technique. In: Dyck V A, Hendrichs J, Robinson A (eds) Sterile Insect Technique, Springer, Dordrecht, pp 651–676
Food and Agriculture Organization (FAO) (2017) The future of food and agriculture: Trends and challenges. http://www.fao.org/3/i6583e/i6583e.pdf. Accessed 1 July 2021
Food and Agriculture Organization (FAO), International Fund for Agricultural Development, UNICEF, World Food Programme (WFP), World Health Organization (WHO) (2021) The State of Food Security and Nutrition in the World 2021 – Transforming food systems for food security, improved nutrition and affordable healthy diets for all. https://www-pub.iaea.org/MTCD/Publications/PDF/TE-1760_web.pdf. Accessed 1 July 2021
Goyal R, Marsh K, McKee N, Welch M (2021) Opposition to Renewable Energy Facilities in the United States. https://climate.law.columbia.edu/sites/default/files/content/RELDI%20report%20updated%209.10.21.pdf. Accessed 1 July 2021
Gross S (2020) Renewables, Land Use, and Local Opposition. https://www.brookings.edu/wp-content/uploads/2020/01/FP_20200113_renewables_land_use_local_opposition_gross.pdf. Accessed 1 July 2021
Habib K, Hamelin L, Wenzel H (2016) A dynamic perspective of the geopolitical supply risk of metals. Journal of Cleaner Production 133:850–858
Heard B, Brook B, Wigley T, Bradshaw C (2017) Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems. Renewable and Sustainable Energy Reviews 76:1122–1133
Higgs S (2018) It Is Official: Vector-Borne and Zoonotic Diseases in the United States and Territories on the Rise-Now What? Vector-Borne and Zoonotic Diseases 18:285
Hong S, Bradshaw C J A, Brook B W (2015) Global zero-carbon energy pathways using viable mixes of nuclear and renewables. Applied Energy 143:451–459
Ingersoll D, Houghton Z, Bromm R, Desportes C (2014a) NuScale small modular reactor for Co-generation of electricity and water. Desalination 340:84–93
Ingersoll D, Houghton Z, Bromm R, Desportes C (2014b) Integration of NuScale SMR With Desalination Technologies. In: Proceedings of the ASME 2014 Small Modular Reactors Symposium. ASME 2014 Small Modular Reactors Symposium, Washington, DC
Ingersoll E, Gogan K (2020) Missing Link to a Livable Climate: How Hydrogen-Enabled Synthetic Fuels Can Help Deliver the Paris Goals. LucidCatalyst, London & Cambridge, MA
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019) Summary for policymakers—Global Assessment. http://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf. Accessed 1 July 2021
International Agency for Research on Cancer (2020) World Cancer Report: Cancer research for cancer prevention. Wild C P, Weiderpass E, Stewart B W (eds). https://shop.iarc.fr/products/world-cancer-report-cancer-research-for-cancer-prevention-pdf. Accessed 1 July 2021
International Atomic Energy Agency (IAEA) (2015) Use of Radiotracers to Study Surface Water Processes. IAEA, Vienna
International Atomic Energy Agency (IAEA) (2018) Climate Change and Nuclear Power 2018. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2020) Nuclear technology review. https://www.iaea.org/sites/default/files/gc/gc64-inf2.pdf. Accessed 1 July 2021
International Energy Agency (2019) Nuclear Power in a Clean Energy System. https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system. Accessed 1 July 2021
International Energy Agency (2020) Coal 2020 Analysis and forecast to 2025. https://iea.blob.core.windows.net/assets/00abf3d2-4599-4353-977c-8f80e9085420/Coal_2020.pdf. Accessed 1 July 2021
International Energy Agency (2021) Electricity Market Report. https://www.iea.org/reports/electricity-market-report-july-2021. Accessed 1 July 2021
International Energy Agency (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector. https://www.iea.org/reports/net-zero-by-2050. Accessed 1 July 2021
International Energy Agency (2021) The Role of Critical Minerals in Clean Energy Transitions, IEA: Paris. World Nuclear Association (2021). Mineral Requirements for Electricity Generation. Accessed here: https://world-nuclear.org/information-library/energy-and-the-environment/mineral-requirements-for-electricity-generation.aspx. Accessed 30 November 2021
International Renewable Energy Agency, International Energy Agency Photovoltaic Power Systems (2016) End-of-life management: solar photovoltaic panels. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf. Accessed 1 July 2021
Intergovernmental Panel on Climate Change (IPCC) (2018) Summary for Policymakers. In: Masson-Delmotte V, Zhai P, Pörtner H, Roberts D, Skea J, Shukla P, Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews J, Chen Y, Zhou X, Gomis M, Lonnoy E, Maycock T, Tignor M, Waterfield T (eds), Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf. Accessed 1 July 2021
IPPC Secretariat (2021) Scientific review of the impact of climate change on plant pests – A global challenge to prevent and mitigate plant pest risks in agriculture, forestry and ecosystems. FAO on behalf of the IPPC Secretariat, Rome
Jaffray D A, Gospodarowicz M K (2015) Radiation Therapy for Cancer. In: H. Gelband H, Jha P, Sankaranarayanan R, Horton S (eds) Cancer: Disease Control Priorities, 3rd edn, Vol. 3. The International Bank for Reconstruction and Development/The World Bank, Washington DC
Jarvis S, Deschenes O, Jha A (2019) The Private and External Costs of Germany's Nuclear Phase-Out (Working Paper 26598). National Bureau of Economic Research, Cambridge, MA
Jasserand F, Devezeaux de Lavergne J-G (2016) Initial economic appraisal of nuclear district heating in France. EPJ Nuclear Sciences & Technologies 2
Jiang Y (2009) China's water scarcity. Journal of Environmental Management 90:3185–3196
Jiménez Cisneros B E, Oki T, Arnell N W, Benito G, Cogley J G, Doll P, Jiang T, Mwakalila S S (2014) Freshwater resources. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 229–269
Jones E, Qadir M, van Vliet M T, Smakhtin V, Kang S-M (2019) The state of desalination and brine production: A global outlook. Science of the Total Environment 657:1343–1356
Karekezi S, McDade S, Boardman B, Kimani J, Lustig N (2012) Energy, Poverty, and Development. In: Global Energy Assessment: Toward a Sustainable Future. Cambridge University Press, Cambridge, pp 151–190
Khandker S R, Samad H A, Ali R, Barnes D F (2014) Who Benefits Most from Rural Electrification? Evidence in India. The Energy Journal 35:75–96
Kharecha P A, Hansen J E (2013) Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power. Environmental Science and Technology 47:4889–4895
Klassen W (2009) Introduction: development of the sterile insect technique for African malaria vectors. Malaria Journal 8

Klassen W, Curtis C F, Hendrichs J (2021) History of the Sterile Insect Technique. In: Dyck V A, Hendrichs J, Robinson A S (eds) Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd edn. Boca Raton, FL, pp 1–44

Klassen W, Vreysen M J B (2021) Area-Wide Integrated Pest Management and the Sterile Insect Technique. In: Dyck V A, Hendrichs J, Robinson A S (eds) Sterile Insect Technique. CRC Press, Boca Raton, pp 75–112

Lee J C K, Wen Z (2017) Rare Earths from Mines to Metals: Comparing Environmental Impacts from China's Main Production Pathways. Journal of Industrial Ecology 21:1277–1290

Liddle B, Sadorsky P (2017) How much does increasing non-fossil fuels in electricity generation reduce carbon dioxide emissions? Applied Energy 197:212–221

Lindberg J C H (2017) Sweden's silent phaseout. Nuclear Engineering International 62:12–14

Lindberg J C H (in press) Building an atomic future: The role for nuclear power in addressing major humanitarian challenges in the 21st century. Journal of Nuclear Engineering and Radiation Science

Mark H E, Dias da Costa G, Pagliari C, Unger S A (2020) Malnutrition: the silent pandemic. BMJ 371

Mekonnen M M, Hoekstra A Y (2016) Four billion people facing severe water scarcity. Science Advances 2

MIT Energy Initiative (2018) The Future of Nuclear Energy in a Carbon-constrained World: An Interdisciplinary MIT Study. https://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/. Accessed 1 July 2021

Niu S, Jia Y, Wang W, He R, Hu L, Liu Y (2013) Electricity consumption and human development level: A comparative analysis based on panel data for 50 countries. International Journal of Electrical Power & Energy Systems 53:338–347

Nuclear Energy Institute (2012) Nuclear Energy's Economic Benefits — Current and Future. http://large.stanford.edu/courses/2018/ph241/may2/docs/nei-apr12.pdf. Accessed 1 July 2021

O'Neil S G (2021) Community obstacles to large scale solar: NIMBY and renewables. Journal of Environmental Studies and Sciences 11:85–92

Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) (2012) The Role of Nuclear Energy in a Low-carbon Energy Future. https://www.oecd-nea.org/jcms/pl_14562/the-role-of-nuclear-energy-in-a-low-carbon-energy-future?details=true. Accessed 1 July 2021

Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) (2019) The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables. https://www.oecd-nea.org/jcms/pl_15000/the-costs-of-decarbonisation-system-costs-with-high-shares-of-nuclear-and-renewables. Accessed 1 July 2021

Qvist S A, Brook B W (2015) Potential for Worldwide Displacement of Fossil-Fuel Electricity by Nuclear Energy in Three Decades Based on Extrapolation of Regional Deployment Data. PLoS ONE 10

Qvist S, Gladysz P, Bartela L, Sowizczal A (2021) Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland. Energies 14

Rao N D, Pachauri S (2017) Energy access and living standards: some observations on recent trends. Environmental Research Letters 12

Rockström J, Steffen W, Noone K, et al. (2009) A safe operating space for humanity. Nature 461:472–475

Rogelj J, Shindell D, Jiang K, Fifita S, Forster P, Ginzburg V, Handa C, Kheshgi H, Kobayashi S, Kriegler E, Mundaca L, Séférian R, Vilariño M V (2018) Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Masson-Delmotte V, Zhai P, Pörtner H, Roberts D, Skea J, Shukla P, Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews J, Chen Y, Zhou X, Gomis M, Lonnoy E, Maycock T, Tignor M, Waterfield T (eds), Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways.World Metorological Organisation, Geneva, pp 93–174

Rosling H, Rosling O, Rosling Rönnlund A (2018) Factfulness. Sceptre, London
Royal Society (2020) Nuclear cogeneration: civil nuclear energy in a low-carbon future policy briefing. https://royalsociety.org/topics-policy/projects/low-carbon-energy-programme/nuclear-cogeneration/. Accessed 1 July 2021
Santayana G (1905) The Life of Reason; or the Phases of Human Progress. Charles Scribner's Sons, New York
Schlömer S, Bruckner T, Fulton L, Hertwich E, McKinnon A, Perczyk D, Roy J, Schaeffer R, Sims R, Smith P, Wiser R (2014) Annex III: Technology-specific cost and performance parameters. In: Edenhofer O, Pichs-Madruga R, Sokona Y, Farahani E, Kadner S, Seyboth K, Adler A, Baum I, Brunner S, Eickemeier P, Kriemann B, Savolainen J, Schlömer S, von Stechow C, Zwickel T, Minx J (eds) Climate Change 2014: Mitigation of Climate Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp 1329–1356
Schmeller D S, Courchamp F, Killeen G (2020) Biodiversity loss, emerging pathogens and human health risks. Biodiversity and Conservation 29:3095–3102
Smittenaar C R, Petersen K A, Stewart K, Moitt N (2016) Cancer incidence and mortality projections in the UK until 2035. British Journal of Cancer 115:1147–1155
Steffen W, Richardson K, Rockström J, Cornell S E, Fetzer I, Bennett E M, Biggs R, Carpenter S R, de Vries W, de Wit C A, Folke C, Gerten D, Heinke J, Mace G M, et al. (2015) Planetary boundaries: Guiding human development on a changing planet. Science 347
Stegen K S (2015) Heavy rare earths, permanent magnets, and renewable energies: An imminent crisis. Energy Policy 79:1–8
Stevens L (2017) The Footprint of Energy: Land Use of U.S. Electricity Production. https://docs.wind-watch.org/US-footprints-Strata-2017.pdf. Accessed 1 July 2021
Tanner A M, Johnston A L (2017) The Impact of Rural Electric Access on Deforestation Rates. World Development 94:174–185
Thayer D W (1993) Extending Shelf Life of Poultry and Red Meat by Irradiation Processing. Journal of Food Protection 56:831–833
Tscharntke T, Clough Y, Wanger T C, Jackson L, Motzke I, Perfecto I, Vandermeer J, Whitbread A (2012) Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation 151:53–59
Tyson A, Kennedy B, Funk C (2021) Gen Z, Millennials Stand Out for Climate Change Activism, Social Media Engagement With Issue. https://www.pewresearch.org/science/wp-content/uploads/sites/16/2021/05/PS_2021.05.26_climate-and-generations_REPORT.pdf. Accessed 1 July 2021
United Nations Environment Programme (UNEP) (2020) Responsible consumption. https://wedocs.unep.org/bitstream/handle/20.500.11822/22747/12_Responsible%20consumption%20and%20production_FINAL.pdf?sequence=1&isAllowed=y. Accessed 12 June 2021
UNICEF (2021) Reimagining WASH—Water security for all. United Nations Children's Fund (UNICEF), New York. https://www.unicef.org/media/95241/file/water-security-for-all.pdf. Accessed 1 July 2021
United Nations (UN) (2021) Progress towards the Sustainable Development Goals. E/2021/58. https://digitallibrary.un.org/record/3930067?ln=en. Accessed 1 July 2021
United Nations Economic Commission for Europe (UNECE) (2021) Use of Nuclear Fuel Resources for Sustainable Development – Entry Pathways. https://unece.org/sites/default/files/2021-03/UNECE%20Use%20of%20nuclear%20fuel%20resources%20for%20sustainable%20development_%20Final_0.pdf. Accessed 1 July 2021
United Nations Water (UN-Water) (2021) Summary Progress Update 2021: SDG 6—water and sanitation for all. https://www.unwater.org/publications/summary-progress-update-2021-sdg-6-water-and-sanitation-for-all/. Accessed 1 July 2021
Van Gosen B S, Verplanck P L, Seal II R R, Long K R, Gambogi J (2017) Rare-earth elements. In: Schulz K J, DeYoung Jr J H, Seal II R R, Bradley D C (eds) Critical Mineral Resources of the

United States — Economic and Environmental Geology and Prospects for Future Supply, U.S. Geological Survey Professional Paper 1802, Reston, pp 539–571

Värri K, Syri S (2019) The Possible Role of Modular Nuclear Reactors in District Heating: Case Helsinki Region. Energies 12

Verma J, Gautam S (2015) Food irradiation and its role in shelf life extension of horticulture produce: a comprehensive evaluation of studies carried out in India and abroad. In: Proceedings of the DAE-BRNS life sciences symposium on advances in microbiology of food, agriculture, health and environment. Bio-Science Group, Bhabha Atomic Research Centre, Mumbai

Vohra K, Vodonos A, Schwartz J, Marais E A, Sulprizio M P, Mickley L J (2021) Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem. Environmental Research 195

Willcox M, Waters L, Wanjiru H, Pueyo A, Hanna R, Palit D, Sharma K R (2015) Utilising Electricity Access for Poverty Reduction. https://assets.publishing.service.gov.uk/media/57a08975e5274a27b20000b5/61290-Electricity_Access_for_Poverty_Reduction_MainReport.pdf. Accessed 1 July 2021

Winther T, Matinga M N, K. Ulsrud K, Standal K (2017) Women's empowerment through electricity access: scoping study and proposal for a framework of analysis. Journal of Development Effectiveness 9:389–417

World Health Organization (WHO), International Atomic Energy Agency (IAEA) (2020) Guidance Framework for Testing the Sterile Insect Technique as a Vector Control Tool against Aedes-Borne Diseases. https://apps.who.int/iris/bitstream/handle/10665/331679/9789240002371-eng.pdf?ua=1. Accessed 1 July 2021

World Health Organization (WHO) (1994) Safety and nutritional adequacy of irradiated food. https://apps.who.int/iris/bitstream/handle/10665/39463/9241561629-eng.pdf?sequence=4&isAllowed=y. Accessed 1 July 2021

World Health Organization (WHO) (2018) Latest global cancer data: Cancer burden rises to 18.1 million new cases and 9.6 million cancer deaths in 2018. https://www.who.int/cancer/PRGlobocanFinal.pdf. Accessed 1 July 2021

World Health Organization (WHO), Food and Agriculture Organization (FAO) (1988) Food irradiation: A technique for preserving and improving the safety of food. https://apps.who.int/iris/bitstream/handle/10665/38544/9241542403_eng.pdf?sequence=1&isAllowed=y. Accessed 1 July 2021

World Nuclear Association (2019) The Silent Giant: The need for nuclear in a clean energy system. https://www.world-nuclear.org/getattachment/Our-Association/Publications/Position-statements/the-silent-giant/the-silent-giant.pdf.aspx. Accessed 1 July 2021

World Nuclear Association (2020) World Nuclear Performance Report 2020. https://www.world-nuclear.org/getmedia/3418bf4a-5891-4ba1-b6c2-d83d8907264d/performance-report-2020-v1.pdf.aspx. Accessed 1 July 2021

World Nuclear Association (2021) The Role of Critical Minerals in Clean Energy Transitions, IEA: Paris. World Nuclear Association (2021). Mineral Requirements for Electricity Generation. Accessed here: https://worldnuclear.org/information-library/energy-and-the-environment/mineral-requirements-for-electricity-generation.aspx. Accessed 30 November 2021

WWF (2020) Living Planet Report 2020 - Bending the curve of biodiversity loss. https://f.hubspotusercontent20.net/hubfs/4783129/LPR/PDFs/ENGLISH-FULL.pdf. Accessed 1 July 2021

Zappa W, Junginger M, van den Broek M (2019) Is a 100% renewable European power system feasible by 2050? Applied Energy 233–234:1027–1050

Ziegler L, Gonzalez E, Rubert T, Smolka U, Melero J J (2018) Lifetime extension of onshore wind turbines: A review covering Germany, Spain, Denmark, and the UK. Renewable and Sustainable Energy Reviews 82:1261–1271

Ziolkowska J R (2015) Is Desalination Affordable?—Regional Cost and Price Analysis. Water Resources Management 29:1385–1397

Chapter 14
Nuclear Newcomer Countries—The Path of the United Arab Emirates

Hamad AlKaabi

Contents

Abstract Embarking on nuclear power requires high-level political decisions and commitments, considerable planning efforts, financial investments and commercial considerations, long-term sustainability for safety; as well as international and legal framework for a nuclear power programme. There are numerous challenges surrounding government decisions to introduce nuclear power into the energy mix of a country. This chapter highlights the United Arab Emirates' (UAE) experience and accomplishments in the development and regulation of its nuclear power programme. In particular, it focuses on the milestones of the UAE path, which might be of interest to nuclear newcomer countries and to a broader international community. This chapter outlines the development of the UAE comprehensive national nuclear law and regulatory framework, which started with the so-called "nuclear policy". It also includes an overview of a strategy that was developed and set the early path for the UAE peaceful nuclear programme, including timelines for specific targets. The international conventions and UAE's nuclear cooperation agreements, as well as the cooperation with the IAEA are also mentioned. Particular attention has been paid to the role of the UAE nuclear regulator and its mandate and the development of the UAE

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regulations and regulatory guides. The licensing of the nuclear power programme, as well as the licensing of other activities and practices involving radiation sources have been also described in the publication. In conclusion, the publication shares some lessons the UAE learnt and on which it will base its efforts towards the continuous enhancement of its legal framework.

Keywords United Arab Emirates (UAE) · Nuclear new build · Newcomer · Legal frameworks · Economic and environmental · Electricity · Nuclear energy · Nuclear power programme

14.1 Inception of the UAE Nuclear Power Programme: Nuclear Policy

Throughout 2007, the UAE government evaluated future energy sources options and studied a potential role of nuclear energy in the UAE's future energy strategy.

The 'energy studies' concluded that nuclear energy has the potential to play a major role in in meeting the growing energy needs in the UAE. Based on the studies, the UAE government developed the Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy (the Nuclear Policy),[1] which was adopted by the UAE Cabinet of Ministers and published in April 2008. The development of the Nuclear Policy, required an in-depth study of best international practices, a broad consultation process within the UAE government, as well as with foreign and international stakeholders, such as the IAEA, determination of guiding principles for the development of the peaceful nuclear energy in the UAE.

The Nuclear Policy outlines the role of nuclear energy in the UAE's energy strategy and the UAE's approach to civilian nuclear power.

Most importantly, in the Nuclear Policy the UAE government documents the Government strategies and commitment to the highest standards of safety, security and non-proliferation and outlines six key principles for the establishment of a peaceful civilian nuclear energy programme in the UAE:

1. Complete operational transparency;
2. Highest standards of non-proliferation;
3. Highest standards of safety and security;
4. Close cooperation with the International Atomic Energy Agency (IAEA) and conformance to its standards;
5. Development of a peaceful domestic nuclear power capability in cooperation with the governments and firms of responsible nations, as well as with the assistance of appropriate expert organizations; and
6. Ensuring a long term sustainability of UAE's peaceful domestic nuclear power programme.

[1] Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy 2008.

At that time, also several key strategic choices were reflected by the UAE government in the Nuclear Policy. Those were to forgo domestic enrichment and reprocessing of nuclear fuel should the nuclear power be one of the component of the UAE's energy mix.

14.2 From Nuclear Policy to Legal Framework

14.2.1 International Conventions

In order to meet the UAE's commitments to transparency, highest standards of non-proliferation, safety and security, as well as to pursue international cooperation as underpinned in the Nuclear Policy, the UAE has acceded to the relevant main international instruments, treaties, conventions, and agreements in the area of nuclear safety, nuclear security, non-proliferation and civil liability for nuclear damage.[2]

1. Convention on Early Notification of a Nuclear Accident, acceded by the UAE on 2 October 1987 and entered into force for the UAE on 2 November 1987.[3]
2. Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, acceded by the UAE on 2 October 1987 and entered into force for the UAE on 2 November 1987.[4]
3. Treaty on the Non-Proliferation of Nuclear Weapons (NPT), acceded by the UAE on 26 September 1995.[5]
4. Agreement between the United Arab Emirates and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (Safeguards Agreement), signed on 15 December 2003 and entered into force for the UAE on 09 October 2003.[6]

[2] Such as the Convention on Nuclear Safety, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Convention on Early Notification and Assistance, the Revised Vienna Convention on Civil Liability for Nuclear Damage, the Convention on Supplementary Compensation for Nuclear Damage, the Joint Protocol, the Convention on the Physical Protection of Nuclear Material and its Amendment, the Comprehensive Safeguards Agreement (CSA) and Additional Protocol to the CSA.

[3] Convention on Early Notification of a Nuclear Accident, opened for signature 26 September 1986 (Vienna) and 6 October 1986 (New York), entered into force 27 October 1986 (Early Notification Convention).

[4] Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, opened for signature 26 September 1986 (Vienna) and 6 October 1986 (New York), entered into force 26 February 1987 (Convention on Assistance).

[5] Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature 1 July 1968 (Vienna, Moscow, Washington), entered into force 5 March 1970 (Non-Proliferation Treaty or NPT).

[6] Agreement between the United Arab Emirates and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear

5. Protocol Additional to the Agreement between the United Arab Emirates and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (Additional Protocol), signed on 08 April 2009 and entered into force for the UAE on 20 December 2010.[7]
6. Convention on Nuclear Safety, acceded by the UAE on 31 July 2009 and entered into force for the UAE on 29 October 2009.[8]
7. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, acceded by the UAE on 31 July 2009 and entered into force for the UAE on 29 October 2009.[9]
8. Convention on the Physical Protection of Nuclear Material, acceded by the UAE on 16 October 2003 and entered into force for the UAE on 15 November 2003.[10]
9. Amendment to the Convention on the Physical Protection of Nuclear Material, accepted by the UAE on 31 July 2009 and entered into force on 08 May 2016.[11]
10. International Convention for the Suppression of Acts of Nuclear Terrorism (acceded, 10 January 2008).[12]

14.2.2 UAE Nuclear Cooperation Agreements

International partnerships and cooperation were recognized by the UAE as the cornerstone of a successful nuclear energy programme. Thanks to such arrangements, technologically advanced countries facilitate access of embarking countries to the peaceful uses of nuclear energy.

As per the principles set out in the Nuclear Policy, the UAE committed to develop its peaceful domestic nuclear power capability in cooperation with the governments and firms of responsible nations and to ensure a long term sustainability of UAE's peaceful domestic nuclear power program.

Weapons, signed 15 December 2002 (Abu Dhabi), entered into force 9 October 2003 (Safeguards Agreement).

[7] Protocol Additional to the Agreement between the United Arab Emirates and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, entered into force 20 December 2010.

[8] Convention on Nuclear Safety, opened for signature 20 September 1994 (Vienna), entered into force 24 October 1996 (CNS).

[9] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, opened for signature 29 September 1997, entered into force 18 June 2001.

[10] Convention on the Physical Protection of Nuclear Material, opened for signature 3 March 1980, entered into force 8 February 1987 (CPPNM).

[11] Amendment to the Convention on the Physical Protection of Nuclear Material, entered into force 8 May 2006 (Amendment to the CPPNM).

[12] International Convention for the Suppression of Acts of Nuclear Terrorism, opened for signature 14 September 2005, entered into force 7 July 2007 (Nuclear Terrorism Convention or ICSANT).

Therefore, the UAE concluded a number of bilateral agreements to benefit from cooperation in the peaceful uses of nuclear energy (the Nuclear Cooperation Agreements (NCA)):

1. Agreement for Cooperation between the Government of the United Arab Emirates and the Government of the Republic of France in the Development of Peaceful Uses of Nuclear Energy, 15 January 2008.
2. Agreement for Cooperation between the Government of the United Arab Emirates and the Government of the United States of America Concerning Peaceful Uses of Nuclear Energy, 21 May 2009.
3. Agreement between the Government of the United Arab Emirates and the Government of the Republic of Korea for Cooperation in the Peaceful Uses of Nuclear Energy, 22 June 2009.
4. Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United Arab Emirates for Cooperation in the Peaceful Uses of Nuclear Energy, 2010.
5. Agreement between the Government of the United Arab Emirates and the Government of Australia on Cooperation in the Peaceful Uses of Nuclear Energy, 31 July 2012.
6. Agreement between the Government of the United Arab Emirates and the Government of Canada for Cooperation in the Peaceful Uses of Nuclear Energy, 18 September 2012.
7. Agreement between the Government of the United Arab Emirates and the Government of the Russian Federation on Cooperation in the Field of the Use of Nuclear Energy for Peaceful Purposes, 17 December 2012.
8. Agreement on Cooperation in the Peaceful Uses of Nuclear Energy between the United Arab Emirates and the Argentine Republic, 14 January 2013.
9. Agreement between the Government of the United Arab Emirates and the Government of Japan for Cooperation in the Peaceful Uses of Nuclear Energy, 2 May 2013.

Such agreements set the basis for cooperation at various levels, including at the industry level, as well as at the government level. As result, a number of bilateral agreements and memoranda of understanding were concluded by the UAE entities with the corresponding foreign counterparts to further pursue the cooperation originating from the NCAs.

14.2.3 Cooperation with the IAEA

To ensure the implementation of a successful and sustainable nuclear energy programme, the UAE was working closely with the IAEA and international partners. The UAE's resolve to work directly with the IAEA and to abide by its standards has been reflected in the ongoing technical cooperation programme covering a variety of fields, particularly in building the scientific and technological capabilities of the IAEA Member States, including the development of human resources.

The UAE consulted the IAEA on every step taken to develop the UAE's nuclear energy programme and took advantage of the IAEA review missions.

In January 2011, the UAE received an INIR mission, the outcome of which had been very positive with no major gaps having been identified. In addition, the UAE had accumulated valuable experience in the IAEA's integrated guidance approach for the development of new nuclear energy programmes.

Also, the UAE presented its first national report to the fifth review meeting of the Contracting Parties to the Convention on Nuclear Safety, where the UAE's work on developing nuclear safety infrastructure had been praised.

In December 2011, the UAE received its first Integrated Regulatory Review Service (IRRS) mission, at an unprecedentedly early stage in a nuclear programme. Thus, the UAE was developing into a model of transparency and responsibility for other nuclear newcomers.

By the end of 2011, before the start of the construction of Unit 1 of the Barakah nuclear power plant, the UAE approved eight new regulations for the safe, secure and peaceful use of nuclear applications and had set up licensing and inspection procedures.

The construction of the first nuclear reactor in the UAE begun in July 2012 following a detailed evaluation of the design, which had taken into consideration early lessons learned from the Fukushima Daiichi accident, making the country the first newcomer to build a nuclear power plant in 27 years. Construction of the second unit had begun in May 2013.[13]

The UAE continued to request and receive comprehensive peer reviews from the IAEA, which were essential to ensure the adequacy of safety measures and national infrastructure. The UAE was also the first country to receive an Integrated Nuclear Infrastructure Review (INIR) phase 3 mission to review the UAE's infrastructure development for a nuclear power programme. The INIR mission was carried out at the invitation of the UAE Government and was the first the IAEA has conducted for a country in the final phase of the IAEA's Milestones Approach, which provides detailed guidance for developing the infrastructure needed for a nuclear power programme.

The UAE signed an integrated work plan for 2013–2017, which defined a holistic framework of cooperation with all departments of the IAEA.

Today, the UAE continues to learn from the IAEA and benefit from its continuous support, through capacity building and the international peer review services in particular, but the UAE is also in a position to share its experience with other countries in joining the international nuclear legal instruments, developing the required legislation and regulatory framework and regulating the nuclear activities. This experience sharing is done through bilateral cooperation as well as at the international level, through inputs in international meetings, participations in nuclear law related working groups of the OECD Nuclear Energy Agency. In this context, the UAE is

[13] IAEA 2014, para 274.

also actively contributing to the development of international standards through its participation in the five Safety Standards Committees and in the Nuclear Security Guidance Committee of the IAEA.

14.2.4 Roadmap to Success

With the issuance of the Nuclear Policy, the UAE began implementation of a Nuclear Energy Program Implementation Organization as recommended by the IAEA, which was identified as the Executive Affairs Authority (EAA) of Abu Dhabi at the very early stages of the programme.

In September 2008, the EAA developed an internal strategy document called the Roadmap to Success, which built on best international practices and the IAEA Milestones covering the 19 nuclear infrastructure issues.

The Nuclear Policy states that UAE has also taken into consideration and intends to be guided by the planning recommendations expressed by the IAEA in its Milestones in the Development of a National Infrastructure for Nuclear Power (the IAEA Milestones).[14]

The IAEA Milestones cover three phases in the development of the infrastructure necessary to support a nuclear power programme. The completion of each phase for 19 nuclear infrastructure issues is marked by a specific milestone, at which the progress of the development effort can be assessed and a decision can be made to move on to the next phase.

The Roadmap to Success set the early path for the UAE peaceful nuclear programme by turning practices into a set of explicit recommendations, goals and objectives, responsibilities for the UAE stakeholders, and timelines for specific targets towards an estimated operation date, which was then set for 2017.

14.3 Towards a Comprehensive National Nuclear Law

The commitment of the UAE to the highest standards of nuclear safety is reflected in its legal, regulatory and institutional framework. The Nuclear Policy served as the reference for the development of legislation for the nuclear sector in the UAE. The Nuclear Policy specified that the UAE should draft a comprehensive national nuclear law, covering all aspects of nuclear law, including safety, security, non-proliferation, nuclear liability and other legislative, regulatory and commercial aspects, and, among other functions, providing legal authority for the establishment of a fully independent nuclear regulatory authority, which is needed as an institution critical to safeguard and sustain operational transparency in a nuclear energy sector. As per the Nuclear

[14] IAEA 2007, 2015.

Policy, the comprehensive national nuclear law was meant to enable the transposition of the UAE obligations under international instruments into the national legislation. Also, the Nuclear Policy defined that the scope of UAE nuclear legislation should include provisions concerning the establishment of a regulatory authority and licensing regime; civil liability for nuclear damage; responsibilities of licencees; management of radioactive waste and spent fuel; decommissioning of nuclear facilities; physical protection of nuclear material and facilities; and non-proliferation obligations, controls and enforcement.

As the legal structure in the UAE runs in two systems—the federal legal system and local system at the level of the seven emirates of the UAE—the government had to decide whether to set the legal and regulatory framework for the UAE at the federal or local level, in the Emirate of Abu Dhabi where a future nuclear power plant was supposed to be located. Also a decision had to be made on whether to build the legislation for the nuclear sector on the elements of existing legal infrastructure or whether to develop new legislation at the federal level. For example, the Radiation Protection Committee existed in the UAE before the 'energy studies' and preparation of the Nuclear Policy, and it was approved by the Cabinet of Ministers then. Also, there was the Federal Law No. 1 of 2002 Regarding the Regulation and Control of the Use of Radiation Sources and Protection Against Their Hazards.

Another challenge was to determine the scope of the mandate of a regulatory body and to ensure that is established as an independent nuclear regulator, not reporting to nor being part of any ministry in the UAE.

The institutional characteristics ensuring the independence of a nuclear regulator were reflected in the Nuclear Policy, which specified that an independent nuclear regulator "would be endowed with the following IAEA recommended powers to: (1) establish requirements and regulations; (2) issue licences; (3) inspect and assess facilities and structures connected to facilities; (4) monitor and enforce compliance with regulations; and (5) establish a State System for Accounting and Control (SSAC) of nuclear material (including spent fuel and radioactive waste) in accordance with IAEA Safeguards obligations."[15] Also, the Nuclear Policy specifies that the regulatory body would be tasked with communicating with the IAEA on an ongoing basis to provide, for example, reports required by international agreements to which the UAE is a party. Another challenging aspect was to ensure that the legislation would guarantee the independence of the nuclear regulator in its decision making, particularly with regard to safety related decisions.

A number of foreign experts from the US, Europe, and Asia as well as the IAEA contributed to the development of the comprehensive national nuclear law. They took into account lessons learned from various legal systems, international standards and offered numerous ideas aiming at putting into practice the lessons learned so far. The IAEA provided support through its legislative assistance programme. The IAEA revised the draft law and also provided comments and advice on selected provisions of the future comprehensive nuclear legislation of the UAE.

[15] Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy 2008, p. 6.

The challenge that the UAE faced then was to choose the right approach to the development of a comprehensive technical legislation that would indeed reflect the best practices gathered around the world, international standards, as well as the lessons learned. The UAE had a limited experience in the drafting and processing through the UAE's legislative process such a complex legislation. The external expertise provided numerous inputs and options. However, the responsibility for evaluation and choosing the most appropriate option always rested with the UAE.

On 23 September 2009, the UAE passed the comprehensive Federal Law by Decree No. 6 of 2009 Concerning Peaceful Uses of Nuclear Energy (the Nuclear Law) providing for the development of a comprehensive system for licensing and control of nuclear material, as well as the establishment of the Federal Authority for Nuclear Regulation (FANR) to oversee the UAE's nuclear energy sector in the area of safety, security, and safeguards. The Nuclear Law defines the responsibilities of the operator and functions and responsibilities of the regulatory body—FANR.

Following the establishment of FANR, the Emirates Nuclear Energy Corporation (ENEC) was established on 23 December 2009, by Law No. 12 of 2009 issued by the President of the UAE in his capacity as the Ruler of Abu Dhabi. ENEC was established as the organization charged with implementing the UAE nuclear energy programme and carried out the non-regulatory work of the Nuclear Energy Program Implementation Organization (NEPIO). As per the Law no. 12 of 2009, ENEC is responsible to develop, build, finance, operate, maintain, manage and possess nuclear reactors to be used for peaceful purposes for energy generation, water desalination, subject to the Nuclear Law. Consistent with the Nuclear Policy objectives, ENEC retains the NEPIO function, which is important for the sustainability of the programme in the long term as ENEC reinforces a mechanism of coordination involving all relevant stakeholders.

Soon after, on 27 December 2009, ENEC announced that it had selected a team led by the Korea Electric Power Corporation (KEPCO) to design, build and assist in operation and maintenance of four, 1400 MWe civil nuclear power units. The announcement came after a year long extensive tendering process.

In order to achieve a comprehensive nuclear legal framework and as required by the international nuclear liability instruments to which the UAE became a party, the UAE issued the Federal Law by Decree No. 4 of 2012 Concerning Civil Liability for Nuclear Damage (the Nuclear Liability Law) in August 2012, which came into effect in October 2012. The Nuclear Liability Law aims to implement the nuclear liability principles such as the channelling of the liability to the nuclear operator, limitation of the nuclear operator's liability in amount and in time, the obligation for a financial security, the principle of non-discrimination, etc., which would apply should an nuclear incident occur within a nuclear installation in the UAE and trigger nuclear damage. The provisions of the Nuclear Liability Law are in line with UAE obligations under the 1997 Vienna Convention on Civil Liability for Nuclear Damage, to which the UAE acceded in May 2012, and takes into account the best international practices. It is also worth noticing that in line with the recommendations formulated by the International Expert Group on Nuclear Liability (INLEX), in order to contribute to the achievement of a global nuclear liability regime the UAE also joined the Joint

Protocol relating to the Application of the Vienna Convention and the Paris Convention in August 2012 and joined the Convention on Supplementary Compensation for Nuclear Damage in July 2014.

14.3.1 International Advisory Board

Further development of the UAE nuclear power programme, including its legislation and regulatory framework, benefitted from the advice and recommendations of the International Advisory Board (IAB). The IAB was established with a view to ensure operational transparency of the programme and to provide the UAE peaceful nuclear energy program with the benefit of the expertise and knowledge of a highly select group of internationally recognized experts in the fields of nuclear safety and security, non-proliferation and the development of human resources. The IAB first met on 22 February 2010 at Abu Dhabi and continued meeting on a semi-annual basis for eight years, until holding its final meeting in October 2017. Throughout its term, the IAB reviewed the progress of the UAE in achieving and maintaining the highest standards of safety, security, non-proliferation, transparency and sustainability and the IAB members provided their valuable insights into optimization of the nuclear power program towards achieving these targets.[16] The recommendations of the IAB are recorded in the 16 semi-annual reports of the IAB which is publicly available.[17]

14.3.2 UAE Nuclear Regulator

The UAE nuclear regulator—FANR—was established by the UAE President His Highness Sheikh Khalifa Bin Zayed Al Nahyan in September 2009. Article 4(1) of the Nuclear Law sets out that "A public organization under the name of "Federal Authority for Nuclear Regulation" shall hereby be established with independent balance sheet and it shall have an independent legal personality, full legal competence and financial and administrative independence in all its matters."

In line with international recommendations, FANR was established as an independent entity which is separated from the entities in charge of the development or the promotion of nuclear energy and nuclear applications and from the users. The members of FANR's Board Management are prohibited from carrying out a regulated activity under the Nuclear Law, either direct or indirect (Article 10(2) of the Nuclear Law) and the reporting of FANR to the government is done through an Annual Report to the Minister for Presidential Affairs (Article 11 of the Nuclear Law). Another important element is the financial independence of FANR addressed in Article 18 of the Nuclear Law which specifies, inter alia, that the Authority's funds

[16] http://www.uaeiab.ae. Accessed 15 October 2021. (Information on the work of the IAB.)

[17] http://www.uaeiab.ae/en/publications.html. Accessed 15 October 2021. (All reports of the IAB.)

consist of the funds allocated to it by the government and income generated by the conduct of its functions.

The responsibilities of FANR are explicitly enumerated in the Articles 4 and 5 of the Nuclear Law, as well as in other provisions, and include the power to regulate, control and supervise the nuclear sector in the UAE toward the peaceful purposes only, and to ensure safety, nuclear safety, nuclear security, radiation protection and safeguards. FANR has also the responsibility to ensure the fulfilments of obligations under international treaties, conventions, agreements related to its mandate and entered into by the UAE.

For the purposes of implementing its responsibilities under the Nuclear Law, FANR undertakes a number of activities which are listed in the Nuclear Law and can be regrouped into four core regulatory functions:

1. The development and issuance of regulations and regulatory guides to support the implementation of the Nuclear Law. Such regulations aim to specify the requirements applicable to specific regulated activities and related facilities, including on safety, physical protection, emergency preparedness, nuclear material accounting and control, transport of radioactive material, import, export, radiation protection or decommissioning. The regulations shall also specify the exclusions and exemptions from all or parts of the regulatory control;
2. The licensing, including the review and assessment of licence applications, the issuance of licences, along with the identification of licence conditions and their amendment, renewal, suspension or revocation:

These two first core activities are further detailed below in this paper.

3 The inspection and assessment of all regulated activities, including the development of a systematic inspection programme within FANR;
4. The identification and implementation of enforcement actions, including fines and other administrative penalties up to criminal penalties, following a graded approach.

These core activities also require FANR to coordinate with the other competent authorities in the UAE in various area such as emergency preparedness, nuclear security, non-proliferation and the transport of hazardous goods. In addition, FANR cooperates and provides advice to the government entities on matters related to nuclear safety, radiation protection, security and also environment protection, public and occupational health, radioactive waste, etc.

At the international level, FANR has established cooperation with a number of foreign nuclear regulators to exchange regulatory experience and also with foreign research centres, institutes and international organizations to support its activities in various areas, such as nuclear safety, radiation safety or research and development. As per the UAE international commitments and the Nuclear Law, FANR is finally responsible for liaising, providing required information, notifications and reports to the relevant international organisations.

14.3.3 Development of Regulatory Framework: Regulations and Regulatory Guides

Developing the nuclear legislation is an essential step that sets the framework allowing for the conduct of all activities in the nuclear and radiation sectors in the country while at the same time ensuring an adequate protection of the people and the environment from the harmful effects of ionizing radiation. However, it is only the first step of a country in the development of a comprehensive nuclear legal framework.

By nature, the UAE Federal Law by Decree No. 6 of 2009 Concerning Peaceful Uses of Nuclear Energy (the Nuclear Law), though meant to be a "comprehensive" legislative instrument on nuclear and radiation matters, can't prescribe all the conditions and requirements governing the conduct of all activities in nuclear and radiation sectors in the country. The detailed regulatory requirements applicable to each specific activity and related facilities are to be included in a comprehensive set of regulations, complemented by regulatory guides. As mentioned above, the power to develop and issue regulations has been granted to FANR in the Nuclear Law, which specifies in its Article 11(4)(j), that the Board of Management of FANR shall have the functions and authorities to issue implementing technical regulations required for the FANR's operation, including "to establish, develop or adopt regulations and guidelines upon which its regulatory actions are based". The same elements are reiterated in the provisions of Article 38 of the Nuclear Law.

The work on the development of regulations was launched immediately after the establishment of FANR, taking into account that the availability of some of the regulations was critical for the development of the nuclear sector in the UAE. The Regulation for Radiation Dose Limits and Optimization of Radiation Protection for Nuclear Facilities (FANR-REG-04), the Regulation on Application of Probabilistic Risk Assessment at Nuclear Facilities (FANR-REG-05), the Regulation for Management Systems for Nuclear Facilities (FANR-REG-01), the Regulation for an Application for a Licence to Construct a Nuclear Facility (FANR-REG-06) and the Regulation for Transport of Radioactive Materials (FANR-REG-13) were approved as early as 2010. Subsequently, the Regulation for Emergency Preparedness for Nuclear Facilities (FANR-REG-12), the Regulation for Radiation Protection and Predisposal Radioactive Waste Management in Nuclear Facilities (FANR-REG-11), and the Regulation for System of Accounting for and Control of Nuclear Material and Application of Additional Protocol (FANR-REG-10), were approved in 2011. Later, the Regulation for the Siting of Nuclear Facilities (FANR-REG-02), the Regulation for Basic Safety Standards for Facilities and Activities involving Ionising Radiation other than in Nuclear Facilities (FANR-REG-24), the Regulation for Certification of Operations Personnel in Nuclear Facilities (FANR-REG-17), and the Regulation for the Design of Nuclear Power Plants (FANR-REG-03) were approved in 2013. Importantly, the Regulations for Requirements for Off-site Emergency Plans for Nuclear Facilities (FANR-REG-15), the Regulation for an Application for a Licence to Operate a Nuclear Facility (FANR-REG-14) and the Regulation on Operational Safety including Commissioning (FANR-REG-16) were approved by FANR in 2014.

Eventually, FANR has developed a set of 23 regulations which cover a broad spectrum of activities conducted in the UAE and their associated facilities, from the siting, design, construction, operation and decommissioning of nuclear facilities, emergency preparedness and response, the predisposal and disposal of radioactive waste, radiation protection, physical protection of nuclear material and related facilities, the security of radioactive sources and also address issues such as nuclear material accounting and control, import and export controls, existing exposure situations and the certifications of operating personnel.

All these regulations have been developed taking into account the relevant IAEA safety standards and security guidance documents as well as regulations developed by foreign regulators which also have served as reference. The regulations are available in Arabic and English on FANR website.

FANR has established a specific process supported by procedures for the development and revision of regulations. Such process ensures a systematic approach to the development of regulations, with the collection of the required inputs at the internal level and from external entities through public and stakeholders consultations. The comments provided through these consultations are assessed and taken into consideration for the development of the final draft regulation. Once approved and issued the regulations are available in both languages on the FANR website and are also published in the UAE Official Gazette. FANR also organizes specific events targeting the users of these regulations to raise their awareness and understanding of the new or revised requirements.

The nuclear regulator has also developed a systematic approach which provides for the regular review and revision, if found necessary, of regulations and the identification of the need for new regulations. The regular review of regulations shall be done at the latest five years after the date of issuance of the regulation. A review may be also triggered earlier to take into account a specific need or circumstance. The review needs to address the continued adequacy of the regulation, taking into account factors such as updates to the IAEA Safety Standards, or Security Guidance documents, operational, regulatory and implementation experience, response to international events or research and development findings.

As an example, following the Fukushima Daiichi accident in March 2011, FANR reviewed its relevant regulations relating to nuclear facilities to assess the need for their immediate revision. Further to this exercise FANR has identified no need for immediate changes to the existing regulations, but listed a number of items to be taken into account during the course of update of the regulatory framework.

FANR regulations are complemented by a set of regulatory guides that are issued to describe methods and/or criteria acceptable for meeting and implementing specific requirements contained in FANR regulations. Similarly to the regulations, the regulatory guides also extensively take into account the IAEA Safety Standards and Security Guidance documents and also adopted many of the guides issued by the regulatory body of the country of origin of the nuclear technology.

To date, 22 regulatory guides have been issued by FANR to support the implementation of the regulations and four more are currently being developed. The development and revision of the regulatory guides also follows a systematic process embedded in the integrated management system of FANR, involving the technical departments in FANR and external stakeholders. The regulatory guides are available in English on FANR website.

14.3.4 System of Licensing

All activities and practices involving the peaceful uses of nuclear energy and ionizing radiation, including the related equipment, information and technology in the UAE, i.e. the regulated activities, are subject to FANR licensing. The exclusive authority of FANR to grant licences for the conduct of those regulated activities is established in Article 6 of the Nuclear Law, while Article 23 of the Nuclear Law prohibits any person from conducting any Regulated Activity in the UAE without a licence.

The Nuclear Law provides in its Article 25 a list of regulated activities subject to a licence which include, inter alia, the siting, construction, operation, commissioning and decommissioning of nuclear facilities. The Nuclear Law further develops specific provisions relating to the licensing including some specific criteria for the granting, revocation, and suspension of licences.

Article 28 of the Nuclear Law requires the applicant for a licence to submit detailed evidence of safety that shall be reviewed and assessed by FANR in accordance with established procedures. Following a review and assessment of a licence application, FANR, through its Board of Management, determines whether to grant the licence, grant the licence with conditions, or to refuse the licence and records the basis for these decisions. As provided by the Nuclear Law, FANR has established a set of regulations which specify, for example, the licensing requirements relating to an application for a licence to construct a nuclear facility (FANR-REG-06) or the requirements for an application for a licence to operate a nuclear facility (FANR-REG-14). More recently, FANR has also issued a specific regulation on the registration and licensing of radiation sources (FANR-REG-29).

These regulations aim to specify the requirements to be complied by the applicant to obtain a FANR licence and have to be read in conjunction with the supporting regulatory guides developed by FANR (see for example FANR regulatory guide on the content of a nuclear facility construction and operating licence applications, FANR-RG-001-V1).

As required by Article 32(3) of Federal Law by Decree No. 6 of 2009:

> FANR is obligated to conduct a thorough review of the applicant's submission to satisfy itself that: a) available information demonstrates the safety of the facility or proposed activity; b) information … in the submissions is accurate and sufficient to enable confirmation of compliance with regulatory requirements; and that c) technical solutions, and in particular any novel ones, have been proven or qualified either by competent authorities, experience or testing, and are capable of achieving the required level of safety.

Therefore, in 2010, FANR developed in its Integrated Management System (IMS) dedicated internal processes consistent with the Nuclear Law and the relevant IAEA safety requirements for the licensing of the regulated activities related to nuclear facilities on one side, and for the licensing of all other regulated activities on the other side. Each process specifies the respective responsibilities within the regulatory authority for the receipt of licence application, issuance of an internal plan with responsibilities and schedule for review of the licence application, initial evaluation and requests for additional information, final evaluation and licence recommendation, licensing decision and issuance of a licence. The process is complemented by a set of procedures and instructions, which detail the methods and criteria to be applied by FANR during its review of a licence application.

As regards the licensing of regulated activities related to nuclear facilities, major milestones have been reached by the UAE over these past twelve years with seven key licences issued to date:

1. The Licence for Selection of a Site for the Construction of a Nuclear Facility, granted to ENEC in February 2010;

As there were no regulations in place at that time yet, the licensing of the site selection was based on guidance from the IAEA and references from the US NRC. The licence was approved by FANR's Board of Management, the highest decision making body at FANR, following FANR's review of the application submitted by ENEC. The issuance of the licence to ENEC marked the formal start of FANR's important role as the independent safety regulator for the UAE's nuclear power programme.

2. The Licence for the Preparation of the Construction of a Nuclear Facility, granted to ENEC in July 2010;

This licence and the 'site selection' licence mentioned previously provide authorization to ENEC to conduct site investigation and preparation activities at the Barakah site, such as the installation of site infrastructure, and construction of parts of the facility not related to nuclear safety.

3. The Limited Construction Licence, granted to ENEC in July 2010;

The licence authorizes the manufacturing, assembly, and testing of certain components as specifically delineated in the licence, including reactor vessels, steam generators, and other primary reactor system components. The licence authorize ENEC and its Prime Contractor, KEPCO, to manufacture and assemble structures, systems and components, such as reactor pressure vessel, steam generators, coolant pumps and other components important to safety of the nuclear power plant. Due to the long lead time for these processes, ENEC has decided to apply for this licence at this early stage.

As stated in the licence itself, the licence was granted at the applicant's risk and without prejudice to any subsequent decision by FANR about the suitability of the siting, design and construction of the nuclear facility or its systems, structures and components. Importantly, the licence is valid until the completion of the construction work of the nuclear facility or until it is earlier suspended or revoked by FANR or surrendered by the licencee.

Three subsequent amendments to the licence were issued in March 2011, in March 2012 and in May 2012 to cover a number of civil works at the site.

4. The Licence for the Construction of Unit one and Unit two of Barakah Nuclear Power Plant, granted to ENEC in July 2012;

It is worth noting that for the issuance of this construction licence, FANR took into consideration all the early lessons learned from the Fukushima Daiichi accident as FANR actively participated in the IAEA Nuclear Safety Standards Committee meetings and associated working groups to discuss the implications of the Fukushima Daiichi accident findings on IAEA Safety Standards. A thorough review of the reactor design and of the areas of the licence application associated with protection against external events and severe accident mitigation was made and FANR requested the licence applicant to undertake an assessment to determine application of lessons learned from the Fukushima Daiichi accident to the proposed Baraka NPP Units 1 and 2 and to provide a supplement to licence application.

5. The Licence for the Construction of Unit three and Unit four of Barakah Nuclear Power Plant and related regulated activities, granted to ENEC in July 2014;
6. The Licence for the Handling and Storage of Unirradiated Nuclear Fuel, granted to Nawah Energy Company PJSC (Nawah) in December 2016;
7. The Licence for the Operation of Unit One of the Barakah Nuclear Power Plant issued to Nawah, the nuclear operator, on 17 February 2020.

The issuance of the first licence to operate a nuclear power plant in the UAE was a significant achievement for the country and the result of extensive investment both from the side of the industry and the nuclear regulator. A thorough review of the 14,000 pages of the application documents submitted by the applicant has been undertaken by FANR, with additional 2000 requests for additional information issued, complemented by the conduct of over 180 inspections prior to the issuance of the licence.

The review and assessment of the licence application has involved all FANR departments of the operations division with the support of the legal affairs department and is documented in the Safety Evaluation Report (SER) of the Operating Licence Application which describes the framework, the methodology and conclusions of the regulatory review and assessment of the licence application for the operation of Unit 1 of the Barakah Nuclear Power Plant. The SER follows a systematic approach and considers 22 overarching topics (such as corporate governance, site characteristics, reactor, instrumentation and control, electrical power, radioactive waste management, radiation protection, accident analysis, quality assurance programme, physical protection, safeguards or decommissioning). It is complemented by the Constructed in Accordance with Requirements report, which provides information and supporting evidence that Unit 1 of the Barakah nuclear power plant has been constructed in accordance with the regulatory requirements and the Ready to Operate report, which summarizes the process and supporting evidence used to reach the regulatory findings that the operating licence applicant is organizationally ready to operate.

The licence for the operation of Unit 2 of the Barakah Nuclear Power Plant was granted to Nawah on 8 March 2021 together with an Amendment to the licence for the operation of Unit 1 of the Barakah Nuclear Power Plant. The licences authorize Nawah to operate the relevant unit of the Barakah nuclear power plant for a period of 60 years and to conduct related regulated activities directly associated with the operation of the concerned unit.[18] The construction of Units 3 and 4 of the Barakah Nuclear Power Plant is close to completion and FANR is currently reviewing the licence application for the application of Unit 3 of the Barakah Nuclear Power Plant.

In addition to the licences related to the nuclear power programme, FANR is assessing, reviewing and issuing a large number of licences for all other activities and practices involving radiation sources, as well as for import and export of nuclear material and dual use items. As an example, in 2020, FANR issued 1097 licences to conduct activities involving radiation sources, including 301 new licences, 304 renewals and 469 amendments of existing licences. To support the processing and evaluation of the applications by FANR and the exchange of documents and information between the applicant for a licence and the regulatory authority, and in line with the national initiative for a smart government, FANR has put into place an 'e-licensing platform', which allows an applicant for a FANR licence to provide all relevant information as required by FANR and supporting documentation. This is an integrated system which will reflects all the regulatory requirements relating to the licensing of activities and integrates safety, security and non-proliferation into one single portal. This e-licensing system is constantly updated to reflect the latest requirements developed by FANR and enables FANR to consider licencee requests and reports more rapidly and accurately.

14.3.5 Enhancing the UAE Legal Framework

Looking back over the past ten years, so much has been accomplished. A comprehensive nuclear legal framework has been developed almost from scratch in the UAE, with a Nuclear Law addressing safety, nuclear security and safeguards, complemented by a nuclear liability legislation. FANR has been established as a strong independent nuclear regulator. A full set of regulations supporting the development of the nuclear power programme, as well as all the other activities involving ionizing radiation in the country has been built and has been complemented by a number of regulatory guides. Hundreds of applications for licences have been assessed, licences issued, including huge milestone licences, such as the construction licences for the 4 units and operating licences for the 2 units of the Barakha Nuclear Power Plant. Last but not least, the UAE has diligently fulfilled its international commitments

[18] https://www.fanr.gov.ae/en/rules-regulations/licenses-regulatory-approval. Accessed 15 October 2021.

and has built a strong network at the international level. This could not have been done without a solid legal framework in place, a strong nuclear regulator and solid expertise available in the country.

However, that does not mean that the work is finished. Complacency is not a word acceptable in the nuclear world and the lessons have to be drawn from these years of experience in developing this ambitious nuclear power programme and implementing the nuclear legal framework. Also, new best practices are constantly identified, regulatory approaches are evolving and new technologies are being developed. Having that in mind and in line with the IAEA recommendations, the UAE nuclear legal framework has to be kept under continuous review.

In this context two different sets of documents have to be considered. On one side, the nuclear regulatory framework needs to be constantly updated. Indeed, it is essential to ensure that our regulations and guides are up-to-date, aligned with the latest international standards, drawing the lessons from the experience from their implementation. As mentioned previously, FANR has put in place a systematic mechanism to review the adequacy of regulations at regular intervals, but it is also essential to scrutinize and monitor developments, progresses in other countries and within international organizations which may require earlier reviews.

It also implies strengthening the internal process and procedures for the development of such regulatory framework. FANR is working towards continuously improving the process of development and review of regulations, to ensure the highest quality in the drafting and the content is strengthened based on the national needs and circumstances to ensure that all activities are conducted in a manner offering the best protection to the workers, the population and the environment of the UAE. In this context, the process for the development and revision of regulations has been recently strengthened to enhance the early involvement and cooperation between the FANR operational departments with a systematic contribution from the legal affairs department. The UAE through its regulator is striving to establish an agile albeit solid regulatory framework.

On the other side, another very important exercise is the regular review of the nuclear legislation. The development of a nuclear power programme cannot take place without a solid and sustainable nuclear legal framework, as highlighted previously. Certain stability was required to ensure the smooth launch and development of the nuclear power programme. However, it is also essential to keep the founding nuclear legislation under scrutiny, identify the gaps, draw the lessons from the implementation of the legal provisions, identify the potential issues and finally establish some actions plans to address them.

The Nuclear Law was adopted in 2009, more than 12 years ago. At the international and at the national level a number of developments took place. New international nuclear legal instruments where joined by the UAE, the UAE nuclear regulatory framework has matured, lessons and recommendations have been identified by international peer reviews missions, the Fukushima accident happened. Also, the world had to face in the past two years a pandemic which obliged the nuclear word, industry and regulators, to perform their work in a different manner. Challenges arose and solutions were developed. Such global crises demonstrated the need to have in place frameworks which also allow flexible, innovative and prompt response to unforeseen situations and circumstances, while at the same time preserving the fundamental safety objective which is to ensure the best protection to the population and the environment against the harmful effects of ionizing radiation. All these factors have to be considered and the UAE is now working towards the review of its founding nuclear legislation to ensure that it continues to serve the country's objectives for the next 50 years.

The strengthening of the nuclear legal framework requires experienced people and a combination of technical inputs supported by legal experts. To this end, the UAE needed to develop and maintain the appropriate nuclear legal expertise with lawyers trained and experienced in developing, revising and implementing nuclear legislation and regulations. The UAE has benefited from the extensive support from the IAEA and other international organisations, such as the OECD Nuclear Energy Agency, which provide highly recognized intensive trainings for nuclear lawyers. In addition, FANR has also been proactive in developing a tailored nuclear legal developee programme, in partnership with a renowned law firms to train young Emirati graduates into nuclear law issues, combining theoretical sessions and on the job training.

References

International Atomic Energy Agency (IAEA) (2007) Milestones in the Development of a National Infrastructure for Nuclear Power, Nuclear Energy Series No. NG-G-3.1. IAEA, Vienna

International Atomic Energy Agency (IAEA) (2014), General Conference Plenary Record of the Fourth Meeting, GC(57)/OR.4. https://www.iaea.org/sites/default/files/gc/gc57or-4_en.pdf. Accessed 15 October 2021

International Atomic Energy Agency (IAEA) (2015) Milestones in the Development of a National Infrastructure for Nuclear Power, Nuclear Energy Series No. NG-G-3.1 (Rev. 1). IAEA, Vienna

Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy. (2008) www.fanr.gov.ae/en/Lists/LawOfNuclear/Attachments/2/20100523_nuclear-policy-eng.pdf

Chapter 15
Building the Nuclear and Radiological Safety and Security Authority in the Kingdom of Morocco: Sharing Experience and Lessons Learned

Khammar Mrabit

Contents

Abstract Following the example of several countries, the Kingdom of Morocco adopted, in the middle of the twentieth century, nuclear techniques in the medical and industrial fields, which have experienced a greater and sustained growth following its membership of the IAEA in 1957. This chapter presents the evolution of the nuclear and radiological infrastructure in Morocco over the last 60 years and the prospects for its future development. The chapter outlines the continuous efforts made by public authorities to upgrade the national nuclear and radiological regulatory

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framework in compliance with international obligations related to safety, security and safeguards. In this regard, the Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR) has, since its inception, been driven by the will and ambition to achieve its vision of establishing itself at the national level as an independent, effective, credible and transparent regulatory body; as well as a leader at the African level and significant contributor in the international arena. The Moroccan experience in safety and security governance and management is highlighted, and the lessons learned and experience gained in this area by AMSSNuR are shared.

Keywords Nuclear techniques in the medical and industrial fields · Nuclear and radiological infrastructure · National nuclear and radiological regulatory framework · Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR) · Safety and security governance and management · Lessons learned · AMSSNuR strategic plan

15.1 Introduction

A report published by the International Atomic Energy Agency (IAEA) in September 2020 at the end of its 64th General Conference,[1] stated that nuclear technology is undergoing considerable development at the international level, particularly in the areas of energy applications, accelerator and research reactor applications, radioisotope and radiation technologies, human health and nuclear techniques in food and agriculture. In its Nuclear Safety Review 2020,[2] the IAEA described global trends and activities related to its various programmes, while highlighting progress and priorities for strengthening nuclear and radiation safety as well as transport and waste safety at the international level.

These statements are directly linked to, inter alia:

- The revision of the IAEA safety standards and security guidance, their application through education and training, peer reviews and advisory services undertaken by the IAEA at the request of its Member States, as well as the lessons learned from the accidents in Goiânia and at the Fukushima Daiichi and Chernobyl nuclear power plants and other accidents and incidents.
- The effectiveness of nuclear, radiation, transport, waste and safety emergency preparedness and response regulations and their implementation.

This progress also concerns the adoption by Member States of the internationally binding conventions and non-binding instruments such as the codes of conduct on the safety and security of radioactive sources, nuclear safety, and the safety of spent fuel management, as well as on the safety of radioactive waste management.

[1] IAEA 2020a.

[2] IAEA 2020b.

In the area of nuclear security, an IAEA report[3] to the 64th General Conference described the activities undertaken in this area, the external users of the Incident and Traffic Database (ITDB), and the past and planned activities of the education and training and collaboration networks.

To this end, States must commit to continuously strengthen safety, security and safeguards and to establish a nuclear governance structure that takes into account their interfaces and specificities. In addition, the IAEA must continue to support, at the request of its Member States, national efforts to establish and maintain effective and sustainable nuclear security regimes.

Within this framework, this chapter presents the evolution of the nuclear and radiological infrastructure in Morocco over the last 60 years and the prospects for its future development, as well as the continuous efforts made by public authorities to upgrade the national nuclear and radiological regulatory framework in compliance with international obligations related to safety, security and safeguards. It highlights the Moroccan experience in safety and security governance and management, and shares the lessons learned and experience gained in this area by the Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR).

15.2 Evolution of Nuclear Applications in Morocco

Following the example of several countries, the Kingdom of Morocco adopted, in the middle of the twentieth century, nuclear techniques in the medical and industrial fields, which have experienced greater and sustained growth following its membership of the IAEA in 1957. Within this framework, Morocco has progressively introduced new programmes in various socioeconomic sectors, particularly health, industry, mining, agriculture, higher education and research. The current situation in these sectors is as follows:

- Medicine (radiology, nuclear medicine, radiotherapy, etc.) accounts for more than 80% of the installations and activities using ionizing radiation sources. Thus, the field of health records over 7000 units of radiology equipment, over 300 scanners, 40 electron accelerators used for treatment and 24 nuclear medicine centres. These figures are expected to increase in the future with the construction of new regional centres and the expansion of mandatory health insurance.
- The production of radiopharmaceuticals is carried out in two cyclotrons in Bouznika and Bosker. These facilities are managed by private companies that supply nuclear medicine centres with radioactive products for radiodiagnostic purposes, in particular fluorine-18. The National Centre for Energy, Science and Nuclear Techniques (CNESTEN) produces other radioelements, such as iodine-131, through the TRIGA Mark II research reactor. CNESTEN also manages the regular import and distribution of several radioelements used by nuclear

[3] IAEA 2020c.

medicine centres, which generates an important activity involving the transport of radioactive material at the national level.

- The industrial sector includes several installations and activities using ionizing radiation sources (IRSs), particularly in such processes as the control of the production of sugar, cement, paper, oil refining, mining and metallurgy. More than ten companies provide technical services in industrial radiography with IRSs, the most important of which is the Public Laboratory of Studies and Tests (LPEE), which provides services for such civil engineering works as building construction as well as road and industrial sites.
- In agriculture, agronomic research studies are carried out by the National Institute of Agronomic Research (INRA), the Hassan II Agronomic and Veterinary Institute (IAV) and the Regional Offices for Agricultural Development (ORMVA). In its regional centre in Tangier, INRA operates a semi-industrial irradiator using a very high activity cobalt-60 source, and has laboratories dedicated to agronomic research and dosimetry. In the veterinary field, in addition to the Hassan II IAV, which provides teaching, training and research activities, a dozen public and private regional centres use radiology equipment for veterinary medicine. The National Office of Food Safety (ONSSA) plans to install an irradiation facility in Agadir using cobalt-60 sources to sterilize pests.
- In the areas of transport and border control, around ten companies are involved in the transport of radioactive material and have special vehicles and authorizations for this purpose. At the borders, ports and airports are equipped with scanners for the control of goods and for security. With regard to port and airport traffic, several security and control bodies, such as the Royal Gendarmerie, police, customs and others deal with safety and security aspects.
- Research and training are conducted mainly by CNESTEN, which has a 2 MW nuclear research reactor since 2009 at the Maamora Nuclear Research Centre (CENM). The CENM includes other facilities and activities using IRSs that are dedicated to the production of radiopharmaceuticals, the management of radioactive waste generated at the national level, industrial and environmental applications, research, calibration of radiation protection equipment, transportation and training. Universities also possess research laboratories that use IRS for research, calibration of measurement equipment, training and teaching in the fields of physics, metrology, medicine, geology, etc.
- In terms of radioactive waste management, CNESTEN was designated in its founding law as the national organization responsible for the centralized management of radioactive waste generated by all medical, industrial and other users. It has at its disposal the facilities and equipment required for the treatment of radioactive waste as well as its conditioning and storage. In cooperation with CNESTEN, AMSSNuR has developed a national policy and strategy for the safety of radioactive waste management and regularly prepares the national report required by the Joint Convention on the Safety of Spent Fuel Management.
- In the area of electronuclear power, in 2009 the Ministry of Energy, Mines and Environment (MEME) set up the Reflection Committee on Electronuclear Power and Seawater Desalination (CRED) and tasked it to study the conditions for

introducing electronuclear power in Morocco in accordance with the guidelines and recommendations of the IAEA. In this context, in 2015 Morocco hosted an IAEA Integrated Nuclear Infrastructure Review (INIR) mission, which resulted in around 15 recommendations and observations, many of which relate to the legislative and regulatory framework, nuclear safety and radiation protection.
- Preparing for and managing nuclear or radiological emergencies according to the IAEA safety standards have led to the implementation of specific regulations and an organization involving all stakeholders, such as the Ministries of Interior and Defence, the General Directorate of Civil Protection (DGPC), the Royal Gendarmerie (GR) and the General Directorate of National Security (DGSN).

15.3 Evolution of the National Regulatory Framework of Nuclear and Radiological Safety and Security

Since it became a member of the IAEA in 1957, the Kingdom of Morocco has been committed to implementing the IAEA safety standards and later security guidance. Thus, the promotion of nuclear and radiological techniques has been pursued in a safe, secure and peaceful manner.

In line with the above, in 1971 Morocco adopted Law No. 005-71[4] relating to the protection against ionizing radiation, as well as its enforcement decrees, to set the general principles of protection against the risk of IRSs in all installations and activities from design through construction, commissioning, use and decommissioning, including the unique research reactor facility in the country. This facility was authorized under joint decrees by the Ministries of Energy and Health, which were in charge of nuclear safety and radiation protection until October 2016.

By adopting a new law, No. 142-12,[5] in 2014 on nuclear and radiological safety and security and the creation of AMSSNuR, Morocco took a significant step towards strengthening its regulatory framework in line with the IAEA's safety standards and nuclear security guidance. This law is based on the IAEA's model legislation integrating safety, security and safeguards (the '3S concept').

The establishment of AMSSNuR as the unique regulatory body was intended to regulate nuclear and radiological safety and security and nuclear safeguards, and separate activities dedicated to promotion from those devoted solely to regulatory control. At the international level, the Kingdom of Morocco has signed and ratified all international treaties and conventions on nuclear safety and security, the latest being the Convention on Nuclear Safety in May 2019.

[4] Official Gazette 1971, p. 1204.

[5] Official Gazette 2014, pp. 4090–4113.

15.4 Role and Achievements of AMSSNuR

AMSSNuR is a public establishment of strategic nature whose mission is to ensure that nuclear and radiological safety and security, as well as activities and facilities involving ionizing radiation sources, are in compliance with the provisions of Law No. 142-12 and related regulations, which in turn are compatible with relevant international instruments, safety standards and nuclear security guidance. Its main functions are to regulate, review and assess, authorize, inspect, sanction and inform the public of safety and security issues while protecting sensitive and confidential information, provide support to the State on relevant issues, and promote regional and international cooperation.

Following the creation of AMSSNuR by Law No. 142-12, I was appointed in 2016 as the first Director General by His Majesty King Mohammed VI to build this strategic institution and establish it as an independent, effective, credible and transparent regulatory body at the national, regional and international levels.

15.4.1 AMSSNuR Governance and Management Model

Based on solid professional experience in safety and security at the IAEA over three decades, I presented the vision, strategic plan 2017–2021 and the associated roadmap, as well as the governance and management mechanisms that were adopted at the first meeting of the Board of Directors, held in October 2016 under the chairmanship of the Head of the Moroccan Government.

15.4.2 Long Term Vision

From its inception, AMSSNuR has been driven by the will and ambition to achieve its vision of establishing itself at the national level as an independent, effective, credible and transparent regulatory body and as a leader at the African level and significant contributor in the international arena.

15.4.3 Strategic Objectives 2017–2021

Considering the prevailing national and international environment at the time of its creation, AMSSNuR has set up its strategies and objectives for the 2017–2021 period to:

(a) Upgrade the national regulatory framework for nuclear and radiological safety and security;

(b) Strengthen the level of nuclear and radiological safety and security at all facilities and activities involving ionizing radiation sources;
(c) Establish and implement the national nuclear security system and the national nuclear or radiological emergency response plan;
(d) Establish a transparent and reliable communication policy on safety and security issues.
(e) Develop and maintain human and organizational capabilities;
(f) Contribute to and strengthen regional and international cooperation;
(g) Monitor experience in the fields of nuclear and radiological safety and security.

In its roadmap, in accordance with Law No. 142-12 and national and international best practices, AMSSNuR has, over the past five years, regularly reported on a yearly basis to the Board of Directors, chaired by the Head of the Moroccan Government, and has carried out self-assessments that have enabled it to continuously improve safety and security nationally and contribute to their strengthening regionally and internationally. AMSSNuR has also planned peer reviews, starting in 2021, including IAEA International Regulatory Review Service (IRRS) and Emergency Preparedness Review (EPREV) missions, which have been postponed until 2022, as well as other IAEA peer reviews such as International Physical Protection Advisory Service (IPPAS) and International SSAC Advisory Service (ISSAS).

15.4.4 Adoption of the Principles of Good Governance Practices

To achieve its strategic objectives and ambitions, AMSSNuR has adopted the principles of the Moroccan Code of Good Governance Practices for Public Enterprises and Establishments (EEP), which have enabled the establishment in 2018 of both the Audit Committee and the Scientific Committee. It also applied the decisions made by its Board of Directors at its yearly meetings, and those of its supervisory authority and the Ministry of Economy and Finance, which aim at accountability, performance and transparency.

15.4.5 Development of the Integrated Management System

Based on IAEA recommendations, AMSSNuR initiated in 2018 the design and implementation of its Integrated Management System (IMS) that covers its regulatory functions as well as the components dealing with the development of its human, financial and quality resources and organizational aspects. The IMS has been designed and implemented as part of AMSSNuR's cooperation with the European Union and has benefited from the feedback of several European regulatory authorities. AMSSNuR's IMS can therefore be considered as being compliant with national regulatory requirements in force in terms of safety, security, safeguards and governance, and with international standards for quality, environmental protection, health protection and information and security systems. The objectives of the IMS contribute to anchoring the culture and leadership of safety and security at AMSSNuR and consequently to maintaining a high level of safety and security in facilities and activities involving ionizing radiation sources in Morocco.

15.5 Main Achievements by Strategic Area

This section highlights the main achievements of the 2017–2021 strategic plan on its conclusion by strategic axis. It also presents the lessons learned as well as the experience gained and the impact of its activities on improving safety and security with a view to sharing them with all sister authorities.

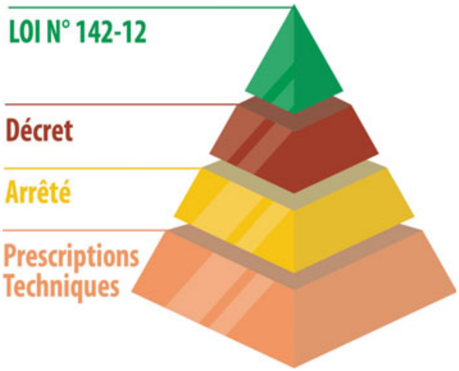
15.5.1 Upgrading the National Regulatory Framework for Nuclear Safety, Security and Safeguards

In accordance with its main functions on the development of national regulations, AMSSNuR has implemented since 2017 a strategy to upgrade the regulatory framework of nuclear and radiological safety, security and safeguards, work that is among its priority obligations as enacted by Law No. 142-12 as well as by the strategic directions adopted by its Board of Directors.

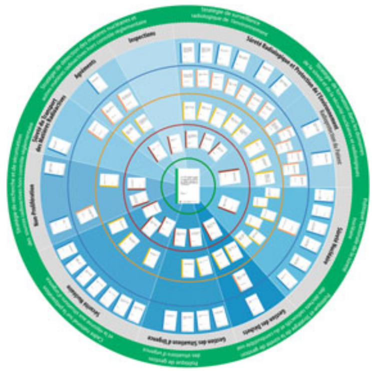
At the end of the 2017–2021 five year plan, AMSSNuR was able to develop and submit to the Head of Government *56* draft regulatory texts necessary for the implementation of Law No. 142-12 covering all aspects of safety, security and safeguards (see Fig. 15.1). These results are the fruit of the consultation work with all the national stakeholders within a national committee composed of more than 30 members. It was set up to upgrade the regulatory framework for nuclear and radiological safety and security established in 2017 with a clear policy and strategy endorsed and implemented by all members of the committee.

15.5.2 Strengthening Safety and Security at the National Level

As part of the implementation of its regulatory functions relating to the review and assessment of safety and security and to regulatory oversight, AMSSNuR has implemented a plan to strengthen nuclear and radiological safety and security at all facilities and activities involving IRSs. In terms of results, over the 2017–2021 period, these activities have resulted in:



Pyramid of national regulatory texts implementing Law No. 142-12



Tree structure of texts implementing Law No. 142-12

Fig. 15.1 Hierarchy of regulatory texts. *Source* Official Bulletin 2014

- The granting of more than 4650 authorizations;
- The inspection of more than 2540 activities and facilities;
- The organization of six regulatory inspections of the CNESTEN research reactor;
- The establishment of the national register of IRSs.

These results were obtained within the framework of a participative and graduated approach adopted by AMSSNuR with all stakeholders. They contributed significantly, inter alia, to the improvement of safety and security cultures.

15.5.3 Support to Governmental Authorities

With regard to support to governmental authorities, in particular assistance to the State in the development of the national nuclear security system and the national emergency and response plan in the case of a radiological emergency, AMSSNuR has managed to fully implement its strategic plan for 2017–2021. In particular, at the end of the implementation of this plan, AMSSNuR was able to develop, in close cooperation with relevant departments and authorities, the following:

- The national nuclear security system;
- The Integrated Nuclear Security Support Plan;
- The national nuclear detection strategy;
- The plan for securing radioactive sources;
- Effective contribution to the implementation of the Global Initiative to Combat Nuclear Terrorism;
- Implementation of the provisions of the Treaty on the Non-Proliferation of Nuclear Weapons;
- The National Radiological Emergency Response Plan.

In addition, AMSSNuR assists and advises the State in the implementation of its commitments under the conventions and treaties ratified by Morocco (designation of points of contact, drafting and submission to the IAEA of national reports, participation in review conferences and review of conventions).

15.5.4 Public Information and Communication

Given the obligation to inform the public about the status of nuclear and radiological safety and security at the national level and to communicate with all stakeholders, AMSSNuR has established a policy and a strategy based on the mapping of stakeholders and has articulated internal and institutional communication as well as media, non-media and social network communication. The communication strategy also covers the international aspect and the monitoring of nuclear or radiological emergencies.

In terms of achievements, AMSSNuR currently has a directory, tools and experience based on:

- The institutional website and social network accounts;
- Annual activity reports, brochures and leaflets;
- Regional meetings with professionals and other conferences and seminars;
- Press coverage (more than 1000 media appearances), media kits and press conferences;

The objective, through the information and communication policy, is to strengthen the transparency and reliability of information.

15.5.5 Development and Maintenance of Human and Organizational Capacities

AMSSNuR is aware of the importance of developing and maintaining nuclear and radiological safety and security capabilities at the internal and national levels, as recommended by the IAEA and the Global Nuclear Safety and Security Network (GNSSN), particularly the four pillars dedicated, respectively, to human resources, education and training in safety and security, knowledge management, and partnership development. It has adopted specific plans for each pillar.

Regarding human resources development, AMSSNuR has increased its staff from one person in 2016 to 84 employees in 2021, while giving primary importance to gender equality, with 48% of employees being female and 43% of leadership positions being held by women. Priority is also given to skills development and continuous training, with approximately 2300 days, or an average of seven weeks, of training per person completed by AMSSNuR during the reporting period.

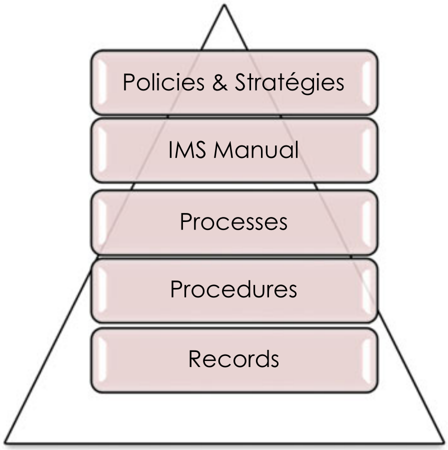


Fig. 15.2 Hierarchy of IMS documents. *Source* AMSSNuR

At the national level, AMSSNuR has established a strategy for theoretical and practical training in nuclear and radiological safety and security, which has enabled the identification of more than 13,000 people to be trained or qualified at the national level and over 300 people to be trained or qualified at the African level.

At the managerial level, AMSSNuR has set up a strategy for the design and implementation of its IMS by developing a manual, a process map, and process and procedure sheets covering the macro-processes dedicated to business, governance and support (22 process sheets, 36 procedures and 19 sub-procedures have been developed) (see Fig. 15.2).

As part of its graduated approach, AMSSNuR initiated the execution of three pilot business processes in 2020 (authorization, regulations and nuclear safeguards) and intends to complete testing, implementation and improvement research operation by the end of 2022 before updating its documentation.

In addition to processes and procedures, AMSSNuR's IMS aims to promote and develop a safety and security culture and leadership at the internal level as well as among the sector's operators. To this end, a number of managerial and national policies and strategies have been set up by AMSSNuR. They are related to:

- Radiological monitoring of the environment;
- Safety of the management of radioactive waste and disused sources;
- Nuclear safety;
- Detection of nuclear materials and other radioactive sources outside regulatory control;
- Preparedness and Response to Nuclear and Radiological Emergencies (PCI-SUNR);
- Training in nuclear and radiological safety and security.

It should also be noted that the major challenge of integrating these different policies and strategies into a single management system will ensure an even higher level of nuclear and radiological safety and security.

In parallel with the implementation of its IMS, AMSSNuR has put in place a set of information systems dedicated to:

- Digitization of business activities related to licensing, regulation, inspections, safeguards, sanctions and nuclear and radiological emergencies;
- Human resources management (HRIS);
- Budgetary and financial management.

15.5.6 Development and Strengthening of Regional and International Cooperation

At the end of its 2017–2021 strategic plan, AMSSNuR was able to develop and strengthen its national and international partnership network by signing:

- Ten cooperation agreements with relevant departments and public authorities involved directly or indirectly in nuclear or radiological safety and security;
- Eight cooperation agreements with sister authorities in Canada, China, France, Germany, Hungary, Russian Federation, Spain and the United States of America;
- Four cooperation agreements with sister authorities in Burkina Faso, Côte d'Ivoire, Mauritania and Rwanda;
- A five year cooperation project with the European Union for €2 million;
- Two triangular IAEA–AFRA–African country cooperation contracts with Côte d'Ivoire and Mauritania, respectively.

AMSSNuR also proceeded, in the framework of the implementation of its cooperation strategy, with:

- The organization, over the period 2017–2020, of more than 100 events of national, regional and/or international scope;
- The contribution to the training of more than 2000 people, representing over 10,000 person-days;
- The mobilization of more than a hundred expert-weeks covering all safety and security activities of AMSSNuR;
- The hosting of more than 20 African fellows that contributed to the strengthening of their nuclear and radiological safety and security activities;
- The strengthening of AMSSNuR's capacity in inspection and control operations of facilities and activities involving ionizing radiation sources at the national level.

In addition, AMSSNuR's cooperation programme is marked by strong interactions with the IAEA, which remains its primary international partner, particularly through:

(a) The recognition of AMSSNuR by the IAEA as:

- Regional Center for Capacity Building in Radiological Emergency Preparedness and Management;
- First IAEA Collaborating Centre in Africa for capacity building in nuclear security.

(b) Chairing cooperative networks:

- Forum of Nuclear Regulators in Africa (FNRBA);
- Global Nuclear Safety and Security Network (GNSSN);
- International Network for Education and Training in Nuclear and Radiological Emergency Preparedness and Response (iNET–EPR).

15.5.7 International Monitoring

By monitoring international developments and exchanging the experiences of other countries in nuclear and radiological safety and security, AMSSNuR:

- Contributes to the meetings of the contracting parties to relevant international conventions and instruments;
- Elaborates, in consultation with national stakeholders, national reports required by international instruments and presents them to their coordinating bodies (Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Convention on Nuclear Safety, Convention on Early Notification and Assistance in Case of Emergency, etc.).

The objective of this monitoring is to ensure adherence to and compliance with the international regime of nuclear and radiological safety and security and to act within the steering and governance bodies of international conventions and their commissions.

15.6 Conclusion

The implementation of AMSSNuR's 2017–2021 strategic plan and its assessment has allowed AMSSNuR to:

- Strengthen the national nuclear and radiological safety and security regime, reinforce the processes of openness, transparency and continuous improvement to which Morocco has subscribed in this field and, consequently, reinforce its credibility at the international level and its positioning at the regional level;
- Consolidate its competences and develop the national capacities of nuclear and radiological safety and security through, inter alia, its activities of sensitization of national stakeholders and of communication and transparency towards the international community;

- Support the development of safety and security culture and leadership at the national and regional levels while confirming its dynamism and leadership;
- Ensure a dynamic regulatory body, following relevant technological and scientific activities;
- Promote regional and international cooperation and partnership;
- Initiate external evaluation operations by the IAEA, in particular IRRS and EPREV, planned in 2022;
- Contribute to the promotion and continuous improvement of safety and security activities through knowledge networks, education and training and sharing of experience and lessons learned.

All these achievements confirm AMSSNuR's continuous commitment as a dynamic regulator and expert contributor to nuclear and radiological safety and security regulatory activities at the national, regional, and international levels. AMSSNuR is ready and willing to share its experience and strengthen its partnership with its sister organizations and relevant partners. In the future, AMSSNuR intends to further strengthen its cooperation with regional and international partners with a view to continuously improving safety and security regionally and globally.

References

International Atomic Energy Agency (IAEA) (2020a) Nuclear Technology Review 2020, GC(64)/INF/2

International Atomic Energy Agency (IAEA) (2020b) Nuclear Safety Review 2020, GC(64)/INF/3

International Atomic Energy Agency (IAEA) (2020c) Nuclear Security Report 2020, GOV/2020/31–GC(64)/6

Official Gazette [Bulletin officiel] (1971) Law No. 005-71 of 12 October 1971 on the protection against ionizing radiation [Loi n° 005-71 du 12 octobre 1971 relative à la protection contre les rayonnements ionisants]. In: El Fekkak M (ed) Labour Legislation Directory [Répertoire de la législation du travail] (1994). Librairie Al Wahda Al Arabia, Casablanca, p 717

Official Gazette [Bulletin officiel] (2014) Law No. 142-12 of 22 August 2014 on nuclear and radiological safety and security and the creation of the Moroccan Agency for Nuclear and Radiological Safety and Security [Loi n° 142-12 du 22 août 2014 relative à la sûreté et à la sécurité nucléaires et radiologiques et à la création de l'Agence marocaine de sûreté et de sécurité nucléaires et radiologiques]. https://www.ilo.org/dyn/natlex/docs/SERIAL/93657/109579/F930113526/MAR-93657.pdf. Accessed 15 October 2021