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Nuclear New Build Renaissance – In Search of New Approaches to Legal Challenges and Regulatory Effectiveness

Edited by
Łukasz Młynarkiewicz
and Piotr Frąckiewicz

Nuclear New Build Renaissance: In Search of New Approaches to Legal Challenges and Regulatory Effectiveness

Pomeranian University in Słupsk

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Proceedings of the XXV INLA Nuclear Inter Jura Congress – Warsaw 2024

Edited by
Łukasz Młynarkiewicz
and Piotr Frąckiewicz

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Reviewer
Ph.D. in Law Denis Philippe,
Extraordinary Professor at the Catholic University of Louvain
and at the ICHEC

Proofreading
Tatiana Grydziuszko

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TABLE OF CONTENTS

Introduction 9

PART I
NUCLEAR NEW BUILD: CONTRACTING, MARKET DESIGN AND BUSINESS MODELS

Chapter 1
Contracting for Nuclear Power Plants – Central Europe Perspective 15
Tomasz Darowski, Kamil Pociecha

Chapter 2
The Role of Nuclear Power in the New EU Electricity Market Design . . . 27
Wojciech Wrochna, Bartosz Brzyski

PART II
SMALL MODULAR REACTORS (SMRs): LEGAL AND REGULATORY CHALLENGES

Chapter 3
Legal Barriers to the Deployment of SMR and ANT Reactors in the European Union: Is the Euratom Treaty Sufficient? 47
Przemysław Gorzkowski

Chapter 4
Planning and Contracting for Small Modular Reactor Deployment 61
Robert Temple

Chapter 5
The Small Modular Reactors: India's Predicament to Liberalise Nuclear Power 75
Riju Raj Singh Jamwal

PART III
NUCLEAR LIABILITY AND TRANSPORT

Chapter 6
Nuclear Damage Claims Regulation in Poland: Analysis and Diagnosis . . . 113
Patrycja Nowakowska

Chapter 7
Liability for Nuclear Transport: A Pragmatic Case Study Approach, Including SMRs. 133
Evelyne M. Ameye

PART IV
RADIOACTIVE WASTE MANAGEMENT

Chapter 8
Progress and Emerging Issues in the Geological Disposal of High-Level Nuclear Waste in Japan 159
Fumito Tomooka

Chapter 9
SMR and AMR Radioactive Waste: A Comparative Legal Analysis 171
Nuria Prieto Serrano (coord.), with contributions by: Istiak Ahmed, Jerry Bonanno, Charles Bressant, Katarína Duchoňová, Stephen Tromans KC, Alexandra Van Kalleveen and Federico Winsens

Chapter 10
Achieving Permanent Disposal of Higher Level Radioactive Wastes. . . . 219
Stephen Tromans KC

PART V
DECOMMISSIONING AND RADIOLOGICAL PROTECTION

Chapter 11
Environmental Impact Assessments for Decommissioning and Dismantling: Analysis of Existing Frameworks and Recommendations for Improving Effectiveness 253
Guan Schaiko, Ellen Vandensande

Chapter 12
Nuclear New Build Renaissance, Decommissioning and Radiological Protection in the United Kingdom: Legal and Regulatory Framework 277
Lorraine Chiwenga

Chapter 13
When Armies March – Radiological Protection During a Time of War . . . 295
Mark Callis Sanders, Charlotta E. Sanders

PART VI
NUCLEAR LAW AND THE NEW SPACE ERA

Chapter 14
Nuclear Law in the New Space Era: Commercial Use of Outer Space and the Future of the Law of Nuclear Energy 323
Jakub Handrlica

References 339

INTRODUCTION

The construction of new nuclear power capacity is, once again, at the centre of the global energy debate. After decades in which very few new reactors were ordered in Europe and North America, a combination of climate commitments, energy security concerns following Russia's invasion of Ukraine, and rapidly growing electricity demand has brought nuclear new build back onto the agenda of governments, regulators, investors and technology suppliers alike. Yet the return of large-scale nuclear construction has also exposed how ill-suited many existing contracting practices, regulatory frameworks and dispute-resolution mechanisms are to projects of this complexity, cost and duration. It is this tension—between the ambition of a "nuclear renaissance" and the practical, legal and regulatory architecture required to deliver it—that formed the starting point for the 25th Nuclear Inter Jura Congress of the International Nuclear Law Association (INLA), held under the theme "Nuclear New Build Renaissance: In Search of New Approaches to Legal Challenges and Regulatory Effectiveness".

The Congress, co-organised with the Lower Silesian Institute for Energy Studies (DISE Energy), brought together representatives of governments, regulatory authorities, nuclear specialists, legal practitioners and academics from across the world, continuing INLA's long-standing mission of promoting the study of legal issues associated with the peaceful uses of nuclear energy and encouraging the exchange of information in this field. This volume collects a selection of the papers presented at the Congress, revised and expanded for publication, and organised into six thematic parts that mirror the principal legal challenges facing the current wave of nuclear new build projects worldwide.

Part I, *Nuclear New Build: Contracting, Market Design and Business Models*, opens the volume with two contributions addressing the commercial and regulatory architecture within which new nuclear projects must be delivered. **Tomasz Darowski** and **Kamil Pociecha** examine why nuclear power plant projects in Central Europe are especially prone to delays and cost overruns, and argue for a move away from traditional, rigid contracting practices towards more flexible remuneration and change-management mechanisms, such as target-price or EPCM arrangements, better suited to the realities of first-of-a-kind projects in the region. **Wojciech Wrochna** and **Bartosz Brzyski** then turn to the European Union's electricity market design, asking whether its current architecture—built with other technologies in mind—adequately accommodates nuclear power, and identifying the challenges nuclear facilities face under new contracting and financial support schemes.

Part II, *Small Modular Reactors (SMRs): Legal and Regulatory Challenges*, reflects the intense international interest in SMR and advanced nuclear technology (ANT) deployment, and the legal uncertainty that still surrounds it. **Przemysław Gorzkowski** examines why, despite numerous announced projects, no commercial SMR or ANT reactor has yet been built anywhere in the world, tracing the roadblock to the rigid and non-harmonised legal frameworks governing certification and construction, and asking whether the EURATOM Treaty itself is equal to the task of accelerating deployment. **Robert Temple** draws on his experience as general counsel of NuScale Power to set out the practical planning and contracting choices facing developers who, as equipment designers rather than full-scope constructors, must assemble a contractual structure capable of supporting project financing. **Riju Raj Singh Jamwal** closes this part with an analysis of the particular predicament facing India, where significant public and political support for SMR deployment coexists with a legal framework—including licensing and liability rules—that has yet to be adapted to allow meaningful private-sector and foreign participation.

Part III, *Nuclear Liability and Transport*, addresses two subjects that are often overlooked until an incident makes them unavoidable. **Patrycja Nowakowska** analyses the gaps in Poland's nuclear damage claims regime as the country prepares to bring its first nuclear power plants into operation, highlighting the absence of clear substantive rules for distributing compensation among multiple claimants where available funds

are limited. **Evelyne M. Ameye** then provides a pragmatic, scenario-based account of third-party liability for nuclear transport incidents, with particular attention to the increased transport activity that the deployment of SMRs is expected to generate.

Part IV, *Radioactive Waste Management*, brings together comparative perspectives on one of the nuclear sector's most persistent challenges: the search for permanent disposal solutions. **Fumito Tomooka** reports on the evolving site-selection process for a geological disposal repository for high-level waste in Japan following the Fukushima accident. A multinational team coordinated by **Nuria Prieto Serrano**, with contributions from practitioners and INLA Working Group members across several jurisdictions, offers a comparative legal analysis of the radioactive waste implications of SMR and AMR deployment. **Stephen Tromans KC** closes the part with a wide-ranging review of the law, politics and institutional arrangements behind permanent disposal programmes in Finland, France, the United States and the United Kingdom, and the scale of investment and collaboration still required if a global expansion of nuclear energy is to be matched by credible waste management solutions.

Part V, *Decommissioning and Radiological Protection*, examines the other end of the nuclear life cycle, which the current wave of new build inevitably runs alongside. **Guan Schaiko** and **Ellen Vandensande** analyse the ambiguity between nuclear safety terminology and environmental law in the context of decommissioning and dismantling, and the resulting uncertainty as to when environmental impact assessment obligations are triggered under instruments such as the Espoo and Aarhus Conventions and the EU EIA Directive. **Lorraine Chiwenga** examines how the United Kingdom's own "nuclear renaissance"—the simultaneous pursuit of new build and decommissioning of its existing fleet—has tested the national legal and regulatory framework for radiological protection, concluding that it has, on balance, proved reasonably effective. In a paper prompted by the invasion of Ukraine, **Mark Callis Sanders** and **Charlotta E. Sanders** ask whether peacetime radiological protection frameworks are adequate—and sufficiently adaptable—to situations in which sovereign control over a nuclear facility is lost during armed conflict.

Part VI, *Nuclear Law and the New Space Era*, looks beyond the terrestrial context altogether. **Jakub Handrlica** examines the legal challenges raised by the prospective deployment of nuclear technologies in outer space, arguing that the current, state-centred legal framework is not equipped

to address the gradual privatisation and commercialisation of nuclear activities beyond Earth, a topic that the international nuclear law community has, to date, largely left unaddressed.

Taken together, these fourteen chapters illustrate both the breadth of the legal community's engagement with the nuclear new build renaissance and the extent of the work that remains to be done. Contracting models designed for a different era, certification regimes that have yet to be harmonised across borders, liability and waste management frameworks still being tested for the first time in several jurisdictions, and entirely new frontiers such as the use of nuclear technology in space all point to the same underlying conclusion: technology is advancing faster than the legal and regulatory architecture built to support it. It is precisely this gap that the Nuclear Inter Jura Congress—and, we hope, this volume—seeks to help close, by bringing together practitioners, regulators, academics and in-house counsel from across the world to share experience and propose new approaches.

We are grateful to all the authors who contributed to this volume, to the International Nuclear Law Association and to the Lower Silesian Institute for Energy Studies for their role in organising the Warsaw Congress, and to the Pomeranian University in Słupsk for its support in bringing this publication to print. We hope that the chapters collected here will prove a useful resource for all those engaged in the legal and regulatory dimension of the global nuclear new build effort.

We would also like to thank the Państwowa Agencja Atomistyki (National Atomic Energy Agency of the Republic of Poland) for its active substantive support in connection with the Congress.

Prof. Piotr Frąckiewicz
Vice-Rector,
Pomeranian University
in Słupsk

Łukasz Młynarkiewicz, PhD
President of INLA (2023–2024)
Assistant Professor,
Head of the Department of Nuclear
Energy Law,
Institute of Law and Administration,
Pomeranian University in Słupsk

PART I

NUCLEAR NEW BUILD: CONTRACTING, MARKET DESIGN AND BUSINESS MODELS

Chapter 1

CONTRACTING FOR NUCLEAR POWER PLANTS – CENTRAL EUROPE PERSPECTIVE[1]

Tomasz Darowski
Partner, DZP
Tomasz.Darowski@dzp.pl

Kamil Pociecha
LL.M., Senior Associate, DZP
Kamil.Pociecha@dzp.pl

Abstract

This article examines the challenges in selecting a model for contracting, remuneration and change management in large nuclear power plant (NPP) projects in Central Europe from the perspective of certainty of delivery dates and budgets. It highlights the inevitability of changes to projects due to factors such as dependency between work packages, legislative changes, force majeure events and market fluctuations. Contractual mechanisms and project management methods traditional in the Central European region, which are often influenced by public procurement regulations, are proving insufficient to meet these challenges, even in far less complex projects.

The article also highlights alternative contracting models, including island, EPCM and target price contracts, as well as the early involvement

[1] The paper was created in October 2024, the content contained therein corresponds to the state of research/thoughts to date.

of all project participants, as potential solutions. Although these models offer benefits, their implementation can be complex and may face challenges at certain levels, especially in embarking countries that are just acquiring the necessary competences.

The authors advocate a more flexible approach than has been used in the region to date. This flexible approach could involve a lump-sum EPC/turnkey contract with robust and viable mechanisms for pricing changes and the ability to do so without formal addenda and excessive corporate governance constraints.

It is ultimately concluded in the article that effective change management in Central European NPP projects requires a move away from traditional practices and the adoption of more flexible models for setting remuneration and completion dates. By carefully considering the specific challenges and opportunities presented by the region, approaches can be developed that can increase project success and mitigate risk.

Introduction

Change is an unavoidable aspect of large projects, especially those involving the construction of NPP. The construction of NPPs is notoriously prone to delays and cost overruns. The complexity of these projects, combined with stringent safety regulations, often leads to unforeseen challenges that can disrupt schedules and inflate budgets. Additionally, long lead times for components and the need to obtain extensive regulatory approvals can lead to delays and cost increases. A well-planned project, including a contracting strategy, as well as effective management and well-prepared documentation (including properly structured contracts) are essential to mitigate the risks associated with changes during NPP construction. By putting in place mechanisms to facilitate adaptation to new conditions, such as flexible change order processes, contingency planning and dispute resolution procedures, project teams can increase their ability to respond to challenges and reduce disruptions to schedules and budgets.

Characteristics of NPP projects – is change certain?

The construction of an NPP is a complex and capital-intensive undertaking that, despite having many common features, nevertheless differs in numerous aspects from other large-scale infrastructure projects.

In NPP construction projects, safety is key and it is rightly understood that it should be a higher priority than costs and schedule.[2] The lengthy certification process must ensure that each component meets the highest safety requirements, i.e. so-called nuclear grade. NPP construction projects are also characterised by a specific cost structure due, among other things, to multi-phase and multi-level supervision and coordination, which, combined with a relatively long implementation period, also makes them vulnerable to changes in the market environment, especially in emerging economies, where labour costs are rising as the wealth of the population increases. Another feature of this type of project is the practical impossibility of changing the contractor during project performance, especially where NPPs are constructed in the form of EPC turnkey projects, as the design solutions are tied to the licences of a specific technology supplier and completing the project in its current form without working with the previous supplier seems impossible. This means that, in many cases, it is the contractor that has the negotiating advantage during the project implementation.

The characteristics indicated lead to NPP projects being more vulnerable to the need for significant changes during implementation. In other words, these projects are especially prone to delays and cost overruns. A number of factors therefore contribute to these challenges, including:

(a) Technical and engineering complexity – a many-piece jigsaw
One of the main challenges in building NPPs is the complexity of the engineering work. The implementation of advanced safety features or innovative technologies means that the creation of design documentation may necessitate extensive testing and development work. Sourcing specialist equipment and materials can also be time-consuming and susceptible to supply chain disruption. These issues are most apparent in the first units built in

[2] International Atomic Energy Agency (IAEA), *Project management in nuclear power plant construction: guidelines and experience*, Vienna: IAEA 2012, p. 78.

a new location and with new technology, i.e. in the case of first-of-a-kind (FOAK) units.[3] At the same time, the different scopes of work have to interact and therefore, during the course of the project, coordination issues arise, which, depending on the NPP contracting strategy, may fall on the contractor (EPC) or the owner (Island or EPCM). Problems with the interface of the scopes carried out by different parties can be one of the main sources of budget overruns and delays (lesson learnt from the Mochovce NPP project in Slovakia).

(b) Licensing and regulatory obstacles
Changing safety regulations and standards and licensing requirements may require changes to be made to the project, leading to delays and additional costs. During a multi-year project, new local law standards and rules may also arise that will have to be taken into account before the NPP is completed. Previous nuclear accidents, e.g. at Chernobyl and more recently at Fukushima, have heightened public concern about nuclear safety and increased regulatory scrutiny, which has had an impact on projects in progress. In addition, obtaining regulatory approvals, including environmental impact assessments and safety reviews, is a lengthy and bureaucratic process. Opposition from the public and local communities can further delay or even halt construction.

(c) Challenges/problems related to construction management
Managing large-scale nuclear projects requires specialist knowledge and efficient coordination between the various parties involved. The quality of both the contractor's and the owner's staff is crucial to the success of the project. With inexperienced staff, the decision-making process can be significantly prolonged and key decisions may turn out to be wrong, if they are made at all.

(d) Force majeure and other events beyond the parties' control
Force majeure and other events beyond the parties' control, e.g. wars, epidemics, labour strikes, supply constraints, breakdowns or delayed equipment deliveries, may disrupt the construction schedule, leading to delays and higher costs. The best examples are the global COVID-19 pandemic and the Russian aggression

[3] Nuclear Energy Agency (NEA), *Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders*, NEA No 7530, Paris: OECD 2020, p. 15.

in Ukraine, and their impact on major projects carried out in Central Europe. Disruption of the supply chain of individual components can have a knock-on effect on the supply chain and consequently on the critical path of the entire project. COVID-19, in particular, hampered the movement of personnel, the Russian–Ukrainian war has reduced labour force resources in the region and the sanctions imposed have necessitated a reorganisation of the supply system in some projects.

(e) Economic factors
The economic factors involved in building an NPP can be significant. Changes in material prices, labour costs and interest rates can affect the overall project budget. Economic downturns or lack of investment capital can also lead to project delays or cancellations. In the case of developing countries, increases in labour costs can be particularly significant and acute for an NPP project budget, especially given the project cost structure (in terms of NPP EPC cost breakdown estimates, labour costs can represent 40% of direct costs and up to 80% of indirect costs).[4]

Addressing these factors requires careful planning, risk management and effective communication between all the parties involved, as well as appropriate and efficient contractual mechanisms that allow changes to be made while avoiding disputes and protracted negotiations.

Contracting models and managing change in large infrastructure projects in Central Europe

Contracting and project management practices in Central Europe are often influenced by the Public Procurement Law (PPL), which poses challenges in managing changes that occur during the project lifecycle.

Features of project management that are key and specific to Central Europe are:

(a) Formalised procedures
Contracts rarely contain change mechanisms that apply automatically. Even adjustment clauses, despite them splitting the risk of an increase in cost drivers between the owner and the contractor,

[4] Ibid., p. 38.

still limit the scale of the increase in remuneration with a built-in (and often quite low) limit. In many projects, especially those implemented under public contracts, any change to the contract requires a formal amendment to the contract by means of an annex, which is usually a time-consuming and bureaucratic process, especially in entities handling public funds.

Even contracts based on international models are modified in a way that prevents the smooth application of the adaptation mechanisms functioning therein, and external entities, e.g. the Engineer appearing in FIDIC conditions of contract, are in practice deprived of the possibility to make independent decisions.

(b) Corporate culture
The introduction of changes often does not depend solely on the project team, but requires the participation of the management board and the relevant corporate approvals (e.g. of supervisory boards or even shareholder meetings). The interference of supervisory boards and general meetings in low-value transactions can hamper speedy decision making in state-owned companies.

(c) Influence of political factors
NPP projects tend to be of strategic importance and are heavily influenced by political factors that can determine how a project is implemented or whether it is abandoned, an example of which is the unfinished Polish NPP project in Żarnowiec.

(d) Dominance of lump sum contracts, lack of flexible change mechanisms and transparent risk allocation
The widespread use of lump-sum contracts may reduce flexibility in responding to changes, particularly in the absence of balanced change mechanisms and transparent risk allocation. Some countries, such as Poland, are only just gaining experience in managing large projects like NPPs. Hence the reluctance for the owner to assess and assume any risks, or to agree to amend the contract if risks materialise. This is the case even if the contractor was unable to foresee or calculate the risks before submitting its tender.

Of course, this necessitates the payment of an appropriate risk premium to EPC contractors, who in turn not infrequently pay a premium to their subcontractors and sub-suppliers, transferring part of the risk to them (the premium overlaps with the subsequent

premium). When forced into aggressive bidding by competition, contractors seek to improve contract profitability through various claims, including legal action to invoke statutory adaptation clauses, which can lead to increased contractual remuneration.

The main contracting model in energy and industrial projects in Central Europe usually comprises a lump-sum EPC/turnkey contract with renegotiation and indexation clauses (often capped by a limit) serving as a change mechanism. Although attempts have sometimes been made to improve this model by allowing owners to impose certain types of change and providing mechanisms for pricing and timing adjustments, the basic challenges remain the same.

Alternative models such as island contracting and EPCM are used less frequently in large infrastructure projects and are almost unheard of in the conventional energy sector.

Nevertheless, one example of EPCM contracting in Central Europe was NPP Mochovce in Slovakia, where a multi-contract strategy of more than 100 contracts was implemented to complete units 3 and 4. The owner engaged engineering, procurement, construction and commissioning service providers.[5] So, among other things, problems with the coordination of the various scopes followed by other unforeseen events, including COVID-19 and the Russian aggression in Ukraine, led to the project, which was supposed to have been completed in 2012–13, only now nearing completion. At the same time, the budget from the planned EUR 2.8 billion as at the end of 2020 was EUR 6.2 billion.[6]

Remuneration models other than lump sum or fixed rate, e.g. cost plus or target price, which are sometimes discussed as potential solutions, have not been adopted as leading solutions in the region. Only now are the first representatives of the construction industry starting to discuss the merits and feasibility of implementing early contractor involvement (ECI).

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[5] International Atomic Energy Agency (IAEA), *Project management in nuclear power plant…*, p. 116.

[6] C. Peachey, *New agreement provides more funding for Mohovce completion*, Nuclear Engineering International, https://www.neimagazine.com/news/new-agreement-provides-more-funding-for-mohovce-completion-8436428/ [access: 25 October 2024].

(e) Securing subcontractors and suppliers
Due to a number of problems and market abuses that have occurred in emerging markets, some jurisdictions have introduced joint and several liability of the owner for the contractor's liabilities to subcontractors and further subcontractors. The PPL regime has sometimes extended to suppliers in this respect. Moreover, in some countries in the region, for example Poland, contractors and subcontractors have the right to demand from the investor or general contractor a guarantee of payment for works, which usually takes the form of a bank or insurance guarantee.

(f) Lack of effective dispute management
There has been no proliferation of conciliation institutions (e.g. dispute avoidance and adjudication boards) during project implementation which would allow disputes and changes to be managed efficiently. The specific nature of complex construction cases requiring detailed expert analyses, combined with problems with the functioning of the ordinary court system, has led to litigation dragging on for years.

Impact of unique Central Europe characteristics on the implementation of NPP projects in embarking countries

There is a lack of human and specialist resources, and a specialised and proven supply chain, that would enable a project to be prepared and carried out on time and on budget.

Consequently, it seems unlikely that investors will opt to implement first projects using an Island or EPCM model, moving away from single point of responsibility. Of course, in subsequent projects, this type of approach should not be ruled out in advance.

The implementation of new NPP projects will build up supply chains and competences that meet the needs of the nuclear industry. However, the initial phases of a project could give rise to a number of problems, arising from existing practices and habits.

First of all, without a change in the approach of decision-makers and the introduction of well-thought-out and flexible change mechanisms allowing the scope and subject matter of contracts to be adapted to

emerging challenges that are unavoidable in projects such as NPP, they will be vulnerable to numerous obstacles.

The complex models for settling the remuneration of contractors and subcontractors also require adequate resources in the teams responsible for project implementation. Current staff could, and should, learn from specialists in countries that already have advanced investment, including nuclear, programmes.

Moreover, countries implementing nuclear power at home have the opportunity, at the threshold of such projects, to think through the inadequacies in the operation of other systems, including the legal environment and dispute resolution models, to ensure that the right conditions are in place.

If the provisions on the joint and several liability of up-tier entities within subcontracting and supply chains were to apply to NPP projects, the control of all levels of subcontracting and supply could present additional challenges in the management of a construction project on the scale of an NPP. However, there is no doubt that the objective of all parties involved should be that no reasonable participant in the project should suffer losses in connection with its implementation. What needs to be considered, however, is whether this objective should be achieved by these or similar legal regulations, or whether the issue should remain within the scope of contractual freedom.

Also, if the right of the contractor and subcontractors at all levels to demand payment of remuneration guarantees were to apply in NPP projects, in addition to the extra cost, this could lead to a significant strain on the insurance and banking sector.

In turn, unless appropriate dispute avoidance and resolution mechanisms are put in place, an investment on the scale of an NPP, coupled with accompanying infrastructure, could overstretch the judicial system, increasing the time taken to resolve disputes, and causing adjudications made years later to lose their economic sense.

Only a combination of the above factors creates a complex and challenging environment for NPP project delivery in Central Europe. Effective risk management strategies, including thorough due diligence, contingency planning and regular monitoring of the project environment, especially effective change management, are essential for successful project outcomes.

Conclusions

The traditional contracting model used in Central Europe based on soft renegotiation clauses will probably not be the most effective in managing the frequent and significant changes encountered in NPP projects. It could lead to lengthy negotiations and abuse of negotiating position.

Island and EPCM contracts, while offering potential benefits, can be complicated to implement and can face challenges in terms of accurate coordination of work and price changes, especially when dealing with interface issues, particularly in countries that are embarking on the nuclear power adventure.

A more promising approach is a lump sum EPC/turnkey contract, as long as it has a robust mechanism for pricing changes, flexibility to implement changes without formal annexes and an effective adjustment/indexation clause. This type of contract, if negotiated and executed outside the public procurement system, can provide greater flexibility and efficiency, and the right mix of staff and project structure will allow for efficient decision-making.

A solution that is tempting in theory is a contract with a target price, which can balance the interests of the client and the contractor and encourage efficient project delivery, including the exclusion in a natural manner of discussions on the pricing of changes (not necessarily their impact on the deadline). However, implementing this solution in the public procurement system may be challenging in some Central European jurisdictions, including Poland.

Other collaborative contracting approaches discussed and applied may prove all the more difficult to implement in a PPL regime and region-specific approach. These approaches, good in concept, are characterised by the assumption of cooperation in a 'no blame' and 'no claims' culture,[7] while entities spending public funds can be held accountable under other legal regulations.

In summary, successfully managing changes in Central European NPP projects requires a move away from traditional practices, overcoming

[7] International Atomic Energy Agency (IAEA), *Contracting and ownership approaches for new nuclear power plants*, Vienna: IAEA 2024, pp. 23–24.

the usual challenges in the region and adopting more flexible and adaptable contractual models. By carefully considering the specific challenges and opportunities presented by the region, an approach can be developed that can increase project success and mitigate risk.

Chapter 2

THE ROLE OF NUCLEAR POWER IN THE NEW EU ELECTRICITY MARKET DESIGN

Wojciech Wrochna
LL.M., Vice President of the Management Board
ORLEN Synthos Green Energy sp. z o. o.
Warsaw, Poland
w.wrochna@kochanski.pl

Bartosz Brzyski
Associate, Energy, Infrastructure & Environment Practice Group
Kochański & Partners
Warsaw, Poland
b.brzyski@kochanski.pl

Abstract

The European Union is setting itself increasingly ambitious targets for both moving away from fossil fuels and decarbonising the economy, with new investments in renewable energy sources and innovative low-carbon technologies being promoted. In this context, there has been heated public debate over the last few years as to whether nuclear power should also be a means of achieving the above targets. The latest position of the EU legislator makes it clear that nuclear energy is essential for the European economy. However, this raises a number of questions about how to align the characteristics of nuclear units (including their technical aspects) with the main assumptions of the EU electricity market reform. In this paper, the authors explain the main principles governing the EU

electricity market and highlight what difficulties they bring in the context of nuclear power. Moreover, they identify the main challenges for nuclear facilities in Europe in relation to new ways of contracting energy, new financial support schemes and the need to ensure flexibility in electricity supply and demand.

Introduction

Opening up and unifying the individual energy markets of each EU Member State has been a great achievement of the European Union. However, ensuring consistent policy mechanisms and balancing different concerns (such as ensuring the security of energy supply, affordable prices, etc.) is not a simple task. The authors of this article will thus focus on the issue of the contemporary electricity market design in the European Union and its impact on the development of new nuclear power plants, as the analysis of the regulation in place leads to justified concerns that the current market structure may not meet the needs of nuclear new build, thus potentially acting as a disincentive for new projects.

The relationship between nuclear energy and the European Union

From its inception, nuclear power was at the very heart of the European Union. After all, the very foundations of the EU we know today are based on two treaties from 1957 – the Treaty establishing the European Economic Community[1] (EEC) and the Treaty establishing the European Atomic Energy Community[2] (Euratom). Although at the time of their signature the latter received less attention—being considered by some as 'irrelevant'[3]—the Euratom Treaty created an organisation which

[1] Treaty establishing the European Economic Community (EEC Treaty), Rome, 25 March 1957.

[2] Treaty establishing the European Atomic Energy Community (EURATOM Treaty), Rome, 25 March 1957.

[3] D. Dinan, *Europe Recast: A History of European Union*, Boulder: Lynne Riener Publishers, Inc. 2014, p. 80.

continues to exist to this day. Moreover, its original tasks remain materially unchanged despite the passage of over 50 years – to contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries.[4]

The above introduction is intended to show that, despite the passage of time, changes in the geopolitical situation and developments in technology, nuclear power continues to be an important industry in the European market. In fact, recent years show that the demand for nuclear new build is rapidly increasing worldwide. In 2023 a political declaration was made of tripling global nuclear energy capacity by 2050.[5] From a European perspective, the motivation behind this aspiration is primarily fuelled by increasing pressure to reduce greenhouse gas emissions and combat climate change. It is also crucial in ensuring energy security, stabilising affordable energy supplies and making 'the Old Continent' less dependent on fossil fuels.

Although nuclear technologies appear to be the ideal means of achieving these goals, a number of significant hurdles must be cleared before their wider implementation in the EU market and wider commitment to selling nuclear generated electricity.

Harmonization of the electricity market in the European Union

The economy of the modern EU is generally based on the concept of the European single market. In principle, this is a market area that covers the territory of all 27 EU member states, as well as—with some exceptions—the territory of three additional European Economic Area (EEA) countries (Norway, Iceland and Liechtenstein[6]) and Switzerland.[7] The European single market is based on four fundamental freedoms:

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4 EURATOM Treaty, Article 1.

5 28th Conference of the Parties to the U. N. Framework Convention on Climate Change – Declaration to Triple Nuclear Energy, 2 December 2023, https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key [access: 17 October 2024].

6 Agreement on the European Economic Area, Porto, 2 May 1992, *OJ* L 1, 3.1.1994.

7 Relationship between the EU and Switzerland is based on the number of bilateral agreements, details available here: Switzerland's European Policy, https://www.

- the free transfer of goods,
- the free transfer of services,
- the free transfer of people, and
- the free transfer of capital.

In simplified terms, the main purpose of the above freedoms is to allow the free flow of their respective subjects between the participants of the European single market. With reference to energy, electricity trading is generally covered by the free transfer of goods,[8] which means that it is falls within the scope of the customs union established in the EU, which involves the prohibition between Member States of customs duties on imports and exports and of all charges having equivalent effect, along with the adoption of a common customs tariff in their relations with third countries.[9]

The removal of the above-mentioned barriers to trade was, however, only one of the elements necessary to promote cross-border energy trade in the European Union. From a historical perspective, the energy sector was primarily administered by state-owned companies, which meant that the energy markets of each EU Member State were relatively isolated from each other, both legally and technologically.[10] Therefore, acting in the spirit of 'an ever closer union among the peoples of Europe',[11] the attempt to integrate the individual national markets and create a single energy market was a natural next step in the development of the EU single market.

One of the first moves in this direction was initiated in 1996 by the adoption of Directive 96/92/EC concerning common rules for the internal market in electricity[12] (the so called 'First Energy Package'). In its text, it has been explicitly underlined that establishment of the internal market

eda.admin.ch/europa/en/home/bilateraler-weg/ueberblick.html [access: 17 October 2024].

[8] CJEU Judgment of 27 April 1994, C-393/92, *Municipality of Almelo and others v NV Energiebedrijf Ijsselmij*, ECLI:EU:C:1994:171; it is also indirectly confirmed in CJEU Judgment of 15 July 1964, C-6/64, *Flaminio Costa v E.N.E.L.*, ECLI:EU:C:1964:66.

[9] Consolidated version of the Treaty on the Functioning of the European Union (TFEU), *OJ* C 326, 26.10.2012, Article 28(1).

[10] A. Ispolinov, T. Dvenadtsatova, *The Creation of a Common EU Energy Market: a Quiet Revolution with Far-reaching Consequences*, "Baltic Region" 2013, No. 2(16), s. 80–81.

[11] Consolidated version of the Treaty on European Union (TEU), *OJ* C 202/1, 7.6.2016, Article 1(1), para 2.

[12] Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity.

in electricity is particularly important in order to increase efficiency in the production, transmission and distribution of this product, while reinforcing security of supply and the competitiveness of the European economy and respecting environmental protection.[13] Moreover, it was stated that an internal market in electricity needed to be established gradually, in order to enable the industry to adjust in a flexible and ordered manner to its new environment and to take account of the different ways in which electricity systems are organized,[14] whilst keeping in mind that this market must favour the interconnection and interoperability of systems.[15] In other words, the First Energy Package set the bar high in its aims to open up and unify the European electricity markets.

The process of creating a single electricity market has not stopped since then and has been subject to constant evolution. Over the following years four additional 'Energy Packages' were adopted, which gradually led to harmonised rules for electricity markets across Europe. A common supranational body (the European Union Agency for the Cooperation of Energy Regulators, ACER) was established in order to fill the regulatory gap at Community level and to contribute towards the effective functioning of the internal market in electricity.[16]

In fact, the issue of creating a single European-wide energy market was so important, that it was ultimately explicitly included in the Treaty on the Functioning of the European Union (TFEU – one of the two key legislative acts governing the European Union). In line with the changes introduced by the Lisbon Treaty, a new article has been added, which states that in the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim, in a spirit of solidarity between Member States, to:

a) ensure the functioning of the energy market;
b) ensure security of energy supply in the Union; and
c) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and

[13] Ibid., Preamble, para 4.

[14] Ibid., para 5.

[15] Ibid., para 6.

[16] Regulation (EC) No 713/2009 of the European Parliament and of the Council of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators (Text with EEA relevance), Preamble, para 5.

d) promote the interconnection of energy networks.[17]

Analysis of all of these legislative developments leads to the conclusion, that cooperation and unification of energy trade rules within the European Union will deepen. The level of harmonisation is currently high enough that, in principle, most of the key rules for the sale of electricity are based in European Union law, with which the national legal frameworks of each Member State should be consistent. This means that despite some of the legal differences that exist in each country with regard to the development of nuclear power plants, the operation of new nuclear units must be somehow framed within the rules governing the electricity market across the entire Europe (which also includes rules on competition).

Merit order and marginal pricing

In order to assess where nuclear power stands in the EU electricity sector, it is necessary to mention some basic principles that govern this market. Some of these rules are described in EU Regulation 2019/943 on the internal market for electricity (EMR).[18] In this context, it is especially worth recalling that:

a) prices shall be formed on the basis of demand and supply;[19]
b) market rules shall encourage free price formation and shall avoid actions which prevent price formation on the basis of demand and supply;[20]
c) market rules shall facilitate the development of more flexible generation, sustainable low carbon generation, and more flexible demand;[21]
d) market rules shall enable the decarbonisation of the electricity system and thus the economy, including by enabling the integration

[17] Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community, signed at Lisbon, 13 December 2007, Article 176A(1) (currently constituting Article 194 of the TFEU).

[18] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast) (EMR) (Text with EEA relevance).

[19] Ibid., Article 3(a).

[20] Ibid., Article 3(b).

[21] Ibid., Article 3(c).

of electricity from renewable energy sources and by providing incentives for energy efficiency;[22]

e) day-ahead and intraday markets shall be organised in such a way as to be non-discriminatory;[23]
f) similarly balancing markets, including prequalification processes, shall be organised in a non-discriminatory way,[24] respecting the need to accommodate the increasing share of variable generation, increased demand responsiveness and the advent of new technologies.[25]

Overall, the above assumptions can be summarised as indicating that the EU electricity market should be non-discriminatory, conducted on a competitive basis, with prices being formulated in a market-driven manner. The application of these rules implies that the market is virtually based on the merit order principle and marginal production cost comparison.

In simplified terms, according to the merit order mechanism, generator supply bids are listed according to their marginal production costs (i.e. costs required to produce an additional unit of electricity), where the cheapest bids are considered first and the most expensive bids last.[26] The productions costs are mostly calculated as the result of 3 factors:

a) costs of fuel used for energy generation – associated with the fuel commodity price,
b) carbon cost – which in the EU is related to purchasing emission allowances under EU Emissions Trading System (ETS),
c) variable operational and management costs – which reflects costs of the plants day-to-day operations, including labour and maintenance.[27]

With reference to the above, the marginal productions costs of electricity produced from fossil fuels (e.g. coal or natural gas) are typically

[22] Ibid., Article 3(f).
[23] Ibid., Article 7(2)(a).
[24] Ibid., Article 6(1)(a).
[25] Ibid., Article 6(1)(d).
[26] A. Gasparella, D. Koolen, and A. Zucker, *The Merit Order and Price-Setting Dynamics in European Electricity Markets, European Commission*, JRC134300, Petten: European Commission 2023, pp. 2–3.
[27] Ibid.

the highest, while the costs of renewable energy sources (e.g. solar, wind, hydro power) are the lowest. In terms of nuclear power, the marginal cost is primarily based on the price of uranium, which has been relatively low and very stable for some years.[28] Nevertheless, this factor will always make nuclear power slightly more expensive than renewable energy, which does not require purchasing fuels for its operation.[29]

After the list of bids of increasing marginal prices has been created, this is cross-referenced with actual market demand at a given time. The market-clearing price is established by the price of the last accepted bid covering the demand (the so called 'pay-as-cleared' mechanism) (see Figure 1 below).[30]

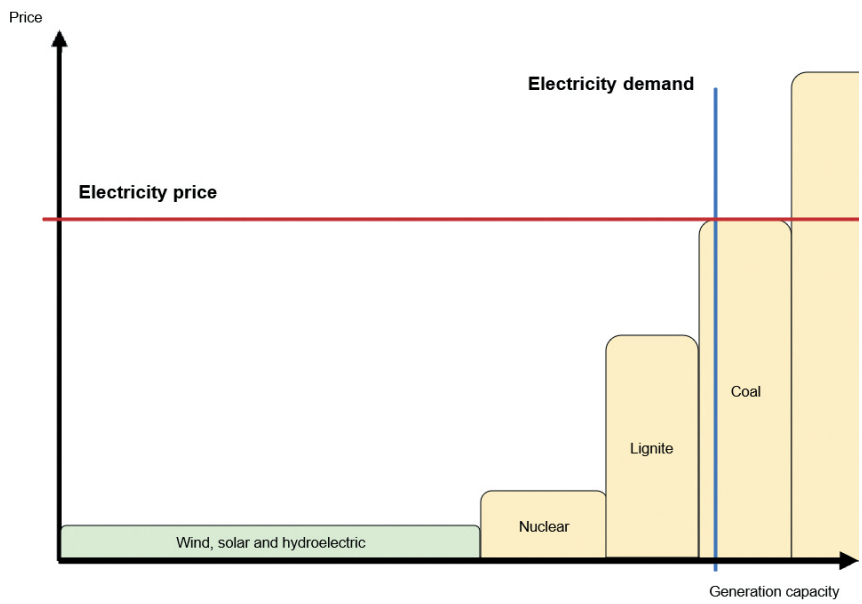

Figure 1. Visualisation of the merit order supply stack

Source: Elaboration based on Figure 2 – *Simplified merit order supply demand stack*, A. Gasparella, D. Koolen and A. Zucker, *The Merit Order and Price-Setting Dynamics…*, p. 3.

[28] Uranium Prices chart, Trading Economics, https://tradingeconomics.com/commodity/uranium [access: 24 September 2024].

[29] A. Gasparella, D. Koolen, and A. Zucker, *The Merit Order and Price-Setting Dynamics…*, p. 3.

[30] Ibid.

Place of nuclear in the electricity market design

In simple terms, the success of deployment of nuclear power plants in Europe is largely based on the ability to efficiently sell electricity at a price that allows the operator to recover its investment costs and generate profit. In this context it could be stated, that this goal may be achieved if the high capacity factor (CF) is reached by the nuclear power plant.

The capacity factor, can be defined as 'The actual energy output of an electricity-generating device divided by the energy output that would be produced if it operated at its rated power output (Reference Unit Power) for the entire year. Generally expressed as percentage.'[31] A high capacity factor is crucial to the success of a nuclear power plant because it significantly improves its economics.[32] In light of this definition, any event that causes a reduction in the energy production capacity (e.g. refuelling, emergency shutdown etc.) will result in a reduction of capacity factor. Ensuring a high CF helps ensure steady energy sales (and thus steady revenues) and allows optimal management of resources, reducing variable costs and offering the best electricity price.[33] Since the energy produced by nuclear fission is, in principle, produced in a constant manner (and requires interruptions only due to the need for refuelling), the fundamental need to achieve high CF is the prerequisite to allow nuclear energy to be sold on the market, and to allow it to be sold at a sufficient price.

However, mechanisms in place in the EU electricity market may potentially impact the possibility to secure a high capacity factor for nuclear power facilities. This is related to the principles governing electricity dispatching and redispatching according to the EMR. For the purpose of this paper, power 'dispatching' can be defined as a decision-making

[31] Glossary of Terms in PRIS Reports, Power Reactor Information System (PRIS), IAEA, https://pris.iaea.org/PRIS/Glossary.aspx [access: 25 September 2024].

[32] B. Mignacca, G. Locatelli, *Economics and Finance of Small Modular Reactors: A Systematic Review and Research Agenda*, "Renewable and Sustainable Energy Reviews" 2020, Vol. 118, p. 8.

[33] Cf. A. Veenstra, X. Li, M. Mulder, *Economic Value of Nuclear Power in Future Energy Systems Required Subsidy in Various Scenarios Regarding Future Renewable Generation and Electricity Demand*, CEER – Policy Papers, no. 12, April 2022, pp. 40–41.

process associated with scheduling the power generation in a way that will ensure inter alia the security of the power grid, low prices and demand coverage.[34] The EMR itself does not define 'dispatch' however, based on the definition of 'priority dispatch' it can be inferred that 'normal' dispatching refers to scheduling energy generation on the basis of the economic order of bids and (depending on the dispatching model) from network constraints, giving priority to the dispatch of particular generation technologies.[35] On the other hand, the term 'redispatching' has been defined in the EMR and means 'a measure, including curtailment, that is activated by one or more transmission system operators or distribution system operators by altering the generation, load pattern, or both, in order to change physical flows in the electricity system and relieve a physical congestion or otherwise ensure system security'.[36]

The dispatching of power-generating facilities in the EU electricity market shall be non-discriminatory, transparent and (subject to few exceptions) market based.[37] This means that it could be very difficult to justify the priority dispatch of electricity from a nuclear power plant to the power grid unless it is based on purely economic criteria.

The same applies to the 'redispatching' mechanism which shall be non-discriminatory, open to all generation technologies and be generally market-based.[38] However, despite the above, the legislation also grants a more preferential status for certain generation sources. For example, power-generating facilities using renewable energy sources shall only be subject to downward redispatching if no other alternative exists or if other solutions would result in significantly disproportionate costs or severe risks to network security.[39] The exception is also provided for the electricity generated in a high-efficiency cogeneration process.[40] Unfortunately there is no such exception provided for nuclear power. This means that if there is a need to use redispatching in order to ensure the security of the electricity system (e.g. against a blackout), the curtailed

[34] Z. Yang, P. Yong, M. Xiang, *Revisit Power System Dispatch: Concepts, Models, and Solutions*, "iEnergy" 2023, Vol. 2, No. 1, p. 43.
[35] EMR, Article 2(20).
[36] Ibid., Article 2(26).
[37] Ibid., Article 12(1).
[38] Ibid., Article 13(1) and 13(2).
[39] Ibid., Article 13(6)(a).
[40] Ibid., Article 13(6)(b).

power generation will likely affect nuclear units first, while renewables and high-efficiency cogeneration sources will be affected later. It should also be noted that the increasing deployment of renewable energy sources is likely to increase the frequency of redispatching. Most common threats to the electricity system (in particular the injection of too much energy in relation to the capacity of the electricity grid) are currently the result of the variable operation of renewable sources, which generate excessive amounts of energy at certain times of the day and cause shortfalls at others.

Since ensuring priority dispatching or providing protection against unplanned redispatching seems difficult in the current legal framework, nuclear power plants may be legally compelled to operate in the load-following mode (flexible operation). This means 'varying the output of a generating unit in a planned way, or in response to an instruction or control signal from the grid control centre, reducing the output when the load (electrical demand) on the system is reduced (e.g. during the night, at weekends and on public holidays) and increasing the output to maximum when the electrical demand is high'.[41] As a rule, load-following implies lower capacity factors for nuclear plants.[42] This is in contrast to the baseload operation model, which means 'operation of a power station or generating unit at steady full load as far as possible, and not load following or providing automatic frequency control'.[43] In other words, in baseload operation mode, reduction in power output is induced by the plant operator's needs, rather than the grid system operator's needs.[44]

The choice of a load-following or a baseload model has also direct implications on the technical and operational aspects of the plant. Most notably it can be stated that:

a) baseload operation may lead to more efficient utilization of nuclear fuel as the thermal output during a fuel cycle is more predictable, and core design is optimized;

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[41] IAEA, *Non-baseload Operation in Nuclear Power Plants: Load Following and Frequency Control Modes of Flexible Operation*, Glossary, IAEA Nuclear Energy Series, No. NP-T-3.23, Vienna: IAEA 2018, p. 166.

[42] R. Loisel et al., *Load-following with nuclear power: Market effects and welfare implications*, "Progress in Nuclear Energy" 2018, No. 109, p. 1.

[43] IAEA, *Non-baseload Operation in Nuclear Power Plants…*, p. 165.

[44] Ibid., p. 4.

b) design and licensing of plants are simpler for operation at constant load, as degradation in design and safety margins as plants age vary more predictably and can be better anticipated during design;
c) non-baseload operation may require increased monitoring and maintenance, and may complicate the reliability and ageing assessments of some systems, structures and components.[45]

The literature points out that in general, capital intensive technologies (such as e.g. nuclear power plants) prove viable if their load factors are higher than 90% in order to recover their high capital cost.[46] Naturally this suggests that nuclear power plants should primarily operate in a baseload mode. This is also achievable in a load-following system, but depends very much on the characteristics of the specific electricity system and availability of other energy sources that could provide required flexibility instead of nuclear. In fact, as indicated in research, in simulations prepared for 2050, only two European regions (Central-Western Europe and Northern Europe) noted NPP operator gains from load-following operation in comparison to baseload operation. In the remaining three regions (Central-Eastern, South-Western and Western Europe) NPP operators would record loses from operating flexibly.[47] This raises a justified concern whether new nuclear power plants would be capable of generating enough profit to recover its investment costs, if their capacity factor is regularly lowered due to the non-market-based redispatching.

Last but not least, in parallel to the legislation in place that seems to promote the load-following mode, the very design of the EU electricity market carries risk for nuclear power in the long term. The European Union is currently focused on achieving its very ambitious goals related to climate neutrality. In fact, it has set itself a binding climate target of a domestic reduction of net greenhouse gas emissions by at least 55% compared to 1990 levels by 2030.[48] Further efforts to reduce emissions in the energy sector can therefore be expected. The current target is that EU

[45] Ibid., p. 6.
[46] R. Loisel et al., *Load-following with nuclear power…*, p. 12.
[47] Ibid., pp. 15–19.
[48] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ("European Climate Law"), Article 4(1).

Member States shall collectively ensure that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 42.5%.[49]

As mentioned above, an EU electricity market generally operates on the basis of a merit order mechanism. If there would be an increase in the capacity of renewable energy sources, it is hypothetically possible that at some periods of time (e.g. on sunny or windy days) the bids related to renewable energy may cover full market demand. This could push nuclear energy further within the merit order mechanism, setting the market-clearing price below the marginal costs of nuclear power (thus potentially not allowing for the effective recovery of investment costs). The visualisation of this scenario is presented in Figure 2 below.

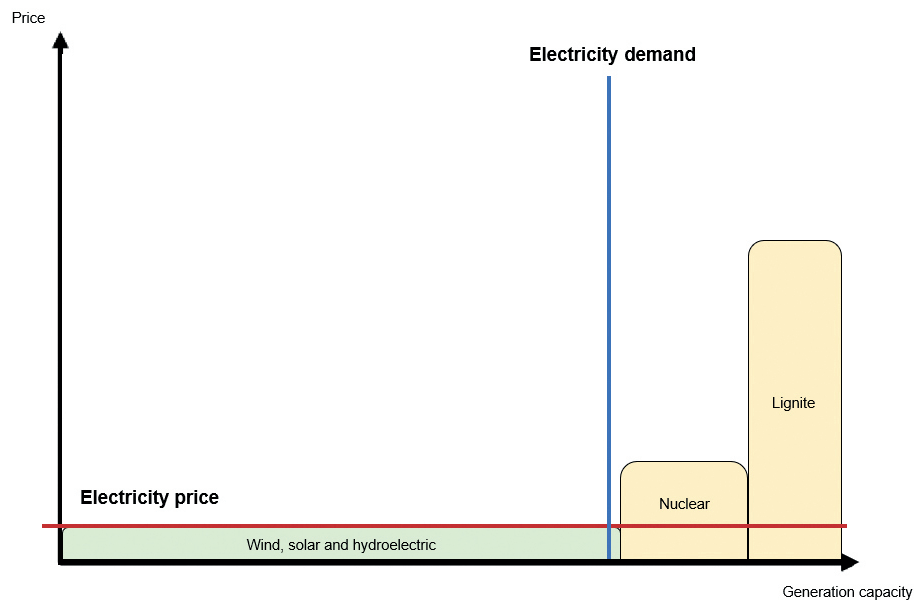

Figure 2. Potential consequences of increasing renewables in the merit order mechanism

Source: Own elaboration.

[49] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, Article 3(1).

State aid and support schemes

Since nuclear energy is naturally less competitive than renewables according to the merit order mechanism, and there is a risk that it can be subject to increasingly frequent redispatching, the question arises of how energy can be sold on the EU electricity market to keep new nuclear power plants profitable and to recover funds invested in their construction. The answer may lie in the implementation of an appropriate public support scheme that could allow nuclear power plants to achieve their primary business objectives, i.e. generating stable revenues.

In addition to the business side of developing a suitable model for state co-financing of energy sales, it is also necessary to pay attention to legal aspects related to this issue in the EU. According to the TFEU, save as otherwise provided in the Treaties, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market.[50] This means that any EU Member State interested in developing nuclear power in its territory is prohibited from freely subsidizing the execution or operation of the nuclear project, if such actions may pose competition concerns.

In practice, introduction of a public financial support scheme in the EU requires prior notification to the European Commission. The Commission then proceeds to verify the notification, and decides whether the notified measure can be considered a state aid, and if yes – whether it is permissible according to EU competition rules.[51] What is also important, is that the Commission is entitled to attach to a positive decision conditions subject to which aid may be considered compatible with the internal market.[52]

Assessing whether a particular support scheme will constitute permissible or impermissible state aid is always a complex and delicate task.

[50] TFEU, Article 107(1).

[51] Council Regulation (EU) 2015/1589 of 13 July 2015 laying down detailed rules for the application of Article 108 of the Treaty on the Functioning of the European Union, *OJ* L 248, 24.9.2015.

[52] Regulation 2015/1589, Article 9(4).

However, the current electricity market design provides for certain hints on which forms of public support are likely to be considered acceptable. In 2024 a major EU electricity market reform took place. The amendments introduced took the form of a regulation[53] and a directive.[54] The main reason to implement new legal measures was to overcome the challenges associated with very high energy prices and volatility in electricity markets which have been observed since 2021.[55]

One of the major changes is the introduction of a new set of regulations established to promote the uptake of power purchase agreements (PPAs)[56] – long term contracts ensuring the sale of energy at a specific price. Moreover, it is assumed that investments in new power-generating facilities based on solar, wind, geothermal, hydropower (however without reservoirs) and nuclear energy will be based on support in the form of two-way contracts for difference (CfDs) or equivalent schemes with the same effects.[57] According to the European Commission a

> two-way contract for difference is a contract signed between an electricity generator and a public entity, typically the State, which sets a strike price, usually by a competitive tender. The generator sells the electricity in the market but then settles with the public entity the difference between the market price and the strike price. It thus allows the generator to receive a stable revenue for the electricity it produces, while at the same time it provides a revenue limitation for generators when market prices are high. In a two-way CfD, if the market price is below the strike price, the generator receives the difference; if the market price is above the strike price, the generator pays back the difference.[58]

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[53] Directive (EU) 2024/1711 of the European Parliament and of the Council of 13 June 2024 amending Directives (EU) 2018/2001 and (EU) 2019/944 as regards improving the Union's electricity market design.

[54] Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design.

[55] Regulation 2024/1747, Preamble, para 1.

[56] Regulation 2019/943, Article 19a.

[57] Ibid., Article 19d.

[58] European Commission, Questions and Answers on the revision of the EU's internal electricity market design, https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_1593 [access: 17 October 2024].

The principle of the two-way CfD mechanism is presented in the Figure 3 below.

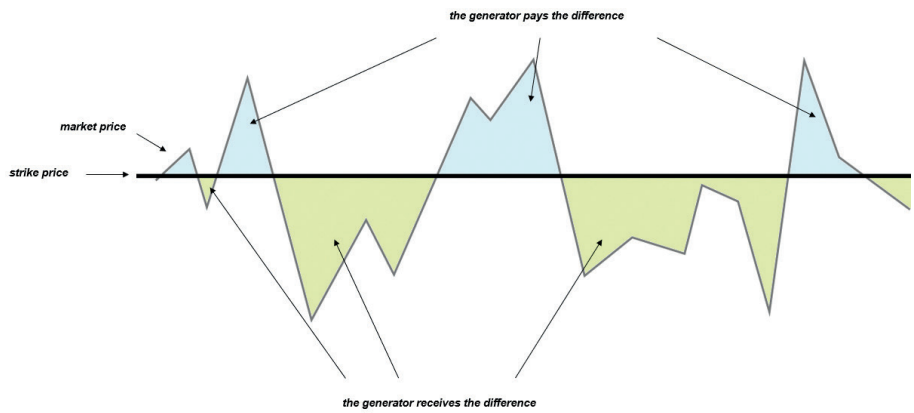

Figure 3. Visualisation of the principles of the two-way CfD contract

Source: Own elaboration based on visualisations made by the European Council and the Council of the European Union, https://www.consilium.europa.eu/en/policies/electricity-market-reform/#0 [access: 17 October 2024].

At a glance, the two-way CfD seems to be a fair solution that protects both the operator of the energy-generation plant and end-users from excessive risks related to price fluctuations. However, in relation to nuclear power, the above model seems not to be fully adapted to the needs of nuclear power plant projects. First and foremost, unlike renewables, nuclear power projects require high initial construction costs, and the construction process itself spans many years. Based on the CfD model, construction costs incurred can be recovered only after the facility is commissioned and has started actual energy sales. This means that prior to that point, it is the nuclear power plant investor who bears most of the financial risk, a fact which can act as a disincentive for new investments. The same comments can be made with regard to the PPA model, where it is possible to secure the stable amount of revenues, but only after the plant begins operations. Moreover, CfDs typically suffer from a general lack of flexibility and are difficult to adapt to the changing market conditions.[59]

[59] A. Ason, J. D. Poz, *Contracts for Difference: the Instrument of Choice for the Energy Transition*, April 2024, OIES Paper: ET34, p. 7.

In summary, the legally promoted financial support schemes may not be sufficient to back up nuclear energy needs in the EU electricity market. At the same time, proposing 'an equivalent scheme with the same effects'[60] as the two-way CfD may present an evidentiary challenge, that will involve heated discussions on design of the scheme as part of the state aid notification procedures in front of the European Commission. This raises concerns as to whether it would be possible to introduce any reasonable alternative, such as for example the Regulated Asset Base (RAB) model.[61]

Conclusions and final thoughts

Legislators in the European Union currently face the extremely difficult task of balancing many different considerations relating to the electricity market. They have to ensure the security of supply,[62] fair competition, affordable energy prices for end users and all while achieving climate targets. In this regard, nuclear power is considered a very stable, zero-emission source of energy, also providing some of the lowest energy prices. Renewable energy sources theoretically could provide even lower energy prices (if based on marginal production costs), however suffer from extreme volatility in production, thus not achieving security of supply.

The current EU electricity market design is evidently focused on relying on market-based mechanisms related to marginal production costs of energy. As such, this promotes the generation of energy from renewable sources, while not addressing the unique needs of nuclear projects throughout their entire development cycle (which is significantly different than for renewables). Without the inclusion of additional protection mechanisms, e.g. from excessive redispatching, nuclear power may prove to be uncompetitive or even uneconomic on the European electricity market.

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60 Regulation 2019/943, Article 19d.

61 Nuclear Regulated Asset Base (RAB) model, Ofgem, https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/nuclear-regulated-asset-base-rab-model [access: 17 October 2024].

62 TFEU, Article 122.

It should be recalled once again that ambitious climate targets are forcing a gradual shift away from the use of fossil fuels in the European energy sector. This means that it is more important than ever to focus on assuring the security of supply. In this field, renewables will be unable to match nuclear power for many more years to come. At the same time, public energy consumption needs are growing now, right before our eyes. If the EU wishes to keep reducing greenhouse gas emissions while ensuring energy security, a greater focus on promoting nuclear power generation would seem to be an obvious solution. If nuclear new build is to take place in Europe, investment incentives must be provided, starting with guaranteeing the sale of energy at appropriate prices and providing support in the early stages of project development. Moreover, the current electricity market design, due to its generally unified approach to all Member States, does not take into account differences in the characteristics of various electricity systems, subliminally emphasising the need to ensure the load-following characteristics of nuclear power plants. From a business perspective this may not be the best mode of operation for countries, which require baseload demand coverage. Ultimately it can lead to both revenue disruption on the part of the nuclear power plant operator and price increases on the part of the general public. All of the above highlight the need to further adapt the principles governing the EU electricity market and explore new options of state aid support schemes for nuclear.

PART II

SMALL MODULAR REACTORS (SMRs): LEGAL AND REGULATORY CHALLENGES

Chapter 3

LEGAL BARRIERS TO THE DEPLOYMENT OF SMR AND ANT REACTORS IN THE EUROPEAN UNION. IS THE EURATOM TREATY SUFFICIENT?

Przemysław Gorzkowski
Attorney-at-law, Chief Legal Officer, Nuclear PL sp. z o.o.
Warsaw, Poland
przemyslaw.gorzkowski@nuclear.pl

Abstract

A rash of news about planned SMR and ANT projects is being observed around the world. More stakeholders are announcing plans, often very ambitious, to build nuclear power plants of this type. At the same time, so far not only has no commercial SMR and ANT reactor been built, but no construction work has even begun, and no technology supplier has passed a full certification process in any jurisdiction. This creates a major challenge and development roadblock. Reasons for this include:

- a rigid legal framework for the certification and construction of all nuclear technologies,
- lack of a common or uniform system of certification or any formal mutual recognition of issued certifications.

These legal problems are additionally exacerbated by major shortage of actual technical experience in the construction of such units, as well as currently observed shortage of experts able to support suppliers and contractors in the process of implementing the project into reality.

What is particularly important, despite the increasingly progressive harmonization of intra-Community regulations, as well as despite the obligation of the Community stated in the EURATOM Treaty to 'create the conditions necessary for the speedy establishment and growth of the nuclear industries'[1] there are little tangible steps towards harmonization of EU regulations on the implementation of ANT nuclear facilities.

The purpose of this research is to specify what are the main reasons for this and what measures can be taken to mitigate risks associated with the remaining obstacles for development of standardised nuclear plants. Within this document the following shall be briefly analysed: certification process for nuclear technology in Poland, main bottlenecks and roadblocks, EURATOM/EU initiatives undertaken so far to mitigate it, how similar problems were resolved (or not) in aviation and railway sector, possible solutions.

The key finding is that some parts in the licensing process shall be standardised at EEU level and the European Commission within EURATOM may play a key role in that.

Introduction

As the climate crisis looms, nuclear technologies are increasingly seen as one of important, if not necessary, instruments of decarbonisation in the world. This includes areas such as Western Europe or the United States, where for many years interest in new deployments of nuclear power was very limited. Limited new deployments over last decades, however, have seen a lot of challenges. Multiple announced projects—some of them even licenced—were abandoned for variety of reasons. Those few, which actually progressed into construction phase, encountered multiple difficulties across all stages of their lifetime, from licencing, to construction, to commissioning, greatly exceeding both anticipated budgets and planned schedules.

It is unlikely that all the problems encountered can be resolved easily by simple decisions or design features, however reduced scale and

[1] Preamble of the Treaty Establishing the European Atomic Energy Community, Consolidated Version of the Treaty Establishing the European Atomic Energy Community, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2016:203:FULL [access: 23 March 2026].

improved standardisation of new nuclear technologies—especially those labelled as Small Modular Reactors (SMRs) or Advanced Nuclear Technologies (ANTs)—might help in overcoming considerable portion. Some challenges, especially regarding public acceptance, may also be reduced by introduction of some 'advanced' technologies providing better efficiency, reduced waste generation and other process-related benefits. Nevertheless, even though features of new technical solutions seem promising as such, any real benefits will only be experienced, if those solutions can be deployed rapidly and in considerable amounts. That will require construction of multiple new plants in quick succession or even in parallel. In order to reduce burden on single investors and countries, and accelerate maturation of new solutions, such projects should appear in many countries. But any attempt to deploy new nuclear reactor designs in multiple countries will inevitably face the problem of separate jurisdictions. Even though the general principles of nuclear safety do not differ between countries as such, actual legal interpretation of those principles and related procedures may differ considerably. The processes are also quite disjointed, requiring any vendor willing to deploy their new design in several countries to repeat the same kind of work in several 'versions'. While this is certainly not the only barrier in development of new nuclear projects, it is surely one which can pose a great challenge already at an early stage of a technology's lifetime, possibly even preventing successful deployment of new designs.

Current status

In the second and beginning of the third decade of the 21st century, the world witnessed a significant retreat from nuclear power with fewer and fewer projects being planned and implemented. However, the market abhors a vacuum and new ideas emerged for the presentation and use of nuclear power in the world. Small nuclear reactors (SMRs) and fourth-generation reactors, the so-called advanced nuclear technologies (ANTs), were advertised as a remedy for existing problems and people's fears about nuclear power. ANT and SMR are presented as those that allow for the highest safety standards while being able to be deployed much faster and cheaper than large Generation III and III+ reactors. In the media releases that appear, one can observe announcements of even

several times shorter implementation times for such technologies, and, in terms of construction costs, lower prices to a fraction of the cost of building large nuclear units.

Despite these announcements, to date no nuclear power plant based on SMR or ANT has been built in Europe.[2] The announced projects are at various stages of the licensing phase and some have been abandoned at a relatively early stage. Any construction work, and only preliminary, is being carried out by Ontario Power Generation in Darlington, Canada, where a nuclear power plant based on GE Hitachi's SMR, the BWRX-300, is planned. Despite the hype, the rapid deployment of SMRs and ANTs is not as noticeable as could be expected from the numerous announcements. It is therefore important to ask the question why this is happening.

An analysis of this issue, based on the Polish market, indicates that there are several categories of problems that prevent rapid implementation of SMR/ANT projects. Among these, one can point to:

- rigid legal framework for certification and construction of all nuclear technologies. In fact, the law does not, as a rule, differentiate requirements based on the size of the reactor or the technology on which it is based;
- high requirements and time-consuming certification procedures that are not differentiated according to the size of the project or the technology used;
- lack of a generic design assessment procedures, as introduced by several countries (notably USA and UK), which could facilitate fleet deployments, supposed to be a highlight of ANT and/or SMR technologies;
- the lack of a common or uniform certification system or formal recognition of issued certificates between different countries, resulting in the need to license the adopted solutions separately in each market where they are to be applied;
- different approach to verification of compliance of both design and actual works between national regulators;[3]

[2] One might argue that certain prototypes from 1970s, 80s and 90s, such as THTR-300 of West Germany or Superphénix of France were, in fact, representatives of ANTs, however these were build in the days of totally different legal framework and are not considered here.

[3] A problem that has already manifested itself in case of traditional nuclear technologies at Olkiluoto-3 project, where French supplier, despite its vast experienced,

- different construction requirements in different countries, which makes it difficult to design standardised buildings, which—on the other hand—in many advanced designs form an integral functional part of safety systems;
- difficulties in demonstrating the credibility of projects due to complex and lengthy licensing procedures, which in turn translates into difficulty for the investor to make a final investment decision.

To be able to analyse the problem, it is necessary to look at the licensing process of nuclear power plants in Poland.

Licensing process in Poland

The process of obtaining required permits, approvals and licences for constructing a nuclear power station is quite extensive and complex, and often causes confusion among entities considering their first nuclear project. Such process cover all type of nuclear reactors to be commercially used, not dividing them in the manner of size, power, technology etc. A diagram shown in Figure 1 presents, in a simplified way, the processes which the stakeholders need to complete in order to obtain the final Building Permit – last formal document before actual power station construction can be started.

The formal permitting and licencing process is started by obtaining a Decision-in-Principle. Then the investor develops a Project Brief and submits it to GDEP, whereupon GDEP issues a decision which identifies an obligation to assess the environmental impact of the project which may have a significant environmental impact, and on the scope of such assessment. At the same time, GDEP launches the transboundary procedure. Once the scope is set, the investor carries out its environmental survey (possibly together with the site evaluation for the 'nuclear licencing needs', as combining the two may lead to lower cost of contracting such surveys; the site evaluation may also be started somewhat later). If performing surveys requires access to a property not owned by the investor, and the owner denies access, the investor may apply for an optional Preliminary Site Decision authorising such access regardless of the

proved unprepared to work according to principles set out by STUK, the Finnish regulator.

opinion of the site owner. Once the environmental survey is completed, and EIA Report compiled, the report is submitted to the GDEP, which reviews it and issues the Environmental Decision. Thereafter, the investor may apply for the Final Site Decision, which enables land use by the investor. In parallel the investor may conduct engineering activities and development of a PSAR. Once PSAR and Site Evaluation Report are completed and reviewed by the PAA, a Construction License may be obtained from the regulator, followed by the Building Permit issued by a non-nuclear authority. This last document authorises the investor to start construction (certain limited preparatory activities may be conducted earlier, as discussed further in this Report).

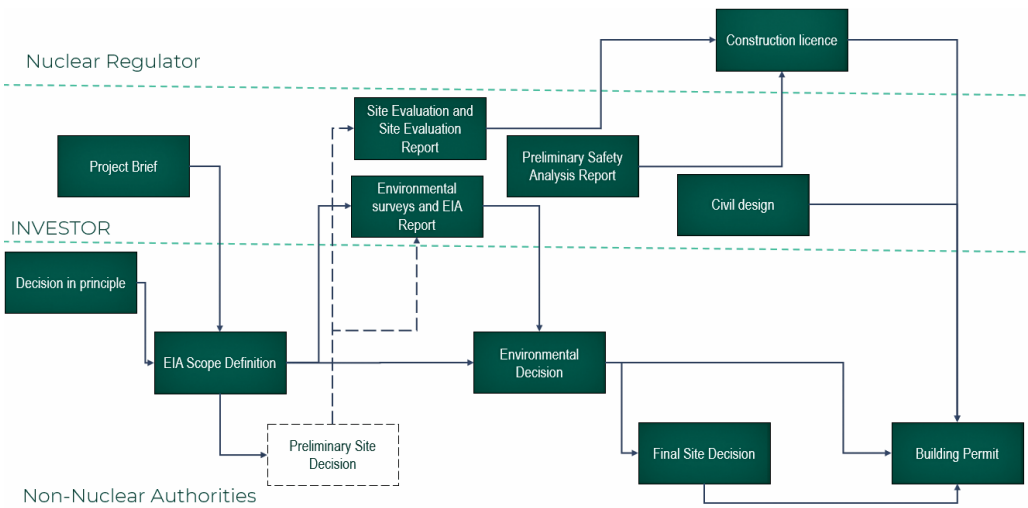

Figure 1. Simplified diagram showing steps and processes leading to obtaining a Building Permit, enabling start of actual power station construction

Source: Own elaboration based on data from Nuclear PL.

The whole process, from the day of submitting a file for Decision-in-Principle until the day of issuance of Building Permit can be expected to take at least seven years. Only a proceeding for issuance of the Construction Licence takes at least two years, but it must be preceded by preparatory of the Preliminary Safety Analysis Report, which shall be based on environmental and site evaluation (additional 2–3 years). Such time shall be extended by the time of delays which, having in mind

number of entities and people engaged in the whole process, number of very complex matter subject matter of this proceedings, plenty of interactions of all stakeholders, etc.

Moreover, abovementioned period does not cover time necessary for business decisions, analyses, surveys, negotiations of contracts with vendors, contractors, financial institutions and other business related issues, which are inevitable steps on the path to deploy the nuclear power plant.

What is of critical importance to any potential fleet deployments of ANT or SMR plants, the entire process is site-specific. While it may be expected that licencing of follow-up plants based on the identical reactor design will proceed smoother, taking into account lessons learned from previous deployments, in formal terms each next licencing process is entirely separate and all the documents have to be evaluated again by the regulator.

All these circumstances create significant roadblock to quickly deploy a SMR or ANT based nuclear power plant. If the preparatory phase, which must be finished before the construction of the facility, takes at least seven years, there are no available remedy steps which may mitigate all delays at the later stage.

Does legal barriers may be eliminated by the change of Polish law?

One of the ideas, presented in a public domain, how to eliminate such legal barriers in development of SMR and ANT projects is a change of Polish law. According to the several proposes, Polish atomic law and act on developing and carrying out investment projects concerning nuclear power facilities and associated investment projects, should be amended to significantly reduce the requirements for technologies classified as SMR or ANT. Arguments which are often raised for such amendment are:

- SMR and ANT facilities are much smaller than large nuclear power plants, so it seems reasonable not to pose such rigid requirements as for bigger units.
- Proposed solutions, especially ANT, are new generation of nuclear technology, which are much safer than older units, so not all requirements shall be binding for these facilities.

At the same time, no specific proposal of amendment of Atomic law and act on developing and carrying out investment projects concerning nuclear power facilities and associated investment projects were observed in the public domain in manner of safety related issues or licensing process. What we can observe are generic statements on the highest safety standards of the proposed solutions and much shorter time of construction due to the size differences.

The main question that may arise is whether such ideas can be implemented in Polish law. The answer is not simple, and depends on a number of factors.

Firstly, the safety issues of nuclear facilities are a priority and any changes to them must not undermine confidence in the proposed solutions. If proposals to amend the law were to involve interference in this sphere, it is necessary to analyse them in detail to ensure that the highest safety standards are maintained and that changes do not create a public perception of deteriorating safety requirements. Moreover, given the complexity of the issue and the peculiar complexity of nuclear safety solutions, the proposed changes may address specific issues rather than changing entire procedures. In turn, it can be assumed with a high degree of probability that such changes will not translate into a significant reduction in the duration of official procedures, and may even be marginal.

Secondly, the changes may cover issues not strictly related to nuclear safety, but concerning construction aspects. Some work can be seen in this area related, for example, to the introduction of new institutions, such as a permit for early construction works, previously unknown to the Polish legal system.[4] Initiatives of this type can, in principle, be applied in our legal order and indeed optimise the time of the entire project. However, they do not in any way affect the acceleration of licensing processes. These have to be preceded by physical work on the construction site, and their conduct before the conclusion of the licensing procedures is de facto undertaken at the investor's risk.

Thirdly, a theoretical solution could be to consider the creation of completely new procedures and requirements (which has also appeared

[4] The Polish legal framework does include a 'Preliminary works permit', but it only enables very limited site preparation – removal of trees, grading, construction yard deployment. No civil works related to actual structures of the final plant may be performed before the final Building Permit though.

in media messages), in which more issues could be carried out in parallel, giving real improvements in time. However, such a concept seems to be a phantasmagoria – it would require a significant amount of time to create them, would result in the nullification of existing efforts for other projects, and, moreover, their implementation and the time required for all stakeholders to adjust would be so significant that the potential benefits (if any) would not compensate for the difficulties involved.

Does legal barriers may be eliminated at the international level?

When change of Polish law does not seem to be the proper solution how to speed up licencing process, some solutions at supranational level to facilitate the licensing process seem desirable. There are examples from other economic sectors that show that international facilitation measures for the certification of technological solutions can bring significant benefits. There are also examples to the contrary: the lack of such facilitation can result in significant business impediments for service providers and benefits for users.

How was it resolved in aviation and railway sectors?

One sector, where similar problems have been resolved, is the civilian aviation. This is one of the industries, where standardised technical products—the airliners—are sold internationally, built in hundreds of examples to identical specifications (at least from safety-related engineering perspective). This has been mostly achieved thanks to internationalisation of the safety approval processes – introduction of single type certificates, additionally mutually recognised between a pan-European certificate and US certificate. This enabled creation of massive fleets of certain types of aircraft, and built basis for an industry, where hundreds of airframes are contracted by customers from all over the world before the first prototype is flown – or in fact before its construction is even approved. Except for greatly facilitating the engineering process and reducing product development costs associated to potential re-engineering for specific national codes and standards, separate certification, and later after-sales support of multiple versions, this situation also leads to

improved operational safety, easier implementation of lessons learned, and—not insignificantly—much better flexibility to operators, who benefit from global maintenance organisations, but also pools of type-trained aircrew who can work in different countries without lengthy and expensive conversion training.

On the other hand, another mode of transportation—the railways—clearly demonstrates difficulties of providing standardised products and services in the market, where such internationalised approach is not adopted. Despite all the efforts to promote rail transport as environmentally friendly (especially when compared to air travel), currently still every EU Member State has its own rail vehicle design approval criteria and lengthy certification processes. Besides, there are still national-specific and mostly incompatible safety systems, and also various and incompatible electrification systems. Because of this, most locomotives or multiple units currently used, can still only be operated in a single country. There is an increasing number of multi-system locomotives or electric/diesel multiple units in operation, but in most cases they are only adapted for two or three systems, with very few cases of four-system compatible trains. There is no single locomotive which could be legally operated in all mainland EU Member States. Therefore, even though railway vehicle suppliers are following the general trend to standardise their products internationally, it is still necessary to design country-specific (or operator-specific) versions of vehicles belonging to the same general design family, and then have them certified in all countries in which they are to be used separately.

In case of railway, this is partially compensated by large sizes of orders coming from single countries or single customers, where despite the need to design multiple versions, each version may be sold in dozens or hundreds of examples. Nuclear industry however cannot hope to cope with the issue in such a way, as no single investor is going to buy dozens of reactors of a new type, due to the very nature of the product and its cost.

What may be done?

As we can see, a path practiced in aviation sector may bring nuclear energy sector a good example how to resolve problems connected with separate systems of technology certification. Therefore, practically the

solution that could allow a significant acceleration of investments seems to be the introduction of advanced standardisation of technology devices and certification procedures, and, in addition, striving to introduce an international certification system for nuclear technologies to the greatest possible extent.

Of course, this kind of 'mutual recognition' must raise a number of questions of a substantive and formal nature, such as those related to: scope of competences of regulators in particular countries; adaptation of standardised solutions in all countries, regardless of their specific conditions; influence of political conditions on decisions of international bodies, as well as a number of other issues. On the other hand, the introduction of mechanisms whereby all or a significant part of the technological solutions are subject to a single, internationally agreed procedure, without the need to duplicate it for each individual project in front of national regulators, will have a significant impact on the timing of individual investments, as well as the costs involved. This, in turn, will result in a decrease in the differences for nuclear power projects compared to conventional power projects – currently, it is the duration of the licensing procedures that is the main difference between these types of energy in terms of implementation time. At the same time, national risks can be mitigated by, for example, staging the various certification phases and allowing regulators to make a sovereign assessment of specific scopes.

The benefits of a form of 'mutual recognition' of certification should encourage their implementation and use.

Who can do that?

The entity which may have proper abilities and power in Europe seems to be the European Commission within European Atomic Energy Community (EURATOM). According to the EURATOM Treaty, a EURATOM was established to contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries. In order to perform its task, EURATOM shall, in particular: (a) promote research and ensure the dissemination of technical information; (b) establish uniform safety standards to protect the health of workers and of the general public and ensure that

they are applied; (c) facilitate investment and ensure, particularly by encouraging ventures on the part of under takings, the establishment of the basic installations necessary for the development of nuclear energy in the Community; (g) ensure wide commercial outlets and access to the best technical facilities by the creation of a common market in specialised materials and equipment, by the free movement of capital for investment in the field of nuclear energy and by freedom of employment for specialists within the Community; (h) establish with other countries and international organisations such relations as will foster progress in the peaceful uses of nuclear energy.[5]

As it was agreed in the EURATOM Treaty, one of the main tasks of the European Commission is to facilitate investments in nuclear energy, promote this type of energy and establish uniform safety standards, however in a very narrow scope. However, the European Commission's powers and capabilities in these areas are modest and mostly limited to managing information and taking a position on planned projects. The power to set standards is minimal. In practice, the Commission has almost illusory powers and tools that could make a real difference in improving projects.

As a consequence, one of the few initiatives, which is clearly visible, is the SMR Industrial Alliance, announced by the European Commission at the beginning of 2024.[6] The general objective of the European Industrial Alliance on SMRs is to facilitate and accelerate the development, demonstration, and deployment of the first SMRs projects in Europe in the early 2030s, by assisting emerging SMRs projects to reach the demonstration and deployment phase. Specific objectives creates an area for collaboration of several SMRs' stakeholders in improvement of their projects. Such an initiative, creating a platform for the exchange of knowledge and experience for those interested in the development of the SMR industry, is necessary and certainly influences the development of their cooperation and can affect the development of many ideas and concepts in this area.

[5] Art. 2 of the Treaty Establishing The European Atomic Energy Community, Consolidated Version Of The Treaty Establishing The European Atomic Energy Community, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2016:203:FULL [access: 23 March 2026].

[6] European Industrial Alliance on SMRs, https://single-market-economy.ec.europa.eu/industry/industrial-alliances/european-industrial-alliance-small-modular-reactors_en [access: 23 March 2026].

At the same time, the European Commission, within the framework of EURATOM, is not pursuing initiatives to effectively speed up projects, simplify procedures, etc. Despite the existence of a strong need for this, as can be seen from the existing status of SMR projects (none of which in Europe has yet gone beyond an early stage of the applicable licensing process), and at the same time bearing in mind the need to develop stable energy sources in the context of a major problem in the fuel market for conventional energy sources, such initiatives are not being taken. An obstacle is, of course, the provisions of the EURATOM Treaty, among others, which are not in line with current realities and needs. However, efforts to change them are unseen. This situation should unfortunately be viewed with some disappointment.

Results

Summarising the considerations raised in this paper, a number of interesting conclusions can be reached.

The global situation where, on the one hand, the fossil fuels supplying conventional power plants (coal, gas), which are essential for the stability of the power systems' foundations, are expensive and the possibility of providing them is uncertain, and, on the other hand, it is necessary to provide energy from low-carbon sources, should naturally promote nuclear energy.

At the same time, nuclear power projects face the problem of long lead times. One of the key issues affecting this is the period needed to certify the technological solutions adopted. Due to the stringent safety regulations for nuclear technology, the lack of experience in designing and building small nuclear and ANT reactors, as well as the need to conduct certification procedures separately for each project, the preparation and implementation time for such a project is longer than for other power plants, including conventional ones.

In these circumstances, it seems reasonable to strive for a situation in which nuclear technology designs are highly standardised, and certification procedures, at least in the major part, are moved to the common highly specialised authorities within the European Union. A natural basis for this would appear to be the development of EURATOM's competences and the creation within it of an organisational structure capable of carrying out such activities.

In order to do so, it is first necessary to adequately amend the EURATOM Treaty. Substantive and in-depth consultations and discussions within the European Union, including consultations with regulatory authorities, as well as nuclear experts from individual Member States, including vendors and consultants and consultancy firms, are necessary for this.

The proposed framework is justified only if a sufficiently large and stable portfolio of SMR and ANT projects has reached a level of technical, commercial and regulatory maturity that warrants the institutional, organisational and financial expenditure required for its implementation. The mere existence of numerous announced projects would not be sufficient; they must be sufficiently advanced to enable the identification of repeatable technological solutions, regulatory issues and assessment methodologies that can meaningfully be addressed through common procedures. The establishment of a common regulatory authority should serve to streamline regulatory processes and, although it would necessarily require the transfer of certain powers from national regulators, should neither deprive them of all or a substantial part of their statutory competences nor extend to matters whose transfer could impair their ability to assess site-specific and other locally relevant factors.

Such changes, introducing regulations for the mutual recognition of nuclear technologies, would provide the basis for clear, uniform certification processes at EU level, without the need to duplicate the same activities in front of individual regulators. At the same time, these regulations should ensure that individual regulators can influence the solutions to be adopted in terms of site-specific and ambient conditions of the planned process. Such a solution, which on the one hand offers the possibility of speeding up and streamlining the work of nuclear projects, and on the other hand ensures that local regulators have adequate scope of authority, seems to be a desirable solution to be opted for.

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Chapter 4

PLANNING AND CONTRACTING FOR SMALL MODULAR REACTOR DEPLOYMENT

Robert Temple[1]
Robert K. Temple, Esq., PLLC
rtemple396@gmail.com

Abstract

Since 2007, NuScale Power, LLC ('NuScale') has been designing and developing for commercial use a light water reactor configured as a small modular reactor ('SMR'). In 2022, the U.S. Nuclear Regulatory Commission ('NRC') certified the NuScale SMR design, allowing it to be deployed via the NRC's expedited 10 CFR Part 52 process. In addition to NuScale being the only NRC-certified SMR, the NRC has issued several first of a kind approvals for the novel NuScale design. In December 2022, NuScale submitted a standard design approval application ('SDA') for

[1] Until August 2024, Bob Temple was the general counsel and board secretary for NuScale Power. His experience includes senior in-house positions with utilities and manufacturing companies serving the electric utility and nuclear power industries, with private practice experience with the firms of Winston & Strawn, Hopkins & Sutter, McGuireWoods, and Haynes and Boone. Prior to becoming an attorney, he was a licensed senior reactor operator at Commonwealth Edison's LaSalle County Station and, before that, an engineering supervisor on US Navy submarines. Mr. Temple continued to consult and provide legal advice in matters related to project finance, corporate fundraising and power project development. Mr. Temple was an active member of the bar in Washington, D.C. and in the states of Oregon, Texas and Washington.

a 250 MWth (77 MWe) 6-NuScale Power Module® (NPM) NuScale Plant design. This design is basically a power uprate for the existing NPM. NRC approval for the SDA is expected by July 2025.

The Poland National Atomic Energy Agency or PAA issued a General Opinion supporting NuScale's SMR for deployment in Poland. A project with plans to deploy NuScale reactors is in the second phase of front-end engineering & design in Romania.

This paper and the related presentation describe key aspects of planning and contracting for SMR deployment. As an original equipment designer, but neither an equipment manufacturer nor a plant constructor, there are some novel approaches to contracting to deploy a NuScale-powered plant and other SMR technologies from other SMR developers. As NuScale's scope of supply does not include the entire plant, the developer or owner of a project needs to consider the contracting alternatives for deploying their SMR project.

This paper provides some ideas and discusses some challenges when contracting to deploy an SMR project, with the goal of having a contractual relationship that will support financing from government sources, export credit agencies and other sources of funding.

This paper and the related presentation describe key aspects of planning and contracting to deploy small modular commercial nuclear plants.

Preface

Since 2007, NuScale Power, LLC ('NuScale') has been designing and developing for commercial use a light water reactor configured as a small modular reactor ('SMR'). The 160 megawatts thermal ('MWth') (nominally 50 megawatts electric ('Mwe')) design in a 12-unit configuration is the first and only SMR designed certified by the U.S. Nuclear Regulatory Commission ('NRC'). In addition to NuScale being the only NRC-certified SMR, the NRC has issued several first of a kind approvals for the novel NuScale design, including: a methodology for an emergency planning zone which may be limited to the site boundary; no safety-related AC or DC back-up power; no emergency make-up water systems; no shift technical advisor in the control room; and as few as three operators in a 12-unit control room. The heart of the plant is the NuScale Power Module™ ('NPM'), with its integral reactor, steam generator and

pressurizer housed inside of its containment. NuScale has developed a standard plant design for the NuScale Plant connecting each NPM with its own steam turbine generator and auxiliary systems. In December 2022, NuScale submitted a standard design approval ('SDA') application for a 250 MWth (77 MWe) 6-NPM NuScale Plant design. This design is basically a power uprate for the existing NPM. NRC approval for the SDA is expected by July 2025.

In December 2023, the Poland National Atomic Energy Agency or PAA issued a General Opinion supporting NuScale's SMR for deployment in Poland. While that General Opinion has expired, in early 2024, NuScale's client advised that they intend to apply for another General Opinion supporting deployment of a NuScale Plant in Poland.

NuScale's launch customer in the EU is RoPower Nuclear S.A. ('RoPower'), which is a joint venture established by S.N. Nuclearelectrica S.A. and Nova Power & Gas S.A. RoPower contracted with NuScale to complete the first phase of front-end engineering and design ('FEED') work for the Doicești SMR project, which was finished in early 2024. RoPower then contracted with Fluor Enterprises ('Fluor') to complete the second phase of FEED work. Fluor subcontracted with NuScale for NuScale to support FEED Phase 2 work. At the end of the FEED 2 phase, RoPower expects to have an updated cost estimate for the project, an updated project schedule, as well as the design and all related nuclear safety and security analyses necessary to support RoPower and its owners to make a final investment decision.

As an original equipment designer, but neither an equipment manufacturer nor an engineering, construction and procurement ('EPC') company, there are some novel approaches for contracting to deploy a NuScale-powered plant. This novelty extends to other advanced nuclear technology companies that are neither EPC companies nor manufacturers.

NuScale's scope of supply includes the NPM and key reactor building components. NuScale provides the license for the intellectual property needed to license, construct and operate the plant as well as the license for the standard plant design needed for plant construction. NuScale also provides simulators and training materials to qualify plant operators and other staff.

Some equipment may be supplied by NuScale directly to the Plant owner while other equipment must be provided to and installed by the

EPC. A well-coordinated relationship between the plant owner/operator, the EPC, and NuScale and clear division of responsibilities is critical to a successful plant deployment and essential to contracting for a financeable project.

Learning from history

The AP1000 plant is a two-loop pressurized water reactor. The design builds on the established technology used in current Westinghouse-designed plants, and their proven, reliable operating experience. Building on the AP600 design previously certified by NRC, the AP1000 plant has unique attributes, including relying on simplified, fully passive safety systems to mitigate all design basis events. The design incorporates innovative modular construction techniques. It also has the lowest plant footprint to power output ratio of any reactor design, and uses fewer valves, pumps, piping, cabling, and concrete than other plants of comparable size. For these reasons and others, the AP1000 technology is among the most advanced commercially available reactor designs. The AP1000 nuclear plant is the first passively-safe next generation reactor operating in the United States. This is on top of four AP1000 plants already operating in China at the Sanmen and Haiyang sites.

The Vogtle project worked through numerous challenges en route to deployment of the AP1000s. The Vogtle project was effectively a first-of-a-kind project. The Design Control Document ('DCD') for the AP1000 plant was sufficiently complete for NRC design certification ('DC') and combined construction and operating license ('COL') purposes and could therefore begin construction. But a comprehensive design was necessary to complete construction of the entire plant. Many detailed design drawings needed to be completed during construction.

These problems revealed a drawback in the NRC's 10 CFR Part 52 process, in that as construction proceeded and design changes became necessary, NRC approval was often required even for minor, non-safety significant changes to the design, including not only changes to information which was designated as critical ('Tier 1') information in the DCD, but also other information ('Tier 2*'). As the design matured and was finalized during the construction process, an extraordinary number of changes required NRC approval. The vast number of license amendment

requests and exemptions—over 200 licensing actions in all—represented a significant burden on the project. For example, when reinforcement bar ('rebar') modifications were made to account for changes in load demand, NRC approval was required even though the changes complied with the licensing basis structural code. Other aspects of the design became the subjects of concerns and allegations, which, even if not substantiated, were distractions for the project, leading to cost increases and delays. For example, a petition for hearing was filed contending the Vogtle nuclear island was sinking and that the basemat settlement was unanalyzed. These claims were unsupported and the petition was dismissed, but this was just one of many such diversions during the construction effort.

A second significant challenge was the need to change the design to accommodate the changed regulatory landscape after the terrorist attacks of September 11, 2001. The NRC certified the original AP1000 design in January 2006, and later certified an amended design in December 2011, shortly before construction on the Vogtle project began in 2012. The revisions in this amended design included changes to close open items for AP1000 COL applicants, standard changes resulting from more detailed design work, and changes to the shield building to comply with the new Aircraft Impact Assessment rule (10 C.F.R. § 50.150), promulgated in 2009. This change, in particular, required significant revisions to the design of many structures, systems, and components.

A third challenge was that many of the other planned AP1000 units were not fully licensed or have not been constructed, hindering the development of economies of scale and efficiencies necessary for the maximum benefit of a standard certified design. For example, between 2007 and 2009, applicants filed COL Applications for 14 AP1000 units in the United States, plus license applications for 4 units in China around the same time. The NRC was unable to provide timely support for all of these applications.

A fourth challenge was the creation of new supply chain capacity after decades where there was no commercial nuclear construction in the US. The creation of a new nuclear workforce required training vast numbers of engineers and craft who had not worked in the industry before, some of whom were not used to the standards expected of NRC-licensed work. Some of these costs were increased by the first-of-a-kind nature of the projects, and here again the US nuclear regulatory process presented challenges at various stages.

And finally, significant challenges surrounding the consortium model used to deliver the projects led to financial challenges and the need to reorganize both the construction organization and Westinghouse itself. Changes that became necessary during construction—whether because of the regulatory changes described above or simply because of the practicalities of actual construction—led to numerous disputes between and among the construction consortium members and the owners, which drained resources and distracted from the objectives of the project.

Some key lessons learned from this experience include:

1. Engage only an experienced module manufacturer, ensure the design can be replicated with consistent quality and performance, and ensure the scale is optimized for modularization and constructability.
   (a) Integrate advanced manufacturing techniques being used to reduce manufacturing times and costs for subsequent facilities.
   (b) Focus on simplicity of design and factory modularization. Simplicity of the design, much less equipment, drives favorable plant economics.
      (i) Passive safety systems eliminate several typical safety-related components both in and out of containment.
         - Limit or eliminate the need for on-site fit-up, assembly, or fabrication.
         - Avoid having manufacturing as critical path. Manufacture in a factory in parallel to the construction of the reactor building and balance of plant.
      (ii) Consider building structures for SMRs, which are simpler and smaller than GW plants.
         - Structures are primarily large monolithic concrete walls with simple 90-degree geometry (no difficult formwork). Open-top construction for the facility. On the other hand, simplicity of the SMR design results in fairly simple, large civil works project without the complexity of GW size facilities. Consider steel composite walls in lieu of rebar and poured concrete.
         - Turbine building has a simple commercial structure intended for asset protection considerations only.
   (c) Smaller sized components are more easily transported and less costly.

(i) Components associated with <300MWe power systems are easier to transport and install pre-assembled on skids. Turbines can be transported as assemblies rather than pieces.
(ii) Smaller piping in systems that support each reactor. (For example, the majority of lines that penetrate NuScale containment are NPS2 (with a nominal pipe size of 2 inches), steam is NPS12 and feedwater is NPS5; by comparison, the AP1000 hot leg coolant piping is 31 inches in diameter.)

2. Test Fabrication Processes – First-of-a-kind components will undergo fabrication testing prior to production.
   (a) Limit the use of first-of-a-kind technology, and perform prototypical demonstrations of first-of-a-kind equipment under plant operating conditions.
      (i) Planned use of predominantly existing, off the shelf equipment.
   (b) To the extent that a technology provider uses first-of-a-kind technology, that technology must successfully complete testing under normal and abnormal plant conditions before the plant is deployed.
3. Complete the Design Before Construction – at least 85% of the plant design will be locked down (construction drawings complete) prior to start of construction.
   (a) With design finalization greater than 85% prior to start of nuclear construction, the technology provider will not still be designing the parts of the plant when construction commences.
   (b) Constructability reviews built into the design process will ensure that the design is not declared 'final' until the technology provider and EPC know how they will build it, including a maximum reasonable allocation of work to the factory and process to true up modules in the factory before they are brought to the field.
4. Regulatory Requirements – ensure key regulatory reviews are complete and approvals received before starting significant construction to minimize the potential for changes to comply with new requirements.
   (a) The DC should not include details that must be altered for each site-specific application or that will unnecessarily constrain the modularization or construction teams.

5. Construction Quality and Execution – engage an experienced nuclear constructor to build plants. SMRs require simpler civil work, smaller work crews, and allow for greater management oversight per capita and a shorter project duration.
   (a) Ensure that the EPC has first-hand knowledge of the problems that were experienced at the western new build nuclear projects and will therefore have integrated lessons learned into its construction planning.
      (i) Constructability reviews are built into the design process; the constructor should be involved early in the design process.
      (ii) Modular construction is being built into the design process. Modularization is done on a smaller and proven scale, similar to experience in the petrochemical industry.
   (b) Smaller peak craft levels associated with SMR construction are inherently easier to manage and effectively coordinate.
   (c) Get to Nth of a kind quality and efficiency with volume manufacturing (technology providers should start early).
   (d) Integrating new plant construction lessons learned into construction and design program.
      (i) Eliminate unnecessary construction/design detail in Design Certification Document.
      (ii) Early start to offsite module assembly facilities in advance of delivery to resolve quality program issues.
6. Commercial Approach – be realistic about costs, uncertainties and contingencies, and plan accordingly.
   (a) The technology provider should maintain a Risk Register with risk mitigation plans. The NRC lessons learned for DC, COL and ITAAC should be incorporated into the Risk Register. The Risk Register should be designed to incorporate lessons learned as well as emergent issues.
   (b) NuScale will work with its customers to obtain a commercially reasonable EPC agreement.
      (i) This means the parties will share contracting risk appropriately, such that the party in the best position to manage risk assumes the risk.
      (ii) No party should bear risk that it cannot manage.

Planning and FEED

Consider the following Project Phases and highlights of what needs to be accomplished.

Technology, EPC and major contractor selection: consider qualifications, design readiness, supply chain readiness, experience, track record; due diligence; confirm bidding approach, requests for information; contracting alternatives; preliminary site selection.

Pre-Final (or Final) Notice to Proceed ('FNTP'): site qualification, environmental assessment including confirming geotechnical conditions, license application preparation; front-end engineering design ('FEED') through non-safety-related site civil & construction; contractor has the opportunity to verify and document pre-existing site conditions, including subsurface and physical conditions, pre-FNTP.

FNTP: safety-related construction to mechanically complete.

Post-FNTP: mechanical completion, start-up testing, commercial operation & warranty period.

Planning and preparation

Use the period prior to the start of FEED work to get a clear understanding of the roles and responsibilities for each of the major project participants through each phase of the project. Recognize the role of all stakeholders, not just the EPC and technology provider, but also the lenders, public, and government. Early engagement with each of the stakeholders is critical to understanding their concerns and mitigating any risks found along the way. Government stakeholders will be more supportive if the local community is in favor of your project.

Categorize and minimize risks before the project starts. The following are examples of some of the risks that should be addressed before being committed to a technology or supplier:

1. Design Selection – does the technology provider have a complete design that is approved and ready to go to field and complete before construction starts.
2. Regulator Engagement – understand the proper and required means of regulatory interaction and have a complete understanding of deployment requirements and ensure they are prepared to review the technology and project:

(a) have you identified all of the permits needed to deploy your project;
(b) is your regulator ready to license your facility;
(c) is your regulator willing to adopt findings and approvals received in other jurisdictions;
(d) does your regulator have a cooperative relationship with regulators that have approved the technology.

3. Safety – safety of design of the technology and safety culture for all project stakeholders:
   (a) new to nuclear countries need to ensure that the project team adopts a healthy nuclear safety culture before trying to deploy a nuclear project.
4. Government-to-Government Cooperation – ensure that export and import requirements are well understood, that tax exemptions are applied for and received, and that the liability conventions and implementing laws are in place to support a project.
5. Owners Engineer – have a qualified owners engineer (or perhaps two) to provide guidance to the Owner and ensure that suppliers/constructors have a project team including subcontractors and sub-suppliers who are experienced in nuclear power plant construction.
6. Owner-Supplier Incentives – understand contract terms that will reward teamwork and achievement of mutual goals; ensure the entire scope of supply is planned for (from fuel supplier to spare parts and maintenance support).
7. Management Oversight – the owner or project developer must have 'boots on the ground' with expertise in large infrastructure project construction, preferably nuclear construction expertise is in-house (not just with the Owners Engineer).
8. Workforce Readiness – ensure that construction, maintenance, and operations staffing training is sufficiently advanced before project start.
9. Project Management Tools – ensure there are tools that allow building a single source of project 'truth': a transparent, integrated work breakdown schedule with critical paths, milestones and dependencies identified; proper interface for supply chain delivery and construction activities.

A detailed division of responsibilities is essential for project success. The owner/developer must also know who is responsible if responsibility has not been allocated. Someone must "own" every aspect of the project and the associated risks.

Front End Engineering & Design

While FEED activities may be time and materials work, the parties should expect to complete FEED, license application preparation, and construction preparation activities pursuant to a budget with milestones and deliverables which are well defined. The more mature the technology, the lower the costs should be; however, site-specific engineering and design work is specific to a project and the owner/developer must monitor developments and change orders.

During the FEED phase is when project contracts are typically finalized. The developer/owner must understand the contract counterparties and have in mind the preferred contracting arrangements with all of the project participants: Technology Provider; EPC Company; Suppliers and Contractors for Project Work outside EPC Scope. For the project itself, the prime counter-party contracting arrangements include:

- Consortium: responsibilities and division of responsibilities is detailed in a consortium agreement; consortium participants operate independent of day-to-day operations of their parent companies with focus exclusively on the project (management control of the consortium rests with the consortium members).
- Joint Venture ('JV'): two or more parties share legal ownership of the venture, risks, profits/losses and governance; the JV may be separately incorporated (management control rests with the JV).
- EPC Prime/others serve as subs to the EPC (technology provider could be prime and others subs); while turnkey projects with the EPC as prime are normal for some projects, it is rare in the western world where the EPC does not want to be liable for the technology risk.
- Bi-lateral contracts with all key participants/suppliers: this is a burden for developer/owner oversight and the points of interface must be more closely managed by the developer/owner.
- Contracts for owner-acquired equipment.

Contracting for a financeable project

True 'turnkey' contracts are unusual for nuclear projects as there is some scope the JV/consortium/EPC may not perform and the EPC, JV or consortium may not take on technology risk (which may manifest as warranty risk). An alternative is an EPC contract and contracts for owner-acquired equipment, with additional contracts for goods and services needed for the project not included in the other agreements. However, for the developer/owner contracts and the form of the contract counterparty, there must be a well-defined total project scope, clear delineation of areas and division of responsibility, responsibility for project areas not expressly assigned (i.e., responsibility = accountability & liability). There must be allocation of responsibility for changes, an obligation for contractor to continue work through claims and disputes; tests and inspections; owner acceptance; and a process for correction, removal, or acceptance of defective work. One alternative to consider if deploying first-of-a-kind technology is to require that the labor and materials be supplied on an open book basis with rights to audit and obtain the information needed to verify actual costs.

Key contract terms to work through with expert advisors in each area:

- Insurance for all project phases
- Set-offs and corrections
- Costs, allowances and unit price work
- Changes – portion of the change that must be paid for in order for work to proceed
- Claims process
- Dispute resolution
- Suspension and termination
- Force majeure and foreseeable events
- Limits of liability, delay and performance liquidated damages, warranty repairs: make clear who is accountable and who is standing behind those who are accountable (performance security – bond, letter of credit, government backstop)

Consider these issues (and perform more diligence if needed): (i) Does the accountable party have the balance sheet to perform?; and (ii) What is your contingency plan if they fail to perform? The developer/owner needs clear rights to information needed to license, construct, operate &

decommission the facility (technology, drawings, software), and to continue the project to completion should any key participant fail to perform.

Finally, consider the following behaviors for the developer/owner to avoid to stay on the right side of the relationship with financing entities:

- Proceeding with work with incomplete plans or specifications
- Owner caused delays
- Payment slow-down or default
- Heavily layered financing with no strong lead
- Inexperienced owner/developer
- Deferred development fees
- Changes in lender involvement
- Changes in communication (owner becoming more distant)
- Adversarial posturing by the owner
- Reluctance towards transparency of financing
- Abnormal invoicing requests
- Cash infusion requests of the contractor by the developer/owner
- Delays in approving/paying change orders

It is essential to maintain good relations with the financing entities to avoid delays in draws during construction or, worst case, the withdrawal of lender support. Advanced nuclear project financing is still under development and poor project performance will make it even more difficult to obtain.

As the project construction is finished, the owner/developer will focus on preparing for plant operations. Plan for the spare parts and consumables needed for operations (stock required spare parts and contract with suppliers for critical just-in-time parts that the supplier stocks). The owner/developer needs to have a complete maintenance plan for the facility and determine staffing and work that will be performed in-house versus work that will be contracted out. Track claims and disputes to resolution and ensure all claims are resolved and project liens are removed before final payments are made to contractors and suppliers.

Conclusion

Projects deploying advanced nuclear technology are hard and should not be undertaken before obtaining government support. While advanced reactors, and SMRs in particular, will be less capital intensive

than traditional large reactor projects, financing will be challenging especially with first-of-a-kind projects. Financeable models for these projects are still under development. Vendor financing and financing from export credit agencies and other government-backed sources come in late and may not cover the project. As a result, don't go into the project without a clear understanding of the equity requirements (plus contingency). All parties must be incentivized to make the project successful and the contracts must allocate risks and rewards accordingly. Of course, allocate risk to the party in the best position to manage it.

Chapter 5

THE SMALL MODULAR REACTORS: INDIA'S PREDICAMENT TO LIBERALISE NUCLEAR POWER

Riju Raj Singh Jamwal
PhD, LLM (Energy Laws), Managing Partner, JRD & Partners (Law Firm)
Practicing Advocate at the Supreme Court of India
Member of INLA
rijurajj@gmail.com

Abstract

Small Modular Reactors (SMRs) have the potential to be an important component at present for the worldwide nuclear energy renaissance. SMRs are simpler to build and operate, as well as being suitable for deployment in harsh environmental conditions, while requiring more diluted investment than Large Reactors (LRs). Around the world, a variety of financial and economic models have been developed by the scientific community in order to assess the competitiveness of SMRs. The paper investigates attractiveness of SMRs for India in the present given scenario. India is the second most populated country in the world with rapid economic growth and a huge requirement for energy. There is also good public acceptance, political support, and judicial consciousness for nuclear power in India which are important factors favoring the deployment of SMR's. Further, Government of India's Policy is that Nuclear Power is critical for achieving India's clean energy targets set in COP-26 and India's effort is to achieve net zero emissions by 2070. The G-20

Summit of 2023 paved the way for development of SMR's, though to negate the concerns regarding viability and efficacy around SMR's, the involvement of the private sector remains a key debate within the Policy circle. India has to reconsider the amendment to the Atomic Energy Laws including the licensing and liability regimes that includes the development motive along with economic benefit to pave a path forward and to provide leeway for involvement of the private sector, foreign investment, and startups to provide a reliable low carbon source of electricity that complements intermittent renewals by way of developing the future of SMR's in India.

Introduction

Economic development and population growth are driving the demand for a secure and expanding energy supply, with electricity being the most convenient and reliable form of energy. Nuclear power, known for its stability and minimal dependence on external factors, stands out as a promising solution. While large Nuclear Power Plants (NPPs) have traditionally dominated,[1] there's a budding curiosity in smaller units. These Small Modular Reactors (SMRs) offer flexibility and are particularly suited for remote areas and distributed energy systems.

SMRs are gaining traction globally as countries recognize the need to expand their energy production capacities to keep pace with rising energy consumption. For remote regions like northern Alaska or isolated parts of Russia, SMRs provide a reliable source of electricity and potable water. Nations like China are investing heavily in both large NPPs and SMRs to meet diverse energy needs. In the USA, significant support from the Department of Energy (DoE) is accelerating the advancement of light water and next-generation reactor designs.[2]

The concept of SMRs has evolved from small, factory-built reactors that are easy to transport and deploy. The International Atomic Energy Agency (IAEA) now categorizes SMRs as Small and Medium-sized

[1] M. Mueller, *Nuclear Power is the Most Reliable Energy Source and It's Not Even Close*, https://www.energy.gov/ne/articles/nuclear-power-most-reliable-energy-source-and-its-not-even-close [access: 30 August 2024].

[2] Ibid.

Reactors, producing up to 300 MWe for small reactors and between 300 and 700 MWe for medium reactors.[3] These reactors are particularly advantageous for areas with small power grids or where extending the main power grid is economically unfeasible. An innovative example as observed in the Russian Federation is the floating nuclear power plant design by OKBM Afrikantov, which can deliver energy to various locations as needed.[4]

SMRs are being developed worldwide, including in Argentina, Brazil, Canada, China, France, India, Japan, South Korea, Russia, South Africa, and the USA. This international effort has led to a wide range of reactor designs, with light water reactors (LWRs) being the centre of attention. However, there is growing interest in Liquid Metal Cooled Reactors (LMCRs) and Gas Cooled Reactors (GCRs). Canada remains unique in its pursuit of the Supercritical Water Reactor (SCWR) concept.[5]

The past of atomic power began with the finding of uranium-235 fission by Otto Hahn and Fritz Strassmann in the early 1930s, particularly in 1938. The first self-sustaining atomic chain reaction was accomplished by Enrico Fermi in December 1942, with the Chicago Pile-1 reactor. Initially used for military purposes, nuclear reactors soon became vital for commercial electricity production. The first commercial NPPs, Obninsk in the Soviet Union and Calder Hall 1 in the UK, were launched in the mid-1950s, leading to a rapid expansion of nuclear energy.

However, the Chernobyl disaster in 1986 significantly decelerated the growth of atomic power. The episode ran into a re-evaluation of nuclear security standards globally. Despite this, the early 2000s saw a revival in atomic energy, with new NPPs being planned and built in the USA and Finland. This period, known as the 'nuclear renaissance,' included significant global projects and China's construction of numerous reactors. The Fukushima disaster in 2011, however, caused another setback, leading Japan to replace atomic energy and prompting other states to reconsider their nuclear strategies.

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[3] J. Liou, *What are Small Modular Reactors (SMRs)?*, https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs [access: 30 August 2024].

[4] V. Aptekarev, *Q&A: The prospects for floating nuclear power plants*, https://www.world-nuclear-news.org/Articles/Q-A-The-prospects-for-floating-nuclear-power-plant [access: 30 August 2024].

[5] R. Duffey, *The Development and Future of the Supercritical Water reactor*, "CNL Nuclear Review" 2016, vol. 5(2), pp. 181–188, 10.12943/CNR.2016.00040.

Today, SMRs are not only seen as sources of electricity but also as providers of process heat and desalinated water. High-temperature SMRs can produce steam for industrial applications, generate hydrogen gas, and integrate with renewable energy sources like offshore wind farms. Many SMRs are designed for high efficiency and long intervals between refuelling, with some capable of operating for up to 30 years without a shutdown.

Safety is a crucial aspect of SMR design. Modern SMRs incorporate inherent and passive safety systems, adopting a 'defense in depth' strategy. Their smaller size simplifies safety measures, as less heat needs to be managed during emergencies. Some designs feature natural convection within the Reactor Pressure Vessel (RPV) through integrated heat exchangers, allowing the reactor to cool without operator intervention in the event of a malfunction. This robust safety approach ensures that SMRs can provide secure, reliable, and sustainable energy solutions for the future.

Objectives

The main aim of this paper is to examine the contribution of (SMRs) in the power evolution, the current standing of SMR technology advancement, and the readiness of atomic supply chains for their placement. It also explores initiatives to blend SMR regulatory parameters and the global licensing process, as well as preparations for international safeguards, with special reference to India to attract private investment and stakeholders.

Scope

This study gathers data from openly accessible, and publications from IAEA, the Nuclear Energy Agency (NEA), and the International Energy Agency (IEA), along with press reports and insights from information associates in this arena in India. The focus of this paper is on the happenings, views, and decisions of energy asset proprietors, technology vendors, controllers, and administrations. It delivers perceptions on how to fully realize the potential of SMRs in the power transition, scrutinizing the opportunities and challenges in India.

Emergence of SMRs

SMRs have roots in the 1940s-1950s military reactors. Increasing interest from technology developers and customers has led many countries to develop national SMR programs, aiming for deployment by 2035 with extensive global cooperation. SMRs are designed to be manufactured in factories, transported, and installed on-site, reducing installation time and costs. Various SMR designs are grounded on well-known and advanced technologies, primarily aiming to generate emission-free electricity and other clean energy products like hydrogen. SMRs offer flexibility for grid stability and are suitable for small grids, remote locations, and industrial applications. Their rise can strengthen the nuclear sector and contribute to energy transition and resilient infrastructure.[6]

SMRs in the Indian context[7]

The Indian subcontinent is one that is surrounded by the Bay of Bengal on one side and the Arabian Sea on the other, the said seas are met by the eastern and the western ghats as soon as it touches Indian soil. Further, in the north-east of the subcontinent stand the great Indian Himalayas. India is also blessed to have the Aravalli range ranging from the capital till the western parts of the nation until met with the Great Indian Thar Desert in the state of Rajasthan.[8] The beautiful and diverse terrain of the nation grants it with various beauties of nature, expanding the scope of tourism within the nation. However, the said boons are accompanied by its own set of adversities, the Indian tectonic plate, is exposed to seismic shifts at a noticeable rate, which at time leads to earthquakes in the mountainous regions rendering any major constructive activities,

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[6] J. Liou, *What are Small Modular Reactors…*

[7] Hriday Ch. Sarma, *WORKING PAPER 31 – Electric Power Scenario in India: Challenges and Opportunities in Transmission and Distribution Sectors*, https://www.sadf.online/working-paper-31-electric-power-scenario-in-india-challenges-and-opportunities-in-transmission-and-distribution-sectors/ [access: 30 August 2024].

[8] *Physical Features*, https://knowindia.india.gov.in/profile/physical-features.php [access: 30 August 2024].

be it of power stations as highly unlikely.[9] The said earthquakes are often responsible for uprooting the electricity transmission lines spread over the region making accessibility to electricity in the mountainous regions a dream for many residents. In lieu of the transmission inefficiencies of electricity and the non-suitability of the contemporary transmission system, one must consider the inefficiencies holistically to advance any possible solution to the problem.

India being the third largest consumer of electric power is ought to produce enough for its needs, the nation meets its needs for power predominantly by coal-based electricity generation requiring the setup of large and hefty thermal power plants. Electricity produced in such plants is then transported using transmission lines and power grids. However, such transmission of electricity from the thermal power plants to the end consumer is not the simplest procedure for the third largest producer of electricity. It has been observed that India, now considered as a developed nation, still lacks the requisite infrastructure to support the transmission needs of the country and such a lacking is witnessed in the congestion in the transmission lines as a result of the rapidly growing energy demands. The uploading of the infrastructure is not a feasible alternative for its capital-intensive nature, India if desirous of upgrading its present infrastructure of power grids and transmission lines would require more land to setup the infrastructure which often requires acquisition of lands by compensating the owner citizens.[10] If at all, the country is able to pump the requisite capital into the infrastructural expansion of its transmission system, the process is yet not free of legal hurdles that come its way by way of litigation by the citizen owners, the lands of whom is acquired for the purpose of such expansion. One may wonder that whether these shortcomings sum all that would come in way of revamping the transmission lines of the country would such an expansion if made possible be an end to all of India's energy concerns?

The answers to the abovementioned questions also lead us to consider the fact that transmission of electricity using electricity lines and power-grids are plagued with high Aggregate Technical and Commercial

[9] *Shocking! India's landmass is shrinking every year by 2 mm, here's why*, https://timesofindia.indiatimes.com/etimes/trending/shocking-indias-landmass-is-shrinking-every-year-by-2-mm-heres-why/articleshow/107586754.cms [access: 30 August 2024].

[10] Hriday Ch. Sarma, *WORKING PAPER 31…*

(AT&C) Losses causing significant losses and financial hardships to the electricity manufacturers and making the field of business far from lucrative. Further, the terrain of the nation is such that it makes last mile connectivity of electricity nearly a distant dream for many a citizen of the nation. Further, the overloading upon the distribution system often leads to uncontrolled voltage and faulty meters and billing further rendering the survival of the electricity manufacturers as difficult in the nation. The transmission issues faced by the Indian electricity system particularly with respect to its transmission, is accompanied by an adverse effect upon the power quality reaching the consumers. Now that the aforementioned highlight the unsuitability of the transmission system of electricity so prevalent in India, one must question as to what is the way forward, what is the path to a sustainable and effective electricity system in India? The short answer to the doubts so raised above is that SMRs will reduce the transmission cost and bring energy generation closer to the consumer, the reasons for which are evaluated extensively in the following paper.

Indian Atomic Energy Act and SMRs

A key component of legislation that controls the progress, use, and regulation of atomic energy in India, is the Atomic Energy Act (AEA).[11] The Act, which was promulgated in 1948 and amended in 1962, which delivers a thorough outline for the management of atomic materials and installations and guarantees the benign and protected use of atomic power. The AEA has been instrumental in the expansion of atomic technology by delivering an equilibrium between the advantages of atomic energy and requirement of strict safety regulations and regulatory monitoring. The Atomic Energy Act attempts to safeguard public health and safety, advance national security, and encourage scientific advancement in the arena of atomic energy by establishing guidelines for the management of radioactive materials and the functioning of nuclear reactors.

Regarding SMRs and the Indian legislation is amidst its development with regards to the use of atomic energy. It has always been difficult to test out new technology in a country like India, with its dense population

[11] The Atomic Energy Act, 1962 (No. 33 of 1962).

and rich diversity. Addressing the matter, our then Union Minister for Technology Minister stated in an interview that the government has allowed joint ventures with public sector projects in the nuclear power sector, but not with the private sector.[12]

The 1962 Atomic Energy Act is being re-examined to permit start-ups and the private sector to participate in the national development of SMR technology. According to the minister, SMR is a potential technology for industrial decarbonization, particularly in situations where a steady and dependable power supply is needed. According to a NITI Aayog research, collaboration amongst the public and private sectors is essential to alleviate associated risks and speed up commercialization because of the technology's young stage and investors' views of business and regulatory risks.

NIT Aayog's report on the universal energy blend, & the associated principal energy sources

According to the NITI Aayog's report,[13] the successor of the planning commission of India, formulated its report in 2023, wherein it stated that conventional power sources equate for approximately 82% of the principal power supply, as illustrated in Table 1. Nonetheless, the proportion of renewables in the principal power blend is consistently rising, as depicted in Figure 1.

The energy sector has the potential to decarbonize at a faster rate. Electrifying end-use sectors is critical for reducing emissions across the entire economy. Many economies have set Net-Zero emission goals to be attained by the year 2050, and IEA research indicates that power demand may increase up to two times to reach these targets by 2050. The energy sector, responsible for 40% of worldwide emissions, requires a comprehensive overhaul to meet net-zero desires. Significant capital is needed for the swift enlargement of low-carbon generation capacity and grid infrastructure, in addition to the incorporation of storing and

[12] PK/PSM, *'India's Nuclear Power generation capacity to increase by around 70 percent in the next 5 years', says Union Minister Dr. Jitendra Singh*, https://pib.gov.in/PressReleseDetailm.aspx?PRID=2028578 [access: 30 August 2024].

[13] *A Report on the Role of Small Modular Reactors…*

supplementary flexibility measures to ensure grid constancy. The evolution from unrelieved conventional fuels to flexible renewable energy sources poses various technical, societal, and political considerations.

Table 1

Principal energy blend in 2021

Fuel	Consumption (EJ)	Percentage	Combined Percentage
Oil	184.21	30.95	
Natural Gas	145.35	24.42	82.28
Coal	160.10	26.90	
Nuclear Energy	25.31	4.25	
Hydroelectricity	40.26	6.76	17.72
Renewables	39.91	6.71	
Total	**595.14**	**100.00**	**100.00**

Source: A Report on the Role of Small Modular Reactors in the Energy Transition, May 2023, https://www.niti.gov.in/sites/default/files/2023-05/The-Role-of-Small-Modular-Reactors-in-the-Energy-Transition-05162023.pdf [access: 30 August 2024].

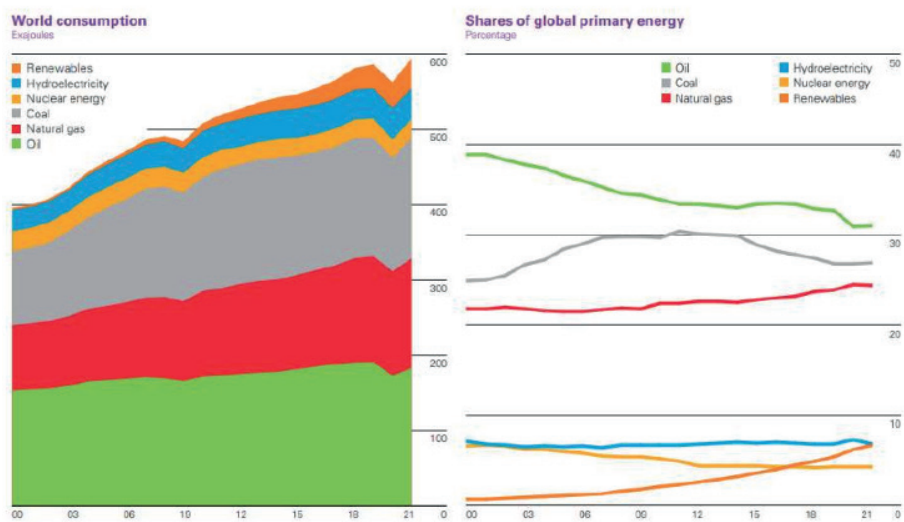

Figure 1. Universal principal energy blend (2000-2021)

Source: A Report on the Role of Small Modular Reactors…

In this context of decreasing conventional electricity volume and swiftly increasing flexible clean energy, atomic based generation of energy guarantees power supply security and grid constancy. Atomic power can significantly contribute to the energy transition by providing baseload capacity, continuous 24/7 availability, and the flexibility to balance variable clean sources of generation. Crucial strategies for achieving flexible functioning in an atomic plant comprise bolstering fundamental power through control manoeuvres, reducing passage through the turbine (via steam venting or rerouting to alternative users in unified systems), and utilizing energy storage for demand response options.

According to the IEA's Net-Zero by 2050 report, atomic energy is a crucial basis for the power shift. The power supply from atomic is expected to increase by 40% by 2030, and by 2050, it is projected to more than double compared to 2020 levels, as illustrated in Figure 2.

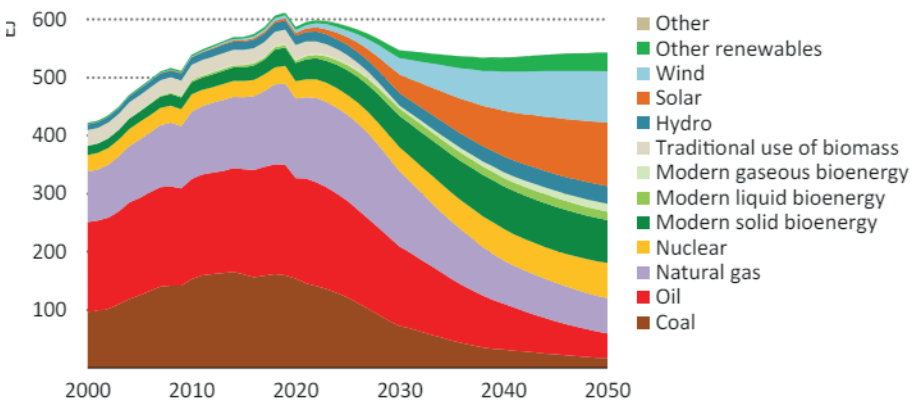

Figure 2. Total energy supply in Net-Zero by 2050 Scenario of IEA

Source: A Report on the Role of Small Modular Reactors…

Currently, atomic energy contributes more than 25% to the entire low-carbon energy generation. Beyond electricity, atomic energy can be utilized for non-electric uses as hydrogen manufacturing, desalination, and district heating. Worldwide, atomic energy reactors generate nearly 2.3 TWh of energy corresponding to power for procedures like desalination and district heating, which accounts for less than 1% of their entire energy yield. This highlights the potential for atomic energy to

enlarge its use in non-electrical uses as part of upcoming decarbonization strategies.

India and its nuclear regulatory framework

India is a participant to only one global convention that is Convention on Supplementary Compensation for Nuclear Damage (1997)[14] and has its own national legislations and policies laying down the framework of the Nuclear Energy in India. The national legislations include Atomic Energy Act, 1962 and residue of the environmental aspects being governed by the Environment Protection Act, 1986.[15]

G20 Summit 2023 and the role of SMRs[16]

The G20 Summit of 2023, convened in New Delhi, India, was a landmark event that underscored the growing importance of SMRs in the international power landscape. Bringing together the leaders of the planet's prime economies, the summit focused on the critical issues of energy security and sustainable development. Among the key highlights was the recognition of SMRs as a vital component in the quest for sustainable energy solutions and in combating the global challenge of climate change.

SMRs were spotlighted for their potential to revolutionize the nuclear energy sector by offering scalable and flexible energy solutions. Unlike traditional large reactors, SMRs can be constructed and deployed incrementally, which provides a significant advantage for countries with varying energy needs and financial capabilities. This scalability allows nations to enlarge their atomic energy ability as required, without the need for massive initial capital investments typically associated with large reactors. For many developing economies represented at the summit, this feature of SMRs presents an attractive option for diversifying their

[14] Convention on Supplementary Compensation for Nuclear Damage, 1997, https://www.iaea.org/topics/nuclear-liability-conventions/convention-supplementary-compensation-nuclear-damage [access: 30 August 2024].

[15] The Environment (Protection) Act, 1986 (Act No. 29 of 1986).

[16] *Final Energy Transitions Working Group Meeting under India's G20 Presidency Concludes*, https://www.g20.in/en/media-resources/press-releases/july-2023/etwgm-concludes.html [access: 30 August 2024].

energy portfolios and meeting growing energy demands in a cost-effective manner.

Another crucial aspect of the discussion was the role of SMRs in supporting renewable energy sources. As G20 nations increasingly turn to renewables like wind and solar power to meet their climate goals, the intermittency of these energy sources poses a challenge for preserving a steady and dependable energy supply. SMRs can serve as a dependable backup, providing continuous baseload power that complements the flexible nature of renewable power. This synergy between SMRs and renewables is essential for creating robust and sustainable power systems that can familiarize to fluctuating power demands and alleviate the effects of climate alteration.

The summit also emphasized the environmental benefits of SMRs, particularly their low carbon emissions. With the G20's commitment to reducing global greenhouse gas emissions and achieving the objectives established by the Paris Agreement,[17] the integration of SMRs into the energy blend represents a significant step forward. By generating electricity with minimal carbon footprint, SMRs contribute directly to the decarbonization of the energy sector, supporting global exertions to curb climate alteration and guard the environment.

A key theme of the G20 Summit was the need for international collaboration in the expansion and deployment of SMRs. Identifying the complexities and challenges involved in advancing nuclear technology, G20 leaders called for enhanced cooperation among member countries. This includes sharing best practices, technical expertise, and regulatory frameworks to streamline the adoption of SMRs worldwide. Nations with recognized atomic capabilities, such as the USA, Canada, and France, pledged to support other countries in developing their SMR programs by providing access to their knowledge and experiences.

Joint research and development initiatives were identified as crucial to accelerating the advancement of SMR technologies. Collaborative efforts in R&D can lead to innovations in reactor design, improve safety protocols, and reduce overall costs, making SMRs more reachable and viable for a wider range of countries. The G20 Summit also proposed the creation of standardized regulations and certification processes to facilitate the

[17] The Paris Agreement, https://unfccc.int/process-and-meetings/the-paris-agreement [access: 30 August 2024].

global market development of SMRs. Harmonizing these regulations would lower the barriers to international trade and investment, fostering a more competitive and dynamic market for SMR technology.

Economic considerations were a central focus of the summit discussions. The leaders acknowledged the need to assess the economic competitiveness of SMRs against large reactors. While SMRs have the advantage of lower initial capital investment, their long-term economic viability depends on operational efficiency, market demand, and regulatory costs. The involvement of the private sector was highlighted as critical for driving innovation, reducing costs, and accelerating the deployment of SMRs. Encouraging private capital infusion and public-private partnerships can render a substantial role in bringing SMR projects to fruition.

Policy reforms were identified as necessary to support the integration of SMRs into national energy policies. Countries were urged to amend their nuclear energy laws to accommodate the unique features of SMRs, such as their licensing, construction, and operational requirements. Streamlined regulatory processes are essential to reduce bureaucratic hurdles and expedite the deployment of SMRs. The G20 Summit set a clear path forward, advocating for joint ventures, regulatory harmonization, and innovative approaches to guarantee that SMRs owes its share to a sustainable and resilient global energy future.

COP26 and climate action[18]

The 26th Conference of the Parties to the United Nations Framework Convention on Climate Change, known as COP26, held in Glasgow in 2021, was a defining moment in the worldwide effort to address climate alteration. The conference gathered nearly 200 countries to reaffirm their vow to the Paris Agreement and to take concrete steps towards restricting global warming to 1.5°C over pre-industry level. This determined goal requires substantial decreases in greenhouse gas releases and a transition to sustainable energy systems.

COP26 was instrumental in strengthening the resolve of nations to enhance their Nationally Determined Contributions (NDCs), which are individual country plans for reducing emissions and adapting to climate

[18] *NEA at COP26*, https://www.oecd-nea.org/jcms/pl_61714/nea-at-cop26 [access: 30 August 2024].

impacts. Countries were encouraged to set more ambitious targets and to outline clear strategies for achieving them. A major focus of the conference was on the need to phase out coal and reduce dependency on fossil fuels, which are major sources of carbon emissions. In this context, nuclear energy, and specifically SMRs, were recognized as crucial elements in the shift to a low-carbon energy future.

SMRs were highlighted for their ability to render a crucial role in the clean energy shift. As low-carbon power sources, SMRs can generate reliable electricity with minimal greenhouse gas emissions, rendering them an lucrative alternative for countries in quest to decarbonize their energy sectors. The versatility of SMRs extends beyond electricity generation; they can also be used for industrial applications such as providing process heat and desalinated water, further contributing to sustainable development goals.

In addition to their environmental benefits, SMRs enhance energy security and resilience. Their modular and flexible design allows for deployment in various settings, including remote and off-grid locations where large reactors would be impractical. This capability is particularly valuable for improving energy access in underserved regions and for supporting decentralized energy systems. By providing a steady and unceasing energy supply, SMRs can help to mitigate the risks associated with energy intermittency from renewable sources and ensure a reliable energy supply in the face of growing demand.

The success of SMRs in contributing to climate action depends on supportive policy and regulatory frameworks. COP26 underscored the need for countries to streamline licensing and approval processes for SMRs to facilitate their rapid deployment. Simplified regulatory frameworks can reduce the time and cost associated with bringing new reactors online, making it easier for countries to integrate SMRs into their energy strategies. Furthermore, providing financial inducements, including but not limited to tax breaks, grants, and subsidies, can boost investment in SMR projects and stimulate the growth of the nuclear energy sector.

International standards and cooperation are essential for the successful deployment of SMRs. Establishing common standards for SMR design, construction, and operation can facilitate international collaboration and trade, making SMRs more accessible to a wider range of countries. COP26 emphasized the importance of continued global cooperation to

share knowledge, resources, and best practices, and to foster partnerships that can advance the development of SMR technology.

Looking ahead, the outcomes of COP26 set the stage for a robust and coordinated approach to deploying SMRs as part of the broader strategy to combat climate change. Nations are encouraged to implement stronger climate policies and to translate their commitments into concrete actions. This includes setting ambitious targets for clean energy adoption and carbon reduction and supporting technological innovation in the nuclear sector. Investment in research and development is critical for progressing SMR technology, making it more cost-effective, efficient, and adaptable to diverse energy needs.

Continued global partnership will be vital to the successful integration of SMRs into global energy systems. By fostering global partnerships, harmonizing regulations, and investing in innovative technologies, countries can unlock the full potential of SMRs and make significant progress toward achieving their climate and energy goals. The leadership demonstrated at COP26 provides a hopeful vision for a future where SMRs contribute to a sustainable, resilient, and low-carbon global energy landscape.

Adoption of SMRs in India

Having analysed the benefits that come along with SMRs, and, the suitability that it can pose in India, it becomes necessary for India to consider adopting of the requisite technological know-how along with the necessary infrastructure to facilitate energy production originating from SMRs in India. It is also intrinsic to mention that Union Minister of State (Independent Charge) Science & Technology; MoS PMO, Personnel, Public Grievances, Pensions, Atomic Energy and Space, recently termed nuclear power as a potential clean energy option for power generation and further announced that Small Nuclear Reactors are being researched by the government to shift to clean energy.[19]

The benefits of the SMRs are known to India by virtue of the aforementioned discussions and the perusal of the results rendered around

[19] SNC/RR, *Union Minister Dr Jitendra Singh says, India taking steps for development of Small Modular Reactors (SMR), with up to 300 MW capacity to fulfill its commitment to Clean Energy transition*, https://www.pib.gov.in/PressReleasePage.aspx?PRID=1879298&reg=3&lang=2 [access: 30 August 2024].

the globe. However, it is equally intrinsic to consider the suitability of the SMRs in the Indian scenario, the consideration being done before such technology is researched, crafted and adopted as a matter of practice to satiate the Indian energy needs.

State-wise power crisis and role of SMRS[20]

Recently, the Secretary, Department of Energy of one of the larger states in the eastern part of India informed[21] that the sudden rise in consumption has left the state with a 200–300 Mega Watt (MW) daily electricity shortage. The state uses about 6,000 MW of power each day, while there are only 5,000 to 5,200 MW of power available from various sources. But nearly every day, the state purchase about 600 MW of power from the exchange for our state's consumers at higher prices.

Some of the most populous states in India have long struggled to provide its citizens with dependable energy. The state's quality of life and economic growth are impacted by the poor and irregular electrical supply, even with recent improvements. The use of SMRs is one viable remedy for this enduring problem. The capacity of several Indian States to generate power is far less than the demand for it. Due to the state's heavy reliance on electricity imports from the national grid, load distribution and frequent power outages are common. The state's inadequate infrastructure for producing electricity, which consists of a combination of thermal, hydro, and renewable energy sources, causes this dependence.

Electricity problems in Northern India

To address the soaring electricity demand and ensure sufficient power supply amid the intense summer, the Ministry of Power has initiated several measures to meet an unprecedented highest requirement of 250 GW. The Northern Region of India had experienced severe heatwave since May 17, 2024, causing a spike in power consumption. Despite these

[20] Business Today Desk, *Power crisis in India: These states facing electricity problems; full list*, https://www.businesstoday.in/latest/story/power-crisis-in-india-these-states-facing-electricity-problems-full-list-332105-2022-05-02 [access: 30 August 2024].

[21] Ibid.

conditions, a record highest requirement of 89 GW was efficaciously fulfilled on June 17, 2024, by bring in 25–30% of the region's energy needs from other regional grids.[22]

Utilities have been instructed to support high-alert and reduce forced equipment fallouts. Under Section 11 of the Electricity Act, 2003,[23] Imported Coal Based (ICB) Stations are mandated to continue generating energy during this period of high demand. Generating units have minimised planned maintenance, and increased efforts to reduce fractional and forced fallouts to extend generation ability to its fullest potential.

Generating companies, under these conditions, were urged to ensure their stations operate at full capacity. Coal-based thermal stations are maintaining adequate coal stocks, while hydro stations are conserving water throughout solar hours and maximising generation throughout non-solar hours.

Surplus power from generating stations is being made available in the marketplace as per the Electricity (Late Payment Surcharge and Related Matters) Rules, 2022,[24] allowing states to procure additional power. States can also arrange power via the PUShP portal. The Ministry of Power directed utilities to remain highly alert and reduce forced equipment outages due to the increased electricity demand from the ongoing heatwave, especially in the northern region awaiting the monsoon.

Although the installed capacity exceeds the demand, not all plants run continuously at optimal capacity, and immediate power transmission is not always possible. As States in Northern India continue to endure heatwaves, in another incident, there was a power outage at Delhi Airport which halted operations for nearly 30 minutes.

The India Meteorological Department predicts no major relief, as the monsoon was expected to reach the northern states by the end of June.

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[22] Rishi Ranjan Kala, *Power Ministry reviews electricity demand-supply situation as intense heat waves bake north India*, https://www.thehindubusinessline.com/economy/power-ministry-reviews-electricity-demand-supply-situation-as-intense-heat-waves-bake-north-india/article68304086.ece [access: 30 August 2024].

[23] The Electricity Act, 2003, (No 36 of 2003), https://cercind.gov.in/Act-with-amendment.pdf [access: 30 August 2024].

[24] Dheep Joy Mampilly, *Government Amends Electricity (Late Payment Surcharge and Related Matters) Rules, 2022 to Ensure Optimum Utilization of Available Power Generating Capacity*, https://www.pib.gov.in/PressReleasePage.aspx?PRID=2010570&reg=3&lang=2 [access: 30 August 2024].

Solutions to improve these problems

The Ministry has reported that to meet the rising power demands, they were keeping power plants dependent on imported coal operational and limiting maintenance shutdowns to the bare minimum. Power generation companies have been recommended to support their plants in optimal condition, while hydropower stations are conserving water during the day and maximising power output at night. Gas-fired power plants are also being used to support the increased demand.

India's power generation relies heavily on thermal power, which makes up about 55% of installed capacity, with coal accounting for 90% and gas for the remaining 10% of thermal capacity. Wind and solar power make up about 30% of installed capacity, but their output is variable due to natural factors, limiting their reliability for on-demand power.

Several strategies can help alleviate the impact of severe power cuts. Improving power sector efficiency through investments in modern technology and infrastructure—such as upgrading power plants, transmission lines, and distribution networks—can reduce losses and enhance reliability. Promoting clean energy sources like solar and wind, which are progressively pocket friendly, is another solution. Encouraging the usage of power-efficient systems, such as home solar setups, can also manage demand and reduce consumption.

Solar energy, a sustainable and renewable resource, offers a reliable electricity supply even during power outages when combined with battery storage. The decreasing cost of solar panels in India makes this an attractive choice. Solar power has significant advantages, including cost-effectiveness, minimal maintenance, and zero greenhouse gas release.

However, the sustainability of the energy sector requires addressing production costs and subsidies. India faces crucial decisions to secure its power future, including the establishment of diverse power production plants while managing environmental impacts. Ignoring certain energy sources, such as nuclear power, due to political reasons would be unwise.

A diversified energy portfolio, including wind and solar power, is essential. Southern India, particularly Tamil Nadu, has untapped potential for wind and solar energy due to its geographic location. Resolving issues like government payment obligations, which have led to the shutdown of wind farms, can unlock significant power potential. Large-scale solar thermal systems could also be implemented in arid regions.

Urbanisation and increased consumption will drive up electricity demand, needing efficiency improvements. Innovative cooling methods that do not rely on electricity should be promoted, like rainwater harvesting initiatives.

A national grid and uniform distribution system for power production are essential for effective policy and load management. Surplus power from high-production states can be distributed to areas in need. A unified grid ensures fair power distribution and reduces regional disparities.

Incentivising households to adopt off-grid solar panels can provide independence from the grid and allow excess power to be fed back into it, offering vast potential for energy generation and stability.

How SMRs will help in overcoming electricity shortage in India

SMRs would have two vital characteristics – small and modular. These fission reactors tend to have an output of about 300 MWe or less. Their modular design enables for centralized manufacturing in a facility, making them mobile to the intended spot for setup and installation. Unlike typical atomic stations that are built on-site, SMRs may be brought, installed, and begin producing electricity much like an appliance. Furthermore, multiple reactors can be installed as needed. SMRs can be deployed on land, on vessels for offshore operations (also referred to as floating nuclear-powered stations), or even in below-ground or underwater locations. Currently, over 70 SMR concepts are being researched worldwide, ranging from minimally modified old reactors to wholly contemporary technologies. To keep up with the rapid pace of progress and creativity in this field, the (IAEA) organized the SMR Regulators' Forum. This forum allows for the exchange of information about shared topics among countries. In 2021, the IAEA issued a Technology Roadmap for Small Modular Reactor Deployment,[25] which tracks and evaluates SMR technologies and fosters collaboration and knowledge exchange amongst innovation creators, stakeholders in the industry, users, and regulatory organizations.

SMRs signify a groundbreaking progression in power generation. Imagine a university campus or an industrial hub like NTPC, BHEL, or Jamshedpur, powered by a discreet yet robust nuclear plant delivering clean, reliable electricity – this is the promise of SMRs.

[25] International Atomic Energy Agency, *Technology Roadmap for Small Modular Reactor Deployment*, IAEA Nuclear Energy Series No. NR-T-1.18, Vienna: IAEA 2021.

On a global scale, SMRs have the potential to revolutionise energy production. These compact nuclear power plants, designed to produce between 30 MW and 300 MW, are ideal for efficiently powering small communities and industrial sites. SMRs offer several advantages over larger reactors, including the ability to be discreetly installed almost anywhere with proper safety measures. Decommissioned thermal plant sites are particularly suitable, as they already possess essential infrastructure such as power evacuation systems, water access, and storage facilities.

Another innovative application is mounting SMRs on maritime barges, which allows for flexible transport to coastal areas. An example of this concept is the 200 MW Taneer Bhavi plant, formerly owned by the GMR group, which demonstrated the feasibility of barge-mounted power plants.

The modularity and standardisation of SMRs are significant strengths. Standardised designs enable mass production, making deployment more cost-effective. The maritime sector has already demonstrated the effectiveness of small nuclear plants, as seen with India's INS Arihant, which houses an 83 MW nuclear reactor.

India: the path ahead with SMRs

India operates 23 atomic reactors, most with a capacity of 220 MWe, and has also constructed an 85 MWe facility for its atomic submarine, demonstrating its ability to design, build, and operate small reactors. Although India hasn't yet utilised modular factory processes, the nuclear equipment manufacturing industry could adapt if the nuclear establishment priorities such reactors.

Recognising SMRs' potential, India's Department of Energy is developing this technology. Kamlesh Nilkanth Vyas, former Secretary of the Department of Atomic Energy (DAE) and Chairman of the Atomic Energy Commission, stated in 2019[26] that designing and refining reactor systems is an ongoing process, but technology development for SMRs needs to fill current gaps before continuing seriously.

[26] *12 More Nuclear Power Plants on the Cards for India*, https://www.iamrenew.com/green-energy/a-dozen-more-nuclear-power-plants-on-the-cards-for-india/ [access: 30 August 2024].

While the DAE monitors SMR advancements, its current focus is on enhancing existing reactors. Progressing from 220 MWe to 540 MWe and 700 MWe, India aims to rapidly expand nuclear electricity generation. The Indo-US nuclear cooperation agreement sought to enable larger reactor imports, although these have faced price and liability issues. Meanwhile, India has successfully developed 700 MWe reactors indigenously.

For a country with growing electricity demand, large reactors are clearly justified. However, SMRs could be useful in specific scenarios, such as replacing decommissioned coal plants. Shrikumar Banerjee, another former Chairman of the Atomic Energy Commission, suggested that some decommissioning coal power plants could be replaced with SMRs, helping to combat air pollution and meet Paris Agreement goals. SMRs could also supplement renewable energy by providing a reliable baseload power source and serve remote areas or islands.

Despite the promising outlook, it remains uncertain whether SMRs will deliver the transformative impact they promise. The urgency for low-carbon electricity has generated significant interest, presenting a major investment occasion for the atomic industry. India must explore options, particularly through private sector involvement. The DAE/Nuclear Power Corporation of India (NPCIL) could support private players in building such reactors once a design is proven. The government could further incentives this through production-linked incentive schemes. Recent atomic collaboration agreements with republics like France, the USA, South Korea, and Russia also include potential collaborations on SMRs.[27]

However, given India's electricity needs, SMRs should be given as much priority by the DAE, as larger nuclear reactors. Developed countries pursuing SMRs are often dealing with stable or stagnant electricity demand and population growth. For them, SMRs represent a way to keep the nuclear industry active and promote new nuclear builds in regions with stalled reactor construction or potential for exports. Diverting significant resources towards SMRs would detract from the focus on quickly constructing planned larger reactors to boost India's power supply in an eco-friendly manner. Long-term policy support is crucial to achieve the timely completion of these larger reactor projects.

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[27] Anil Sasi, *20 years after nuclear deal, New Jersey firm's proposal for small reactor opens a door*, https://indianexpress.com/article/business/20-years-after-nuclear-deal-new-jersey-firms-proposal-for-small-reactor-opens-a-door-9607315/ [access: 30 August 2024].

Atomic energy can play a significant role in clean power shifts

Atomic power plays a crucial role in energy manufacturing, providing 10% of the worldwide energy supply in 2018. In progressive economies, it books for 18% of production and is the leading low-carbon electricity source. However, its share of global energy supply has been decreasing, mainly due to ageing nuclear fleets in advanced economies, the slow addition of new capacity, and the retirement of reactors constructed in the 70s and 80s of the previous century. This decline has hindered progress in the direction of a clean energy system. Notwithstanding significant progress in solar and wind energy, the complete portion of green power in the entire energy supply in 2018 remained at 36%, equivalent to the past two decades, because of the reduction in atomic power. Reversing this trend is essential to accelerating the decarbonisation of energy supply.

A variety of innovations, notably atomic electricity, will be necessary for worldwide sustainable power transitions. As the worldwide power system grows progressively power-based, the key for greening power systems is to change the power sector from the most significant CO_2 emitter into a low-carbon source that cuts fossil fuel emanations in conveyance, heating, and industrial use. While green sources will continue to lead, nuclear power, combined with fossil fuels using carbon capture, utilization, and storing, can also play an important role. Countries planning to integrate nuclear technology in their future power mix account for majority of the world demand for energy and CO_2 emissions. To line with sustainability aims and international environmental objectives, the spread of renewable energy must be three times quicker than it is now, needing 85% of worldwide energy to originate from renewable sources by 2040, in contrast to 36% today. This would need significant expenditures in efficiencies and renewables, coupled with an 80% rise in worldwide nuclear power generation by 2040.

Nuclear power facilities boost electrical security in numerous ways. They assist stabilise power grids and can modify their procedures to fit requirements and supply changes. As the share of renewable energy sources like wind and solar photovoltaics (PV) increases, the necessity for such services will expand. Atomic reactors can offset the effects of seasonal variations in renewable output and boost power safety by lowering reliance on imported fuels, especially in India, which experiences varied temperatures and weather conditions throughout the year.

Lifetime extensions of atomic reactors are vital to bring the energy shift back on track

Policy and regulatory choices are grave for the replacement of old reactors in prosperous nations, where the average age of an atomic fleet is 35 years. The European Union and the United States have the oldest and biggest atomic fleets, both surpassing 100 gigawatts, with median age of reactors between 35 and 39 years, respectively. Most reactors were initially built for a 40-year service lifespan. By 2025, around one-fourth of present-day nuclear capacity in industrialized economies will be heading for a shutdown, mostly due to regulations aimed at diminishing nuclear energy's role. The eventual utilization of the residual capacity rests on choices concerning lifetime renewals in the years that follow. In the US, around 90 reactors have 60-year licenses to operate, however seven were deactivated early, and several more are facing the risk of shutting down. In Europe, Japan, and other industrialized economies, opportunities for extending plant lifespan are equally questionable.

Economic variables play a crucial effect as well. Prolonging the lifespan of current reactors is considerably less expensive than constructing new ones and affordable with other energy generation methods, notably new wind and solar projects. However, major expenditure is still necessary to repair and renovate crucial components to ensure continuing safe operation. Low wholesale power and carbon prices, coupled with new limitations on water use for chilling reactors, render certain plants in the United States commercially unfeasible. Furthermore, markets and regulatory institutions sometimes penalize atomic power by disregarding its worth as an environmentally friendly power source and its involvement in electrical security. Therefore, most atomic power stations in industrialized economies are at danger of untimely closure.

Selective privatization of SMRs in India: a strategic approach to balancing energy demand, sustainability, and security

India's energy sector stands at a crucial juncture where balancing increasing demand with sustainability and security is imperative. Amidst this challenge, Small Modular Reactors (SMRs) present an innovative solution that warrants selective privatization within the nuclear sector. Unlike

traditional large-scale reactors, SMRs offer several advantages, including reduced capital costs, shorter construction timelines, and enhanced safety features, making them particularly suitable for private sector involvement. India has lofty plans to become a leading power in harnessing electricity from SMRs. This was evident by the revelation by India's Finance Minister, Ms. Nirmala Sitharaman in her Budget Speech[28] on 23rd July 2024, of plans to take the route of Private-Public Partnerships to develop 220-megawatt SMR called 'Bharat Small Reactor'. Following her speech, the Tata Group announced that it would be collaborating with the Department of Atomic Energy to set up 40–50 BSRs in the coming decade.

Privatizing the entire nuclear sector is neither necessary nor advisable given the strategic and security implications associated with nuclear technology. However, selectively allowing private companies to invest in and develop SMRs could significantly benefit India's energy landscape. SMRs are designed to be modular and factory-built, which not only reduces construction costs but also ensures a consistent and scalable approach to expanding nuclear capacity. This modularity also allows for flexible deployment in various locations, including remote areas, thereby enhancing energy access and grid stability.

The involvement of the private sector can drive technological innovation and operational efficiency in the development of SMRs. Private companies, driven by competitive market forces, are likely to invest in advanced research and development to improve reactor designs, enhance safety measures, and lower operational costs. This can lead to the rapid commercialization of SMR technology, making nuclear energy more accessible and cost-effective.

Moreover, private sector participation can attract substantial investment, both domestic and international. Such investments are crucial for overcoming the financial limitations of government-funded projects and accelerating the deployment of SMRs. By fostering a robust supply chain and industrial base for nuclear components and services, private sector involvement can also create high-skill jobs and spur economic growth.

To facilitate this selective privatization, it is vital to create a clear and supportive regulatory framework. This framework should differentiate

[28] Speech of Nirmala Sitharaman, Minister of Finance, Budget 2024-2025, https://www.indiabudget.gov.in/doc/bspeech/bs2024_25.pdf [access: 30 August 2024].

SMRs from traditional nuclear reactors, addressing specific licensing, safety, and liability issues. Streamlined regulatory processes can reduce bureaucratic hurdles and provide clarity and assurance to private investors. Additionally, policies that promote public-private partnerships, offering inducements such as tax breaks, subsidies, and grants, can further inspire private sector participation.

Public perception and acceptance are vital for the success of nuclear projects. Therefore, extensive awareness campaigns are necessary to highlight the safety features and environmental benefits of SMRs. Transparent communication and community engagement can help address fears and misconceptions about nuclear energy. Demonstrating the reliability and safety of SMRs through pilot projects can build public trust and pave the way for broader acceptance of privatized nuclear initiatives.

Going by media reports, elaborate discussions are on-going at the highest levels to evaluate the effectiveness of SMRs. The Prime Minister of India, on his recent visit to the USA met with the promoter of Holtec International – considered to be one of the largest exporters of capital nuclear components. Holtec, a small privately held company has proposed a private-public partnership to deploy 'its proposed SMR-based projects and the possibility of joint manufacturing at some point in the future'. This has come as the first tangible beacon of light in a two-decade long tunnel of time since India and the US had their civil nuclear agreement.[29]

Regulatory Framework for Small Modular Reactors (SMRs) in India: Drawing Parallels with Digital Economy Regulations to Enhance Energy Security and Sustainability

India's evolving energy landscape necessitates the implementation of regulations for Small Modular Reactors (SMRs) similar to how the country has approached regulation in other critical sectors. The strategic deployment of SMRs can significantly enhance India's energy security, reduce carbon emissions, and address the growing demand for electricity. However, just as with other advanced technologies, the integration of SMRs requires a robust regulatory framework to ensure safety, efficiency, and public confidence.

The need for regulation of SMRs can be likened to previous regulatory milestones in India, such as the regulation of the digital economy

[29] Anil Sasi, *20 years after nuclear deal…*

through the Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021,[30] and the regulatory oversight established by the Data Protection Bill. These regulations were implemented to address new challenges posed by technological advancements and to protect the interests of users and stakeholders. Similarly, the landmark case of *Internet and Mobile Association of India vs. RBI*[31] underscores the necessity of creating clear and supportive regulatory environments for emerging sectors to foster growth while safeguarding public and national interests.

The IT Rules (2021) were introduced to regulate digital content, curb misinformation, and protect user data, reflecting the government's proactive stance in adapting to the digital age. These regulations provided much-needed clarity and guidelines for intermediaries and digital media, ensuring accountability and transparency. This approach is crucial for SMRs, where clear regulations can address safety standards, operational protocols, and emergency response measures, thereby mitigating risks associated with nuclear technology.

In the context of the Data Protection Bill, the emphasis on safeguarding personal data and ensuring privacy parallels the necessity for stringent safety and security measures in the atomic sector. Just as the Data Protection Bill aims to protect individual privacy and foster trust in digital services, SMRs regulations would aim to protect public health and safety, build public trust in nuclear energy, and promote environmental sustainability. Comprehensive regulations would encompass site selection, design approval, construction standards, operational safety, waste management, and decommissioning procedures.

The precedent set by the *Internet and Mobile Association of India vs. RBI* case highlights the importance of creating enabling regulatory frameworks that do not stifle innovation. In this case, the Apex Court struck down the RBI's blanket ban on cryptocurrency transactions, emphasizing the need for balanced regulation that fosters innovation while addressing potential risks. Similarly, regulations for SMRs should be designed

[30] *The Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules*, 2021, https://www.meity.gov.in/static/uploads/2024/02/Information-Technology-Intermediary-Guidelines-and-Digital-Media-Ethics-Code-Rules-2021-updated-06.04.2023-.pdf [access: 30 August 2024].

[31] Supreme Court of India, *Internet And Mobile Association Of ... vs Reserve Bank Of India on 4 March, 2020*, https://indiankanoon.org/doc/12397485/ [access: 30 August 2024].

to encourage technological innovation and private sector participation without imposing overly restrictive barriers. By fostering a conducive environment for SMR development, India can attract investments, both domestic and international, and accelerate the deployment of this clean energy technology.

The Digital Personal Data Protection Act (DPDP)[32] underscores the importance of safeguarding public interest while embracing technological advancements. Regulations for SMRs would similarly need to prioritize public safety and environmental protection while enabling the deployment of advanced nuclear technologies. This balanced approach would ensure that the benefits of SMRs, such as lower carbon emissions and reliable power supply, are realized without compromising safety or public trust.

Evolving India's Legal Framework: Drawing Constitutional Parallels for Regulating Small Modular Reactors (SMRs) India's legal framework is dynamic, evolving to meet new challenges and opportunities

This adaptability is enshrined in the Indian Constitution,[33] which allows for amendments to address the changing needs of society. The regulatory landscape for Small Modular Reactors (SMRs) can be shaped by this same flexibility, ensuring that the deployment of this innovative technology is both safe and efficient. Several landmark cases illustrate how the Indian Constitution has evolved over time to reflect contemporary realities, which support the argument for the establishment of a regulatory framework for SMRs.

One of the most significant cases demonstrating the Constitution's flexibility is ***Kesavananda Bharati v. State of Kerala* (1973)**.[34] This case recognized the doctrine of the basic structure, which states that while the Constitution can be amended, its fundamental framework cannot be altered. This decision underscored the importance of a balance between change and stability, allowing for progressive amendments while

[32] The Digital Personal Data Protection Act, 2023, https://www.meity.gov.in/static/uploads/2024/06/2bf1f0e9f04e6fb4f8fef35e82c42aa5.pdf [access: 30 August 2024].

[33] The Constitution of India, https://www.indiacode.nic.in/bitstream/123456789/19150/1/constitution_of_india.pdf [access: 30 August 2024].

[34] Supreme Court of India, *Kesavananda Bharati Sripadagalvaru ... vs State Of Kerala And Anr on 24 April, 1973*, https://indiankanoon.org/doc/257876/ [access: 30 August 2024].

preserving core principles. The doctrine established by the Supreme Court of India has enabled numerous amendments that have progressively modernized India's legal and regulatory environment, paving the way for new policies and frameworks that address emerging technologies like SMRs.

Similarly, the case of ***Minerva Mills Ltd. v. Union of India*** **(1980)**[35] reinforced the idea that the Constitution's amendments should not destroy its essential features, but allowed for necessary changes to facilitate the nation's progress. This case highlighted the need for a responsive legal system that can adapt to new developments, which is crucial for integrating advanced nuclear technologies. By drawing on this precedent, India can develop specific regulations for SMRs that align with modern safety and environmental standards while upholding constitutional principles.

The ***S. R. Bommai v. Union of India*** **(1994)**[36] case further exemplifies the Constitution's adaptability. This ruling clarified the scope of federalism in India, showing that the Constitution could accommodate changes in the political and administrative structures to better serve the nation's needs. Similarly, regulating SMRs will require a collaborative approach between the central and state governments to guarantee that these reactors are deployed in a manner that maximizes their benefits while minimizing risks.

The introduction of the **Goods and Services Tax (GST)**[37] in 2017 is a contemporary example of significant constitutional change to address economic needs. The 101st Amendment Act[38] unified the taxation system across the country, demonstrating the Constitution's ability to adapt to economic and administrative requirements. This precedent supports the argument for amending regulatory frameworks to accommodate SMRs, ensuring that India's energy policies are as modern and efficient as its economic policies.

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[35] Supreme Court of India, *Minerva Mills Ltd. & Ors vs Union Of India & Ors on 31 July, 1980*, https://indiankanoon.org/doc/1939993/ [access: 30 August 2024].

[36] Supreme Court of India, *S.R. Bommai vs Union Of India on 11 March, 1994*, https://indiankanoon.org/doc/60799/ [access: 30 August 2024].

[37] Goods and Services Tax, https://services.gst.gov.in/services/gstlaw/gstlawlist [access: 30 August 2024].

[38] The Constitution (One Hundred and First Amendment) Act 2016, https://gstcouncil.gov.in/sites/default/files/2024-02/consti-amend-act.pdf [access: 30 August 2024].

Impact on India after adopting SMRS[39]

The adoption of (SMRs) in India has the potential to significantly impact the country's economy, presenting both opportunities and challenges. By diversifying the energy mix, SMRs can improve energy security and decrease dependency on imported traditional fuels. This diversification minimizes risks associated with supply disruptions and volatile international energy prices, contributing to a more stable economic environment. Furthermore, SMRs provide a reliable source of electricity, essential for continuous industrial operations and economic activities. This reliability can help mitigate power outages that currently hinder productivity and economic growth.

The development and deployment of SMRs can also stimulate the domestic manufacturing sector. India has the potential to become a hub for SMR production, creating jobs and fostering technological advancements. Additionally, the modular nature of SMRs allows for deployment in remote and underserved regions, promoting regional development and reducing urban-rural economic disparities. This regional development can lead to a more balanced economic growth across the country.

The growth of the SMR sector can create numerous high-skilled jobs in engineering, construction, operation, and maintenance. The demand for a highly skilled workforce in the nuclear industry will likely lead to increased investment in training and education, enhancing the overall skill level of the workforce and creating long-term human capital benefits. This investment in human capital is crucial for sustaining the growth and development of the nuclear sector.

Adopting SMRs can also bring significant environmental and health benefits. By replacing coal and other fossil fuels with nuclear power, SMRs can substantially reduce air pollution, leading to healthier population and decreased healthcare costs. Additionally, the low carbon footprint of nuclear energy can help India meet its climate change goals, avoiding economic damages associated with climate change impacts. This dual benefit of improving public health and mitigating climate change is essential for sustainable economic development.

[39] *A Report on the Role of Small Modular Reactors…*

The economic impact of SMRs is further amplified by their potential to attract both domestic and international investments. The advanced nuclear technologies embodied in SMRs can foster economic growth by drawing investments into infrastructure, services, and supply chains. This investment can lead to positive multiplier effects across the economy, creating new business opportunities and stimulating economic activity.

However, the adoption of SMRs also presents significant challenges and costs. The initial investment required for SMR development and deployment is high, and financing these projects could strain public finances or necessitate substantial private investment. Ensuring robust regulatory frameworks and safety standards for SMRs is essential but can be complex and time-consuming, potentially delaying economic benefits. Effective management of nuclear waste remains a critical challenge that requires long-term solutions, incurring additional costs.

The adoption of SMRs can spur innovation and technological advancement in nuclear technology and related fields, positioning India as a leader in atomic research and development. By advancing in SMR technology, India can enhance its global competitiveness in the energy sector, potentially exporting SMR technology and expertise to other countries. This global competitiveness can open up new markets and create additional economic opportunities.

In summary, the adoption of SMRs in India presents a transformative opportunity with the potential for significant economic benefits, including enhanced energy security, job creation, regional development, and environmental improvements. However, these benefits must be weighed against the challenges of high initial costs, regulatory hurdles, and waste management. Strategic planning and investment will be crucial to maximizing the positive economic impact of SMRs on India's economy.

Impact on treasury of India after adopting SMRs

The adoption of Small Modular Reactors (SMRs) in India is poised to impact the country's treasury across various dimensions, encompassing both expenditures and potential revenue streams. Initially, substantial investments would be required for infrastructure development, including the construction of nuclear power plants and associated grid integration. Moreover, research and development efforts aimed at adapting SMR technology, enhancing safety standards, and ensuring regulatory compliance would necessitate significant financial allocations. Establishing

robust regulatory frameworks would also incur costs related to licensing, inspections, and monitoring activities.

Once operational, SMRs would entail ongoing costs for maintenance, fuel procurement, and waste management, necessitating continued financial support from the treasury. However, the electricity generated by SMRs would provide a steady revenue stream through its sale to the national grid. Additionally, India could capitalize on export opportunities by leveraging its expertise in SMR technology, thereby generating substantial revenue and bolstering economic growth.

The deployment of SMRs is expected to excite economic activity and create employment occasions across various sectors, leading to increased tax revenues for the government. Indirect taxation, such as goods and services tax (GST) and excise duties, would also see an uptick due to heightened consumption and business activity.

In conclusion, while the adoption of SMRs in India would necessitate significant upfront investments and ongoing operational costs, it also presents promising opportunities for revenue generation, economic expansion, and technological advancement. Effective financial planning, strategic investments, and regulatory frameworks will be critical to optimizing the positive impact of SMRs on India's treasury and overall economy.

Impact on energy sector of India after adopting SMRs

The adoption of SMRs in India holds the promise of a transformative shift in the nation's energy sector, touching upon various dimensions from energy generation to environmental sustainability and energy security. By integrating SMRs into the energy mix, India can diversify its energy sources, dropping dependence on traditional fuels and bolstering energy security. These reactors offer reliable base load power, complementing intermittent renewables like solar and wind energy, ensuring a stable electricity supply to meet rising demand. Additionally, SMRs enable capacity expansion, contributing to overall electricity generation and meeting the energy demands of a rapidly developing economy.

In terms of environmental impact, SMRs provide a low-carbon energy alternative, aiding India's efforts to decrease its carbon footprint and battle climate change. By displacing coal-fired power plants, SMRs can significantly mitigate greenhouse gas emissions and improve air quality

by decreasing pollutants like sulphur dioxide and nitrogen oxides, benefiting public health and environmental quality.

The adoption of SMRs would stimulate innovation and research in nuclear technology, fostering advancements in reactor design, safety features, and operational efficiency. This could position India as a leader in nuclear technology development and offer opportunities for skill development and capacity building in the nuclear energy sector, enhancing the expertise of Indian scientists, engineers, and technicians.

Moreover, SMRs could play a crucial role in rural electrification efforts, providing clean and reliable electricity to remote and off-grid areas where conventional grid infrastructure is inadequate. While the initial investment in SMRs may be substantial, the long-term operational costs could be competitive compared to other energy sources, contributing to energy affordability and reducing the financial burden on consumers.

In terms of energy security, SMRs offer the potential to reduce India's dependency on imported conventional fuels, bolstering energy security and decreasing vulnerability to geopolitical risks associated with energy imports. These reactors can also bolster grid steadiness by offering a steady and continuous energy supply, thereby reducing the risk of blackouts and ensuring reliable electricity supply for industrial and commercial activities.

Overall, the adoption of SMRs in India represents a significant opportunity to revolutionize the country's energy sector, offering a sustainable, reliable, and low-carbon energy solution that addresses key challenges such as climate change, energy access, and energy security. Effective policy support, investment in infrastructure, and collaboration with international partners will be crucial for comprehending the full potential of SMRs in India's energy shift journey.

Impact on environment of India after adopting SMRs

The adoption of SMRs in India is poised to have a substantial impact on the environment, offering both benefits and challenges in the context of sustainability and ecological preservation. One of the prime environmental benefits of SMRs is their ability to produce electricity with minimal carbon emissions. Unlike traditional conventional fuel-based power facilities, which produce great quantities of carbon dioxide (CO_2) and other pollutants which are left into the atmosphere, SMRs generate

electricity through nuclear fission, emitting virtually no greenhouse gases during operation. This reduction in carbon emissions can contribute significantly to India's pains to battle climate change and diminish its overall carbon footprint. By replacing coal-fired power plants with SMRs, India can recover air quality and alleviate the harmful effects of air pollution on public health and the environment. Coal combustion releases various pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM), which contribute to respiratory diseases, smog formation, and environmental degradation. SMRs offer a cleaner alternative, producing electricity without emitting these harmful pollutants, thus promoting better air quality and environmental well-being. SMRs also require significantly less land and water resources compared to traditional fossil fuel-based power plants. Coal mining and natural gas extraction, which are integral to conventional power generation, often entail habitat destruction, water pollution, and ecosystem disruption. In contrast, SMRs operate within a compact footprint and do not rely on large-scale resource extraction, thereby minimizing their environmental impact and conserving precious natural resources. While SMRs produce radioactive waste as a byproduct of nuclear fission, advancements in nuclear technology have enabled more efficient and safer waste management practices. Proper disposal and storage of nuclear waste are essential to avert environmental contamination and safeguard public health. India would need to develop robust waste management substructure and regulatory outlines to guarantee the safe treatment and long-term storage of radioactive materials generated by SMRs. Despite their environmental benefits, SMRs also pose certain environmental risks, particularly related to nuclear accidents and radioactive contamination. While modern SMR designs incorporate progressive safety features to minimalize the likelihood of accidents, the potential consequences of a nuclear incident could be catastrophic for the environment and human health. India must prioritize stringent safety standards, regulatory oversight, and emergency preparedness measures to mitigate these risks and ensure the safe operation of SMRs. Overall, the adoption of SMRs in India has the ability to substantially diminish carbon emissions, recover air quality, and conserve natural resources, thereby giving a share to a more sustainable and environment-friendly energy landscape. However, it is imperative for India to address the environmental challenges associated with nuclear energy, implement stringent safety measures, and invest in

sustainable waste management practices to maximize the environmental benefits of SMRs while minimizing their potential risks.

Nuclear audit authority; a step towards welcoming SMRS

Recently, the Government of India has also advanced a step towards welcoming SMRs in India by announcing to setup a Nuclear Audit Committee which is ought to be bestowed with the responsibility to promote Bharat Small Reactors by working hands in gloves with the IAEA. At the same time, the government is further planning to bring in key and significant developments in the Civil Liability pertaining to and arising out of The Civil Liability for Nuclear Damage Act, 2010[40] paving way for attracting investments in SMRs in India.

The way forward

SMRs have the potential to offer clean electricity, hydrogen, and process heat, making them versatile solutions for various energy needs.[41] They can provide stable baseload electricity while also supporting the incorporation of renewable energy sources into the grid. Additionally, SMRs can aid non-electric utilisations like desalination and district heating, and micro SMRs can supply both energy and heat to remote populations. While SMR technologies like PWR and PHWR have reached a mature stage, others such as HTGR, LMFR, and MSR are still in the research and development phase. Safety standards and legal frameworks have been established for some reactor types, but others require further development. Challenges may arise during the deployment of innovative SMR designs, necessitating adjustments to legal, regulatory, and safeguards outlines. Initial demonstration of SMR plants can mitigate risk perception, attract investment, and stabilize the industry. Harmonization of licensing and regulatory approaches, along with government support, is vital for the evolution of the global SMR market under net-zero

[40] The Civil Liability for Nuclear Damage Act 2010, https://www.indiacode.nic.in/bitstream/123456789/2084/5/A2010-38.pdf [access: 30 August 2024].

[41] PK/PSM, *'India's Nuclear Power generation capacity…*

emissions initiatives. To render a worthy role in climate change extenuation, first-of-a-kind SMR units should be deployed by the early 2030s. Successful deployment of SMRs requires leveraging private sector investment and establishing a technology-neutral policy framework that considers factors like taxonomies and environmental, social, and governance criteria.

PART III

NUCLEAR LIABILITY AND TRANSPORT

Chapter 6

NUCLEAR DAMAGE CLAIMS REGULATION IN POLAND: ANALYSIS AND DIAGNOSIS

Patrycja Nowakowska
Attorney-at-law, Counsel at KKG Legal Kubas, Kos, Gałkowski i Wspólnicy sp.k.
Kraków, Poland
patrycja.nowakowska@kkg.pl
ORCID: 0009-0009-6082-9025

Abstract

The construction of Poland's first nuclear power plants is scheduled for the upcoming decade. This presents an opportunity to review the legal framework that will govern nuclear power plants once they become operational, particularly regulations concerning claims for nuclear damage. The Vienna Convention does not address the specifics of claims procedures, establishing only general rules. A particular challenge in the claims process is the multitude of claimants seeking compensation compared to the limited amount of funds available. This necessitates the adoption of rules for the satisfaction of claims, including the distribution of available funds and order of satisfaction. Polish regulations concerning claims are incomplete. In procedural terms, the Atomic Law Act requires the establishment of a limitation of liability fund if the amount of the liability limit is insufficient to satisfy all claims. However, there is no autonomous regulation regarding substantive law principles for the distribution of the available amount. The Atomic Law Act refers to the Civil Code

and the Maritime Code. The Maritime Code refers to LLMC. This gives rise to interpretive uncertainties. Poland, therefore, faces the challenge of regulating the issue of claims in advance, both in terms of out-of-court settlement and the procedure for mass litigation, as well as substantive law principles for the distribution of the available amount. A revision of the regulations seems necessary.

1 Introduction

Poland is developing its nuclear energy program, with the first installations expected to commence operations within the next decade. This presents an opportune moment to revise the existing legal framework governing nuclear power plants, particularly during their operational phase. Regulations pertaining to the pursuit of claims for nuclear damage warrant particularly close scrutiny, especially in light of international law and contemporary legislative trends. The rules governing the claims process should be designed to ensure speedy and efficient proceedings, enabling both liable entities and claimants to conclude compensation processes promptly and smoothly without undue or additional costs.[1] In particular, the experience gained from the Fukushima accident has highlighted the critical role of a precise claims process[2] in situations where hundreds of thousands of individuals may be affected.[3] Regardless of the merits of the claims, the operator, insurer, and, ultimately, the court must be equipped to handle this immense organizational challenge.[4]

Poland is a party to the Vienna Convention on Civil Liability for Nuclear Damage of 21 May 1963,[5] and has also acceded to the Protocol Amending the Vienna Convention of 12 September 1997[6] and the Joint

[1] *See* R. Majda, *Cywilna odpowiedzialność za szkodę jądrową w polskim prawie atomowym*, Łódź: Uniwersytet Łódzki 2006, p. 260.

[2] The system adopted in Japan evolved over time, and it was essentially working on a living organism. *See* more E. Feldman, *Fukushima: Catastrophe, compensation and justice in Japan*, "DePaul Law Review" 2013, Vol. 62, No. 335, p. 352.

[3] *See* N. Pelzer, *Facing the challenge of nuclear mass tort processing*, "Nuclear Law Bulletin" 2017, Vol. 99, No. 1, p. 45.

[4] Ibid., p. 46.

[5] Official Journal of Laws "Dziennik Ustaw" 1990, No. 63, item 370.

[6] Official Journal of Laws "Dziennik Ustaw" 2011, No. 4, item 9.

Protocol Relating to the Application of the Vienna Convention and the Paris Convention (on Nuclear Third Party Liability) of 21 September 1988.[7] However, it is not a party to the CSC.

Domestically, the principles of civil liability for nuclear damage have been implemented into the Act of 29 November 2000 – the Atomic Law[8] (Articles 100–108). Polish law generally complies with the fundamental principles of the 1997 Vienna Convention and implements the liability rules derived therefrom. However, in terms of the rules for claiming compensation, the Atomic Law introduces an original solution that may give rise to interpretative doubts – the limited liability fund (Article 102(2)).

The Atomic Law does not establish a comprehensive, autonomous set of procedural and substantive rules for the compensation of nuclear damage. Deciphering the relevant norms requires reference to numerous legal acts. Consequently, a pertinent question in the current state of affairs is whether the law fulfills its intended purpose despite the dispersion of regulations. Regarding procedural norms, this purpose is the efficient and prompt payment of compensation to victims, with the operator's resources being used rationally. Indeed, in the event of a significant-scale accident, where hundreds or thousands of claims are anticipated, it is evident that as the duration of the claims settlement process increases (whether through litigation or other solutions), the operator's costs of handling these claims will rise proportionally. In terms of substantive legal grounds, the goal should be a fair distribution of available funds to compensate victims to the fullest extent possible. The challenge lies in the multiplicity of creditors in conjunction with the limited amount of funds available to satisfy their claims. In the current state of affairs (both legislative and in terms of the organizational realities of the Polish judiciary), the demands for speed and equitable distribution of funds may be practically impossible to meet without detailed, dedicated regulations. Although the risk of a large-scale accident is very low, if such an event were to occur, the dynamics of the situation would not permit the ongoing refinement of these rules.

This article presents a step-by-step analysis of the system of procedural and substantive norms governing the recovery of claims for nuclear

[7] Official Journal of Laws "Dziennik Ustaw" 1994, No. 129, item 633.

[8] Consolidated text as published in the Official Journal of Laws "Dziennik Ustaw" 2024, item 1277.

damage under Polish law. The aim of this analysis is to assess the existing legal framework and identify legislative areas that do not meet the aforementioned criteria. This enables the formulation of several *de lege ferenda* proposals.

2 The Legal Framework for Pursuing Claims for Nuclear Damage in Poland

The Atomic Law does not establish a comprehensive, autonomous set of procedural and substantive rules for the redress of nuclear damage. Rather, it is a mosaic of numerous provisions scattered across various legal acts. Procedural rules, in particular, are only partially regulated in an autonomous manner within the Atomic Law. According to Article 100a(1) of the Atomic Law, the redress of nuclear damage occurs on the basis of the provisions of the Civil Code, subject to the exceptions provided for in the Act. Moreover, pursuant to Article 107(2) of the Atomic Law, in matters of compensation, to the extent not regulated in Chapter 12, the provisions of the Civil Code also apply. The provision regarding compensation is superfluous in light of the broader concept of damage reparation (redress). For court proceedings concerning compensation, the provisions of the Code of Civil Procedure shall apply (Article 106(2) of the Atomic Law). In terms of subject-matter jurisdiction, pursuant to Article 106(1) of the Atomic Law, where nuclear damage has resulted from a nuclear accident on the territory of the Republic of Poland, cases relating to the recovery of claims for nuclear damage fall within the subject-matter jurisdiction of district courts.[9]

[9] The Act does not, however, specify exclusive local jurisdiction, so the general rule in this regard must be assumed, which in practice means that the district court having local jurisdiction over the defendant's registered office, and thus primarily the operator, will be the competent court (Article 30 of the Code of Civil Procedure). Nevertheless, the provisions of the Act provide for the possibility of claiming compensation for nuclear damage directly from the insurer, and in the event of the insurer's failure to fully compensate the damage, the subsidiary liability of the State Treasury for nuclear damage, but limited to the amount of 300 million SDR. Since there may be at least two defendants independently, this means that different courts may have local jurisdiction to hear the cases.

A particularly unique feature of the Atomic Law is the limited liability fund (Article 102(2) et seq.), which, presumably, was intended to serve as a mechanism for consolidating all claims within a single legal proceeding and possibly establishing rules for distributing the fund among the victims. The institution of the limited liability fund was included in the original version of the Act of 2000, but a detailed explanation and justification for introducing these regulations cannot be found in the explanatory memorandum to the draft.[10] The provisions of the Act of 18 September 2001—the Maritime Code[11]—on limiting liability for maritime claims apply *mutatis mutandis* to proceedings concerning the establishment and distribution of the fund, subject to Articles 102(3–5) of the Atomic Law. In turn, the Maritime Code, in the provisions on the limited liability fund, implements the provisions of another international instrument – the Convention on the Limitation of Liability for Maritime Claims, 1976 (LLMC)[12] and the LLMC itself applies directly to the fund itself (Article 339(1) *in fine*).

The 1997 Vienna Convention, as a ratified international treaty, also finds direct application. However, regarding the rules for claiming compensation, the Convention does not provide detailed provisions, leaving this matter to the discretion of the contracting parties. This constitutes an additional argument in favor of the proposition that these rules should be regulated comprehensively in domestic law.

The legal situation outlined above leads to the conclusion that regulation is dispersed and does not constitute a single coherent system. This can, by its very nature, lead to difficulties in applying and interpreting the norms.

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[10] Parliamentary document "Druk Sejmowy" No. 1724 of 15 February 2000.

[11] Consolidated text as published in the Official Journal of Laws "Dziennik Ustaw" of 2023, No. 1309.

[12] Journal of Laws "Dziennik Ustaw" of 2012, No. 146; Article 97(1) of the Maritime Code: 'The liability of a debtor for maritime claims may be limited in accordance with the provisions of the Convention on the Limitation of Liability for Maritime Claims, 1976, done at London on 19 November 1976 (Journal of Laws of 1986, No. 175), as amended by the Protocol done at London on 2 May 1996 (Journal of Laws of 2012, No. 146), hereinafter referred to as the 'Limitation Convention', together with any amendments in force as of the date of their entry into force in respect of the Republic of Poland, which have been properly published.'

3 The Limited Liability Fund

3.1 The Concept

A detailed analysis of the limited liability fund should be made, as an institution dedicated to consolidating claims in a single proceeding, in a situation where the amount specified in Article 102(1) of the Atomic Law (300 million SDR) is insufficient to satisfy all claims. The operator is mandated to establish such a fund in these circumstances. Consequently, a fund would be created in response to any significant nuclear accident.

As mentioned, the provisions of the Maritime Code apply *mutatis mutandis* to proceedings concerning the establishment and distribution of the fund, subject to Article 102(3–5) of the Atomic Law. An additional complication arises from the fact that specific provisions are not listed, and a technique of subject-matter reference is used instead.[13] The provisions on the limited liability fund are generally found in Articles 339–344 of the Maritime Code. However, the reference in the Atomic Law mandates the application of all provisions of the Maritime Code that in any way relate to the establishment of the fund, its distribution, and the limitation of liability for maritime claims. The Maritime Code itself adds an additional layer of complexity, which both implements and directly refers to the LLMC.

The foregoing leads to two significant systemic conclusions:

a. First, from the outset, significant difficulties and doubts will arise at the stage of decoding the norms that should apply, both at the substantive and procedural levels. Additionally, regarding the reference to the Maritime Code, whose provisions, within the scope specified by the legislator, are to be applied *mutatis mutandis*. A need will arise for their appropriate interpretation, adapting

[13] Section 156(4) of the Regulation of the Council of Ministers of 20 June 2002 on 'Principles of Legislative Technique' (consolidated text: Journal of Laws "Dziennik Ustaw" of 2016, No. 283): 'If a given legal institution is regulated as a whole, and an exhaustive list of the legal provisions to which reference is made is not possible, a subject-matter reference may exceptionally be made, provided that these provisions can be unambiguously distinguished from others; the referring provision is formulated as follows: "To ... (definition of the institution) the provisions on ... (subject-matter definition of the provisions) shall apply *mutatis mutandis*."'

them to the proceedings concerning nuclear damage.[14] This may be particularly difficult because, due to the exceptional nature of such events and the status of the Polish nuclear program, no ongoing practice of their application is being developed.

b. Secondly, the reference to the Maritime Code has another important implication. Since the Maritime Code implements the provisions of the LLMC and refers directly to it, in a sense, we are dealing with the penetration into the regime of civil liability for nuclear damage, which is intended to be regulated autonomously in accordance with the rules of the 1997 Vienna Convention and domestic law not inconsistent with the Convention, of another international legal act that does not directly concern this issue.[15] Although both regimes are based on a similar mechanism of a quantitative limitation of liability, the limitation of liability for maritime claims is regulated differently and is of a facultative nature. This creates interpretative challenges and raises doubts from the perspective of public international law.

3.2 Proceedings concerning the determination of the right to establish a fund

Pursuant to Article 102(2) of the Atomic Law, the only party with standing to initiate proceedings for the establishment and distribution of a fund is the operator. Thus, even though Article 104(1) of the Atomic Law grants the insurer passive standing, it cannot initiate fund proceedings. As it follows from Article 339 § 1 of the Maritime Code in conjunction with Articles 102(3) and (4) and Article 106(2) of the Atomic Law, the proceedings are conducted in the form of non-litigious proceedings and are subject to the provisions of the Code of Civil Procedure, as well as—as mentioned—the provisions of the LLMC. The District Court of Warsaw is the competent court for fund proceedings.[16] The application to initiate proceedings must meet the formal requirements specified in Article 102(4) of the Atomic Law and Articles 511 in conjunction with

[14] G. Wierczyński, *Redagowanie i ogłaszanie aktów normatywnych. Komentarz*, Warszawa: Wolters Kluwer Polska 2016, p. 793.

[15] A similar conclusion is drawn by R. Majda. *See* R. Majda, *Cywilna odpowiedzialność za szkodę jądrową…*, p. 262.

[16] Article 102(3) of the Atomic Law.

Articles 187 and 126 of the Code of Civil Procedure and must contain at least the following elements:

a. designation of the court to which it is addressed;
b. designation of the parties (and their legal representatives and attorneys) – in this case, it seems that it is sufficient to designate the applicant, since the other parties to the proceedings are not known at this stage – creditors will only come forward at a later stage of the proceedings. Alternatively, whether the insurer is a party to the proceedings may be considered; however, this is not explicitly stated in the provisions. It may be argued that the insurer should be a mandatory party to these proceedings, both due to its obligations under the insurance contract and its passive standing (Article 104(1) of the Atomic Law);
c. designation of the type of document filed – an application to initiate proceedings for the establishment and distribution of a fund;
d. the substance of the application and statements;
e. the name of the nuclear installation;
f. a statement of the facts on which the party bases its application or statement, and an indication of the evidence to prove each of these facts – from a combined interpretation of Article 126 § 1(5) of the Code of Civil Procedure with Article 102(4), (1) and (2) of the Atomic Law, it follows that the statement of facts will consist primarily of identifying the nuclear accident from which the claims arise, and information about the proceedings aimed at establishing the course of this accident, and determining the type of claims and creditors for whose satisfaction the fund is to be allocated, as well as information about claims already pursued in court that are known to the applicant;
g. information on whether the interested parties have attempted mediation or other alternative dispute resolution, and if such attempts have not been made—an explanation of the reasons for not making them—this requirement resulting from Article 187 § 1(3) of the Code of Civil Procedure in the case of claims for nuclear damage should be understood to mean that the applicant should indicate whether and to what extent the claims arising from the accident have been voluntarily satisfied outside of court proceedings or whether such an attempt has been made. Prior voluntary satisfaction of any claims will have an impact

on the amount of the fund due to the quantitative limitation of liability;

h. a statement of readiness to establish the fund, justification of its amount, and a definition of the method of its establishment;
i. the signature of the applicant (legal representative or attorney) and a list of attachments – in accordance with Article 102(5) of the Atomic Law, the application must be accompanied by documents containing data that affect the amount of the fund.

The filing of an application implies an obligation for the court to conduct a hearing to examine the grounds for establishing the fund.[17] It is assumed that filing an application for the establishment of a fund is not subject to a time limit.[18] After conducting the hearing, the court should issue a preliminary ruling on the right to establish a fund.[19] Already at this stage, due to the differences between the regimes of liability for nuclear damage and maritime claims, doubts arise as to what and how the court should examine before issuing a preliminary ruling. This is primarily because the limitation of liability for maritime claims is facultative,[20] while the mandatory nature of the limitation of liability for nuclear damage results from Article 102(1) of the Atomic Law. In addition, more entities are entitled to benefit from the facultative limitation of liability (Article 1 LLMC). In contrast, according to the principle of direction expressed in Article 101(1) of the Atomic Law, the only liable entity is the operator. Moreover, Article 6 of the LLMC establishes different liability limits depending on the nature of the damage, which should result in the establishment of two sub-funds (separate property masses) – one intended to cover claims for death or personal injury of passengers and the other intended to cover other claims.[21] There is, therefore, a clear doubt as to whether two sub-funds should also be established for nuclear damage.

Even the premise for establishing a fund can give rise to interpretative doubts. Neither the Atomic Law nor the provisions of the Maritime Code

[17] Article 342 § 1 of the Maritime Code.

[18] I. Zużewicz-Wiewiórowska, *Commentary on Article 340 of the Maritime Code*. In: D. Pyć, C. Łuczywek, I. Zużewicz-Wiewiórowska (eds), *Kodeks morski. Komentarz*, Warszawa: Wolters Kluwer Polska 2022, p. 1078.

[19] Article 342 § 1 of the Maritime Code.

[20] I. Zużewicz-Wiewiórowska, *Commentary on Article 340…*, p. 1078.

[21] Ibid., p. 1080.

provide a clear answer on how this assessment should be made – whether it should be based on claims that have already been brought to court or whether it is sufficient to merely report a claim for payment to the operator or insurer? Or perhaps the court should make some kind of approximate estimate, taking into account the scale of the event? In the literature, the view has been expressed that the operator will not be obliged to establish a fund if it only suspects that the total value of claims may exceed the statutory limit, and only when the value of claims exceeds 300 million SDR does this obligation become actual, and until then, claims should be satisfied in full.[22] Although the literal wording of the premise justifies this view, such an interpretation will cause the institution of the fund to fail to fulfil its role of accumulating and satisfying claims in a single proceeding quickly, effectively and fairly. In the event of a large-scale event, for which there will be a high probability of the resulting damage exceeding the statutory limit, waiting to establish a fund until a sufficient number of claims are reported will be inefficient and will not contribute to the fair distribution of available funds. This is all the more justified since the Atomic Law establishes a number of obligations regarding the monitoring of radiation events (Chapter 11). The scale of potential damage could be easily estimated. It is possible to formulate a proposal to change the premise of the mandatory establishment of a fund to the existence of a high probability that claims from a given event will exceed 300 million SDR.

Considering the mandatory content of the application, it can be assumed that the court should examine, as appropriate, whether the applicant has the status of an operator and is liable for claims arising from the incident, whether the claims constitute nuclear damage, and also—taking into account the information contained in the application and the evidence submitted—assess whether the claims exceed the statutory liability limit.[23] However, such an assessment may prove difficult without

[22] R. Orzechowska, *Wpływ różnic między Prawem atomowym a Konwencją wiedeńską o odpowiedzialności cywilnej za szkodę jądrową na osobie na warunki ubezpieczenia odpowiedzialności cywilnej za szkody jądrowe. Część I*, "Prawo Asekuracyjne" 2023, Vol. 117, No. 4, p. 42.

[23] Cf. respectively in the area of maritime claims: D. Pyć, C. Łuczywek, I. Zużewicz-Wiewiórowska (eds), *Kodeks morski…*, p. 1087: 'The preliminary ruling concludes the first stage of the proceedings. The court issues it after conducting a hearing. In the preliminary ruling, the court determines the applicant's right to establish a fund on

the involvement of an expert at this stage. Based on the general rules of evidence in civil proceedings, it can be assumed that a request to take expert evidence would be admissible already in the application. However, there is no explicit statutory regulation in this area.

According to Article 342 § 1 of the Maritime Code, a preliminary ruling on the right to establish a fund shall specify its amount and method of establishment, as well as the deadlines for the payment of sums or for the submission of security documents in a specified manner. The court has discretion to determine the method of establishing the fund – it may be established by paying an appropriate amount of money into an interest-bearing bank account held by the court, or by securing the payment of this amount by a bank or insurance company with its registered office in the Republic of Poland. Considering the obligation to conclude an insurance contract contained in Article 103 of the Atomic Law, it should be assumed that the primary method of establishing a fund in the case of nuclear damage should be the establishment of security by the insurer with whom the contract was concluded, provided that it has its registered office in Poland. If there are circumstances that preclude the establishment of a fund, the court shall refuse to establish it. In the event of a dispute as to these circumstances, the court may suspend the proceedings until the dispute is resolved through a lawsuit. At the applicant's request, the court may, to secure the claim, order the suspension of enforcement proceedings conducted to satisfy a claim covered by the fund (an optional element of the application), and a complaint lies against such a ruling. On the other hand, an appeal lies against the ruling on the right to establish a fund.

3.3 Proceedings Concerning the Establishment of a Fund

The finality of a positive preliminary ruling opens the next stage of the proceedings – the actual establishment of the fund. The applicant must fulfill the obligations imposed on them by the preliminary ruling within a specified time. Pursuant to Article 343 § 1 of the Maritime Code, the

account of its liability for maritime claims arising from a specific event, indicates the amount of the fund, determines the manner and deadline for completing the actions necessary for its establishment, and specifies the type of claims subject to limitation to the amount of the fund. The court should consider whether the subjective and objective conditions for establishing a limited liability fund are met and whether there are any circumstances excluding the establishment of the fund.'

court, after conducting another hearing, shall issue a ruling on the establishment of the fund and the commencement of divisional proceedings or on the refusal to establish the fund. This ruling may be appealed.

It is important to determine the effects that arise upon the finality of the ruling establishing the fund. In this regard, Article 343 § 3 of the Maritime Code refers to Article 13 of the LLMC.[24] The evident influence of another international legal act that does not concern civil liability for nuclear damage is noticeable here. While Article 13(1) of the LLMC is unambiguous, paragraph 2 is not as clear. This provision regulates institutions specific to maritime claims, such as the release of a ship's arrest. Of course, attempts can be made to apply this provision appropriately if any property of the operator has been seized, but according to the already expressed view, the very concept of such a multi-source regulation creates uncertainty as to the wording of the specific norm.

The views expressed in the literature on the limitation of maritime claims agree that the establishment of a fund is a form of securing the debtor's assets: its establishment protects other components of the debtor's assets from actions by creditors who may assert their claims against the fund, taken in security and enforcement proceedings.[25] It is indicated that the constitution of a fund resembles the deposit of a claim with

[24] Article 13 of LLMC:

1. If a limitation fund has been established in accordance with Article 11, no person making a claim against the fund may pursue his rights in respect of that claim against any other property of the person who or on whose behalf the fund was established.
2. After a limitation fund has been established in accordance with Article 11, any ship or other property belonging to the person on whose behalf the fund was established, arrested or attached within the jurisdiction of the Contracting State in respect of a claim which may be made against the fund, or any security may be released upon the order of a court or other competent authority of that State. However, such release shall always be ordered if the limitation fund has been established: a) in the port where the incident occurred or, if the incident occurred outside a port, in the first port of call, or b) in the port of destination in respect of claims for loss of life or personal injury, or c) in the port of discharge in respect of damage to cargo, or d) in the State in which the arrest was made.
3. The provisions of paragraphs 1 and 2 shall only apply if the claimant may make a claim against the limitation fund before the court administering the fund and the fund is actually available and freely transferable in respect of that claim.

[25] I. Zużewicz-Wiewiórowska, *Postępowanie nieprocesowe w sprawach o ustanowienie i podział funduszu ograniczenia odpowiedzialności za roszczenia morskie*, "Prawo Morskie"

a court (Article 467(1) and (3) of the Civil Code). The effective deposit of a claim relieves the debtor of liability if the creditor is unknown to them and in the event of a dispute as to who the creditor is.[26] Personal liability is transformed into a property-based liability limited to the property mass, which is the fund.[27] It should be assumed that such an effect also occurs for the operator in the regime of civil liability for nuclear damage. Another important consequence of establishing a fund is the lack of liability for interest after the effective establishment of the fund.[28]

3.4 Proceedings concerning the distribution of the fund

The final establishment of a fund initiates the last stage of the proceedings: the distribution of available funds. A commendable solution is the institution of an expert commissioner, who should be appointed by the court at this stage. This means that in the phase of distributing funds, the court no longer acts independently but is supported by a specialized entity. The expert commissioner should have appropriate qualifications and may be a natural person or a legal entity.[29] Given the scale of claims that may arise from a nuclear accident, it would be justified to appoint a legal entity as an expert commissioner – an organization possessing the appropriate qualifications and the resources for the tasks assigned within the fund proceedings. The expert commissioner is obliged to prepare a draft list of creditors and a draft plan for the distribution of the fund, as well as a written justification of these documents.[30] The provisions of the Code of Civil Procedure relating to experts apply to them, but in addition, they are authorized to conduct correspondence with creditors. The conduct of the necessary evidentiary proceedings regarding disputed matters is reserved for the court, and the expert commissioner has the initiative in this regard. The court may entrust the expert commissioner with the management of the funds of the fund, to which the provisions

2019, No. 36, p. 52; D. Pyć, C. Łuczywek, I. Zużewicz-Wiewiórowska (eds), *Kodeks morski…*, p. 1091.

[26] J. Łopuski, *Odpowiedzialność za szkodę w żegludze morskiej*, Gdańsk: Wydawnictwo Morskie 1969, p. 269.

[27] D. Rydlichowska, *Charakter prawny funduszu ograniczenia odpowiedzialności za roszczenia morskie*, "Studia Prawnicze i Administracyjne" 2017, Vol. 19, No. 1, p. 57.

[28] D. Pyć, C. Łuczywek, I. Zużewicz-Wiewiórowska (eds), *Kodeks morski…*, p. 376.

[29] Article 344 § 1 of the Maritime Code.

[30] Article 344 § 2 of the Maritime Code.

on the management of property in enforcement proceedings apply accordingly.[31]

The detailed rules for the announcement of the establishment of a fund and the opening of divisional proceedings are set out in Article 346 of the Maritime Code. According to paragraph 1, claims should be filed within six months of the publication of the summons. Failure to file a claim within the deadline will result in its exclusion from the list of creditors and the distribution plan. The court, upon the request of a late filer but no later than the approval of the distribution plan, may, for justifiable reasons, reinstate the deadline for filing, applying the provisions of the Code of Civil Procedure accordingly. From the perspective of the types of damages that may occur—in particular, personal injuries in the form of ailments that may only manifest after a significant period of time following irradiation—this deadline should be considered relatively short and may prevent the full satisfaction of all claims. On the other hand, it contributes to the realization of the principle of the speed of proceedings. To some extent, the regulations of the Atomic Law prevent the failure to satisfy claims for damages that manifest with a delay. Firstly, pursuant to Article 103c(1), if a nuclear accident, in addition to damage to property or the environment, also causes personal injury, 10% of the insurance guarantee sum is allocated to secure claims for nuclear damage to persons. Secondly, pursuant to Article 103c(2), if within five years from the date of the nuclear accident, claims for personal injury made against the operator do not exceed in total the insurance guarantee sum allocated exclusively to the satisfaction of such claims (i.e., 10% of the total), the remaining part of the guarantee sum shall be allocated to satisfy claims for damage to property or the environment, as well as claims for personal injury made before the expiry of 10 years from the date of the nuclear accident. Since these regulations concern the securing of an appropriate part of the insurance guarantee sum and apply to situations where, within five years, the liability limit (which is determined by the level of the guarantee sum) has not been exceeded in practice, then, according to a literal interpretation of the condition for establishing a fund, they will have no significance for the fund.[32]

[31] Article 344 § 4 of the Maritime Code.

[32] R. Orzechowska seems to present the view that the regulations concerning the establishment and amount of the fund and those concerning the redistribution of insurance

The foregoing naturally implies considerations regarding the substantive legal basis for the distribution of the available funds. Firstly, a general norm can be found in the Vienna Convention. Article VIII.1 provides that the nature, form, and extent of compensation, as well as its appropriate distribution, shall be governed by the law of the court seised of the matter. However, Article VIII.2 establishes a priority for the reparation of personal injury in the event that the sum of claims exceeds the amount allocated for their satisfaction. Article 103c of the Atomic Law is, in a sense, an implementation of the convention principle. According to the explanatory text to the 1997 Vienna Convention, as a result of this regulation, when compensating for damage, priority should be given to personal injury, as it is the most harmful to the victims.[33] However, the explanatory text emphasizes the autonomy of states in establishing the principles of distribution of available funds.[34] Nevertheless, the Atomic Law does not provide further, detailed rules for the distribution of funds.

Given the reference to the Maritime Code also in the matter of the principles of fund distribution, it is necessary to refer to the provisions

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funds should be read separately, in the sense that the fund should be established in the amount of the statutory liability limit of the operator, and Article 103c of the Atomic Law is directed to the insurer, who is the beneficiary of the guarantee sum and acts pursuant to the provisions of insurance law (*see* R. Orzechowska, *Wpływ różnic między Prawem atomowym…*, pp. 42–43). While the literal wording of the provisions allows for such an interpretation, it clearly reveals the lack of coherence in the regulation of the distribution of funds from the available amount. After all, the establishment of security in the form of concluding an insurance contract does not create an additional pool of funds from the insurer. There is one available limit of funds, and the performance of the obligation by the insurer relieves the operator in this respect of the obligation to provide compensation to the injured party. Hence, close cooperation between both entities is necessary at the stage of satisfying claims.

[33] International Atomic Energy Agency, *The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage – Explanatory Texts*, IAEA International Law Series No. 3, Vienna: IAEA 2020, pp. 49–50.

[34] Ibid.: 'Thus, for example, the law of the competent court is to direct the granting of annuities and their amounts, as well as the effect on the claim of contributory negligence on the victim's part. Moreover, it is for the law of the competent court to decide whether measures for equitable distribution should be taken in advance or at the time when the actions are brought. Such measures may involve providing a limit per person suffering damage or limits for damage to persons, damage to property and other kinds of nuclear damage.'

of this Act. Article 100 of the Maritime Code similarly allows for the derivation of the primacy of compensation for personal injury.[35] The Act itself does not contain autonomous substantive rules for the distribution of the amount, as these are contained in the LLMC. According to Article 12(1) of the LLMC, the fund should be divided among the claimants in proportion to their claims against the fund.[36] More detailed rules apply to the division of sub-funds for personal injury and other damages (Article 6(2) of the LLMC).[37] However, it is difficult to apply them appropriately to nuclear damage since the amount of the pool allocated to cover the various types of damage is calculated based on the ship's tonnage (Article 6(1) of the LLMC). Therefore, it is reasonable to conclude that in the Polish legal order, apart from the preferential status of personal injury and the requirement of proportional satisfaction of the victims, there are no other specific regulations, which places Poland at the opposite end of the spectrum compared to other European regulations.[38] This state of the law should be critically assessed.

Returning to the course of the divisional proceedings, in the absence of such clear criteria, the expert commissioner should prepare drafts of the list of creditors and the distribution plan, guided by the principles of the priority of personal injury and the principle of proportionality. The drafts are served on the participants, who have the opportunity to submit written comments and objections within a month. Both documents are approved by the court in the form of an appealable order: at a closed hearing in the absence of comments or objections; at a hearing if these have been submitted.[39] Disputed claims should be included in the distribution plan, and if, at this stage, a dispute arises as to the validity

[35] Claims for damages to devices and port basins, waterways, and navigation devices shall be satisfied with priority over other claims, except for claims for death, personal injury, or impairment of health.

[36] R. Majda, *Cywilna odpowiedzialność za szkodę jądrową…*, p. 262; I. Zużewicz-Wiewiórowska, *Postępowanie nieprocesowe w sprawach…*, p. 58.

[37] I. Zużewicz-Wiewiórowska, *Postępowanie nieprocesowe w sprawach…*, p. 58.

[38] For example, Slovakia, where a percentage distribution of the available amount has been established depending on the deadline for filing claims. *See* the Act dated 19 March 2015 On Civil Liability for Nuclear Damage and on its Financial Coverage and on changes and amendments to certain laws, Section 7 subparagraph 5 and 6 – English version: https://www.ujd.gov.sk/wp-content/uploads/2021/10/E54_2015.pdf [access: 21 September 2024].

[39] Article 346 § 2 of the Maritime Code.

or amount of a claim included in the list of creditors and in the distribution plan, the court should refer the matter to the court process and decide on the exclusion of the appropriate amount.[40] A final approved distribution plan has the force of an enforcement title and serves as the basis for the payment of amounts from the fund, which the court may entrust to the expert commissioner.[41] If, at this stage, further creditors come forward and the fund has not yet been exhausted, the court should order the preparation of an additional list of creditors and a distribution plan.[42] An order to discontinue the proceedings closes the whole case, against which an appeal may be lodged.

4 Assessment and Directional Legislative Proposals – Summary

The above-described rules for claiming nuclear damages under Polish law should be assessed as fragmented and piecemeal, inadequate to contemporary procedural realities, especially when compared to international experiences, such as in the aftermath of the Fukushima disaster, or in relation to other European legislations. The provisions for the establishment of a limited liability fund remain unclear and may give rise to significant interpretative doubts in practice. The most serious conclusion is that the reference to the Maritime Code results in the infiltration into the nuclear damage liability regime of another international legal act – the LLMC. Moreover, the provisions of the Maritime Code and the LLMC relate to entirely different types of events, which makes their appropriate application difficult and leaves many interpretative gaps. In turn, the more uncertainty and room for interpretation, the worse the situation is for the operator and the victims.

The author's primary proposition is to autonomously describe the procedural and substantive legal principles for claiming damages in the Atomic Law and to abandon the reference to the Maritime Code. The idea of divisional proceedings concentrating claims is sound in itself, but the institution must be adapted to the realities of claims arising from nuclear damage. A reasonable solution would be to make it mandatory

[40] Article 346 § 3 in conjunction with Article 344 § 5 of the Maritime Code.
[41] Article 347 § 1 and 2 of the Maritime Code.
[42] Article 347 § 3 of the Maritime Code.

to pursue claims within a single formalized divisional proceeding conducted by a single entity, regardless of whether the amount of claims formally exceeds the statutory liability limit or whether there is only a high probability that funds will be insufficient to fully satisfy them. Within such proceedings, it would be possible to divide claimants into groups depending on the characteristics of their claims (e.g., claims for personal injury, property damage, damage to economic activity). This would promote transparency and proportionality in the awarding of damages in every situation and would also have a positive impact, in particular, on the economics of the proceedings. The legislator must consider where it wishes to place the jurisdiction to hear cases. At the European level, German, French, Swiss, and Dutch legislation allows for the establishment of an independent entity to resolve disputes that is not a court.[43] It seems that adopting a similar solution would be permissible under Polish law, provided that it does not violate the constitutional principles of the right to a court and the adjudication of a case in two instances (Articles 45, 78, and 176(1) of the Constitution of the Republic of Poland[44]). This would, therefore, require the voluntary submission of a dispute for resolution by a dedicated extrajudicial body, and the party dissatisfied with the decision would still have the right to file a lawsuit in a common court and have the case heard by a court of two instances. An additional advantage of this solution is also that the hearing of cases by a dedicated entity would constitute a kind of pre-selection for undisputed or trivial cases, and primarily difficult and complex cases requiring professional legal knowledge and experience would be referred for judicial resolution.

Another legislative solution worth considering, which could significantly facilitate the handling of claims at the operational level before the distribution phase of funds, would be to introduce an obligation for the operator and its insurer to prepare a claims management plan.[45] The purpose of this document would primarily be to formalize and streamline the process of filing claims at the initial stage. Such a plan should establish channels and communication between the victims and the

[43] *See* N. Pelzer, *Facing the challenge…*, p. 52.

[44] Official Journals of Laws "Dziennik Ustaw" 1997, No. 78, item 483; 2001, No. 28, item 319; 2006, No. 200, item 1471; 2009, No. 114, item 946.

[45] https://www.marsh.com/ie/industries/energy-and-power/insights/ten-fundamentals--effective-nuclear-liability-claims-management.html [access: 25 September 2024].

operator and insurer, a sample claim form or a list of questions for victims if the claim is reported by telephone, and the rules of cooperation between the operator, insurer, and public authorities. The nuclear regulatory authority should also approve the plan before the nuclear power plant begins operation.

In summary, the rules governing the pursuit of claims for nuclear damage in Polish law require urgent legislative intervention. It is necessary to introduce a modern system for their satisfaction, taking into account past experiences and legislative trends in Europe and worldwide. This will improve not only the situation of potential victims but, above all, the liable entity – the operator.

Chapter 7

LIABILITY FOR NUCLEAR TRANSPORT: A PRAGMATIC CASE STUDY APPROACH, INCLUDING SMRS

Evelyne M. Ameye
LLM, President of INLA ESPAÑA
Partner in EU competition/antitrust law and EU Nuclear Energy Law
EA Law (www.eameye.com)
Member of the Brussels Bar and Madrid Bar
evelyne@eameye.com

Abstract

Nuclear new build and the deployment of SMRs in the wake of climate change will increase global transport of nuclear substances.

The present article pragmatically answers two questions:

(1) ***Who*** is liable in case of an incident during nuclear transport?
(2) ***Where*** is this company liable in case of an incident during nuclear transport?

It explores how the international conventions interact to allow for the necessary flexibility of transport while guaranteeing legal certainty of civil nuclear third party liability in case of an incident occurring during transport of nuclear substances.

It is key for all stakeholders to know in advance of any business involving transport of nuclear substances across various countries which party is liable towards third party victims in case of an incident and in which country this party will be held liable, i.e. before which courts.

The issue is important irrespective of policy considerations given that both operating and decommissioning nuclear power plants and SMRs involve multiple cross-border transport transactions, e.g. the transport of nuclear fuel, nuclear spare parts, nuclear spent fuel or nuclear waste.

In the present article, various scenarios are depicted in order to illustrate the main rules that apply at international level in an attempt to depict a highly complex issue in a pragmatic fashion. It is therefore not meant as an exhaustive, in-depth analysis of the wide range of complex legal entanglements that may arise but as basic guidance on liability scenarios in case of nuclear transport.

Finally, special attention is paid to the transport of small and modular reactors (SMRs). Given their small physical size and modular production in factories, SMRs will involve more nuclear transport than nuclear power plants have done to date (e.g. when SMRs are used to replace diesel generators on mining sites in remote regions).

Table of Contents

Abstract
1 Nuclear Transport Incidents: who is liable? where is this company liable?
2 Who is liable when an incident occurs during transport of nuclear substances?
2.1 Which legal document provides the answer?
2.2 The overarching principle
2.3 A pragmatic analysis of various scenarios
2.3.1 Preliminary remarks
2.3.2 Possible scenarios
(a) Nuclear transport from a Convention State to a Convention State
(b) Can companies deviate from the rule?
(c) Nuclear transport from a Convention State to a Non-Convention State
(d) Nuclear transport from a Non-Convention State to a Convention State
(e) What about mixed loads?
(f) What about temporary or incidental storage?
(g) What about incidents of transportable small modular reactors (SMRs)?
(1) A SMR does not contain nuclear substances during transport
(2) A SMR contains nuclear substances during transport (e.g. fuel or spent fuel) but produces no energy during transport
(3) A SMR contains nuclear substances during transport and produces energy during transport
3 Where is a company liable for an incident during nuclear transport?
(a) Nuclear transport incidents in Convention States
(b) Nuclear transport incidents in Non-Convention States
Conclusion

1 Nuclear Transport Incidents: who is liable? where is this company liable?

When engaging in business involving transport of nuclear substances, the issue of liability for nuclear incidents is one of the main deterrents given the exposure to high liability risks. Even though lower liability limits are usually foreseen for incidents that occur during the transport of nuclear substances as compared with incidents that occur on site of nuclear power plants,[1] liability still remains at a high level.

Legal certainty on two questions is therefore key for business.

The first question is *'**Who** is liable?'*

The second question is *'**Where** is this company liable?'*

Those two questions are not easy to address. However, legal certainty on the responses to both questions is crucial for commercial decision-making.

2 Who is liable when an incident occurs during transport of nuclear substances?

2.1 Which legal document provides the answer?

The answer to this question lies in the international nuclear liability conventions.

Indeed, world-wide, third party liability stemming from nuclear damage is characterised by the coexistence of various international conventions and different legal regimes. Some States are party to the Paris Convention of the OECD's Nuclear Energy Agency (the Paris Convention).[2] Other States are party to the IAEA's Vienna Convention (the 1963 Vienna Convention).[3] Other States are party to the free-standing Convention

[1] *See* below, in section 2.1.

[2] The Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960, http://www.nea.fr/html/law/nlparis_conv.html [access: 28 October 2024]. The original 1960 version of this convention is not in force anymore. Only the 2004 revised Paris Convention is in force (since 1 January 2022). *See* footnote 5.

[3] The Vienna Convention on Civil Liability for Nuclear Damage of 21 May 1963, http://www.iaea.org/Publications/Documents/Infcircs/1996/inf500.shtml [access: 28 October 2024].

on Supplementary Compensation for Nuclear Damage (Convention on Supplementary Compensation).[4] This medley is commonly called the international nuclear liability conventions.

This medley is amplified by numerous supplementary conventions and protocols amending these conventions. Moreover, some States are not a party to any international nuclear liability convention. Those States either abide by domestic nuclear liability laws or have no nuclear liability rules at all.

Regarding the liability amounts, lower liability limits are usually foreseen for incidents that occur during the transport of nuclear substances as compared with incidents that occur on site of nuclear power plants. The 2004 revised Paris Convention,[5] for example, provides for liability amounts of minimum 80 million € for nuclear incidents during transport (instead of minimum 700 million € for incidents occurring on site of nuclear power plants). Even though the 1963 Vienna Convention, the 1997 revised Vienna Convention[6] and the Convention on Supplementary Compensation do not foresee lower liability limits for nuclear incidents during transport, they provide for a reduced liability amount for low-risk activities of 5 million IMF special drawing rights. In addition many national laws, transposing the international nuclear liability conventions into national law, expressly introduce lower liability limits for nuclear incidents during transport. The present article does not address liability amounts, which involves complex considerations of national laws transposing the limits of the conventions, as well as State funds (e.g. the Convention on Supplementary Compensation or the Brussels Supplementary Convention[7]). It limits

[4] The Convention on Supplementary Compensation for Nuclear Damage of 12 September 1997, http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc567.pdf [access: 28 October 2024].

[5] A Protocol amending the Paris Convention was adopted on 12 February 2004 and entered into force on 1 January 2022, https://www.oecd-nea.org/jcms/pl_20361/2004-protocol-to-amend-the-paris-convention [access: 28 October 2024].

[6] A Protocol amending the Vienna Convention was adopted on 12 September 1997 and entered into force on 4 October 2003, https://www.iaea.org/publications/13633/the-1997-vienna-convention-on-civil-liability-for-nuclear-damage-and-the-1997-convention-on-supplementary-compensation-for-nuclear-damage-explanatory-texts [access: 28 October 2024].

[7] The Brussels Supplementary Convention to the Paris Convention of 31 January 1963, https://www.oecd-nea.org/jcms/pl_20318/brussels-convention-supplementary-to-

itself to 'who is liable?' and does not address 'for how much is the company liable?'.

Regarding 'who is liable?', the rule of thumb is that, when it comes to incidents arising from nuclear transport, international transport conventions defer to the international nuclear liability conventions. The 1971 Convention relating to Civil Liability in the field of Maritime Carriage of Nuclear Material of the International Maritime Organisation (IMO),[8] for example, expressly states that a person liable for a nuclear transport incident under maritime transport conventions is exonerated if the sending or receiving nuclear power plant operator is also liable for the same nuclear transport incident under the international nuclear liability conventions (the 2004 revised Paris Convention, the 1963 Vienna Convention, the 1997 revised Vienna Convention or the Convention on Supplementary Compensation) or national law similar in scope. Similarly, the 1970 international railway convention on the carriage of goods (CIM) annexed to the Convention on the International Carriage by Rail (COTIF)[9] recognizes the primacy of the international nuclear liability conventions in case of transport incidents involving nuclear substances.

2.2 The overarching principle

The international nuclear liability conventions set out an overarching principle for liability in case of incidents during nuclear transport. This overarching principle is called 'channelling'.

In a nutshell, 'channelling' implies that, in case of an incident involving nuclear substances, only the operator of the nuclear installation (i.e. the license-holder[10]) is liable for damage to third parties. Liability

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the-paris-convention-on-third-party-liability-in-the-field-of-nuclear-energy-brussels-supplementary-convention-or-bsc [access: 28 October 2024].

8 The Convention relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material of 17 December 1971, https://www.imo.org/en/About/Conventions/Pages/Convention-relating-to-Civil-Liability-in-the-Field-of-Maritime-Carriage-of-Nuclear-Material-(NUCLEAR).aspx#:~:text=The%201971%20Convention%20provides%20that,Field%20of%20Nuclear%20Energy%3B%20or [access: 28 October 2024].

9 Art. 39 of the Uniform Rules Concerning the Contract of International Carriage of Goods by Rail (CIM) of 9 June 1999, Appendix B to the Convention concerning International Carriage by Rail (COTIF), https://www.cit-rail.org/secure-media/files/documentation_de/freight/cim/cim_1999_2010-12-01_fr-de-en_rev_ns.pdf?cid=306960 [access: 28 October 2024].

10 The operator of a nuclear installation is defined as the person designated or recognized as the operator of that nuclear installation by the competent public authorities. Where

is channelled towards the operator regardless of the incident's cause. Irrespective of their possible contribution to the incident, none of the other players—nuclear plant designers and constructors (architects-engineers), suppliers of nuclear material or fuel, transporters of nuclear material or fuel to and from the nuclear power plant, subcontractors, test operators, consultants, etc.—bears any responsibility towards third parties in the event of a nuclear incident. The latter are protected from third party litigation in the case of an incident.

Channelling is an oddness of nuclear liability law. It deviates from the nuts and bolts of ordinary tort law provided for by both civil law and common law systems.[11] This is the most glaring exception of nuclear law: it generally allows suppliers and designers of defective reactors to escape any responsibility in case of a nuclear incident. This implies that, even if a meltdown is due to a defective reactor design, the designer will never bear any liability for an ensuing nuclear incident. Or if a supplier provides defective emergency equipment, he will not be held liable if these technological flaws lead to a nuclear incident. In both cases, the nuclear power plant operator will be exclusively liable for a nuclear incident.[12]

Channelling of civil[13] nuclear third party liability has been recognised as 'the most characteristic concept of nuclear law'[14] by the renowned Polish Professor Tadeusz Gadkowski.

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there is a system of licensing or authorization, the operator is the licensee or person duly authorized. In all other cases he will be the person required by the competent public authority to hold the necessary financial protection to meet third party liability risks. *See* Art. 1(a)(vi) of the 2004 revised Paris Convention. Art. I(1)(c) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 1(1)(d) of the Annex to the Convention on Supplementary Compensation.

[11] E. Ameye, *Channelling of Nuclear Third Party Liability towards the Operator: Is it Sustainable in a Developing Nuclear World or is there a Need for Liability of Nuclear Architects and Engineers?*, "European Energy and Environmental Law Review" 2010, Vol. 19, Issue 1, pp. 33–58, https://kluwerlawonline.com/journalarticle/European+Energy+and+Environmental+Law+Review/19.1/EELR2010003 [access: 28 October 2024].

[12] Idem, *United States and India: two nuclear states with legislation that truly holds responsible parties liable in case of a nuclear accident*, "Journal of Risk Research" 2014, Vol. 18(8), pp. 1070–1082, https://doi.org/10.1080/13669877.2014.971421.

[13] Channelling only concerns civil liability and does not affect criminal law proceedings.

[14] T. Gadkowski, *International Liability of State for Nuclear Damage*, Delft: Eburon, Poznań: Adam Mickiewicz University Press 1989, p. 83.

Legal channelling[15] has been incorporated in nearly all nuclear laws world-wide. This is because most countries have adhered to the above-mentioned international nuclear liability conventions and because all these international conventions provide for legal channelling:

- Article 6(f) of the 2004 revised Paris Convention: 'The operator shall have a **right of recourse only**: **(i)** If the nuclear damage caused by a nuclear incident results from an act or an omission done **with intent to cause damage**, against the individual acting or omitting to act with such intent; **(ii)** If and to the extent that it is so provided **by contract**.'
- Article X of the 1963 Vienna Convention and the 1997 revised Vienna Convention:[16] 'The operator shall have a **right of recourse only – (a)** if this is **expressly provided for by a contract in writing**; or **(b)** if the nuclear incident results from an act or omission done **with intent to cause damage**, against the individual who has acted or omitted to act with such intent. The right of recourse provided for under this Article may also be extended to benefit the Installation State insofar as it has provided public funds pursuant to this Convention.'
- Article 10 of the Convention on Supplementary Compensation: 'National law may provide that the operator shall have a **right of recourse only**: **(a)** if this is **expressly provided for by a contract in writing**; or **(b)** if the nuclear incident results from an act or omission done **with intent to cause damage**, against the individual who has acted or omitted to act with such intent.'

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[15] There are two forms of channelling, namely **legal channelling**, on the one hand, where victims can only sue the operator, who cannot, in turn, reclaim the disbursed compensations from other parties who caused the incident, e.g. a reactor designer or uranium supplier (this regime is applicable in most of the EU); and **economic channelling**, on the other hand, where victims can sue both the operator and any other party who caused the incident, e.g. a reactor designer or uranium supplier, but where the operator—whose insurance needs to be an *omnibus coverage* or *umbrella insurance* covering these other parties' third party liability as well—ultimately needs to indemnify the said parties (this regime is applicable in the US). For more details, *see* E. Ameye, *Channelling of Nuclear Third Party Liability…*, pp. 33–58.

[16] The original 1963 Vienna Convention is still in force, in parallel with the revised 1997 Vienna Convention, which entered into force the States that acceded to it or ratified it.

2.3 A pragmatic analysis of various scenarios

2.3.1 Preliminary remarks

The response to the question of 'who is liable?' for transport incidents involving nuclear substances from one State to another State (possibly through one or more transit States) is set out in the international nuclear liability conventions.

However, as set out above, there is a medley of international nuclear liability conventions.

In addition, some States are not a party to any international nuclear liability convention.

The response to 'who is liable?' will therefore differ when nuclear substances are transported to and from States that are a party to the international nuclear liability conventions, on the one hand, and when nuclear substances are transported to and from States that are not a party to any international nuclear convention, on the other hand.

The scenarios below summarise the common rules regarding liability in case of a nuclear incident during transport.[17]

These common rules concern liability for transport incidents involving nuclear substances. Due to the lower risks involved, liability is excluded in case of transport incidents involving, on the one hand, natural or depleted uranium and uranium ores and, on the other hand, radioisotopes which have reached their final stage of fabrication so as to be usable for scientific, medical, agricultural, commercial or industrial purposes (e.g. radiography).

To ensure legal certainty on the contents of the shipment, the international nuclear liability conventions require operators of nuclear power plants to provide certificates of financial security (CoFS) to carriers and transporters,[18] comprising detailed information regarding the shipment, namely the type of nuclear substance contained in the shipment, details

[17] Given the complexities involved in real nuclear liability cases, the present article should not be relied upon as legal opinions of any kind as to how liability would play out for actual nuclear incidents.

[18] Art. 4(d) of the 2004 revised Paris Convention. Art. III of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 3(1) of the Annex to the Convention on Supplementary Compensation.

of the operator of the nuclear installation, a declaration of the competent public authority confirming the name of the operator, and the amount, type and duration of liability.

Importantly, when the scenarios that I will describe in section 2.3.2 address transport 'from a Convention State to a Convention State', it implies the *same* Convention, e.g. transport from a Paris Convention State to another Paris Convention State or transport from a Vienna Convention State to another Vienna Convention State. In other terms, if nuclear substances are transported from a Paris Convention State to a Vienna Convention State, this is not considered as transport from a Convention State to a Convention State, but transport from a Convention State to a Non-Convention State because the States are not parties to the *same* Convention. However, there is an exception as regards the Paris and the Vienna Convention. The exception is that, if both States are parties to the 1988 Joint Protocol,[19] then Vienna Convention States are considered 'Convention States' in their relations with Paris Convention States for transport liability purposes and, *vice versa*, Paris Convention States are considered 'Convention States' in their relations with Vienna Convention States for transport liability purposes. Hence, the 1988 Joint Protocol plays an invaluable role in transport liability.

Liability under the international nuclear liability conventions also depends on the geographic coverage of these conventions. Whether conventions apply or not depends on whether the damage caused by the nuclear transport incident falls within their geographic scope. They only apply in scenarios where nuclear transport incidents cause damages 'in a Convention State'. One therefore needs to understand what is meant by damage 'in a Convention State'. Is it in the territory of the State or also in its territorial waters? What about a ship registered with a Convention State navigating on high seas? What about reciprocity bridging different Conventions? This is set out in precise rules for each Convention. However, each Convention has different rules when it comes to the geographic scope of their coverage. The 2004 revised Paris Convention has a broad scope.[20]

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[19] The Joint Protocol on the application of the Paris and Vienna Conventions of 31 September 1988, https://www.iaea.org/sites/default/files/infcirc402.pdf [access: 28 October 2024].

[20] The 2004 revised Paris Convention applies if nuclear damage is suffered in the territory (including the maritime zones, i.e. territorial sea, contiguous zone, exclusive economic zone and continental shelf) or on board of a ship/aircraft registered in either

So does the 1997 revised Vienna Convention.[21] The geographic scope of the 1963 Vienna Convention is unclear.[22] Importantly, the 1988 Joint Protocol bridges the geographic scope of the 2004 revised Paris Convention with the Vienna Conventions (both the 1963 Vienna Convention and the 1997 revised Vienna Convention).[23] It provides a reciprocal application of the advantages of their respective regimes and the elimination of the conflicts arising from the simultaneous application of both conventions to the same nuclear incident. This means that Paris Convention State operators are liable under the Paris Convention rules for damage suffered in the territory of a Vienna Convention State and *vice versa*. Finally, given its complementary nature the Convention on Supplementary Compensation logically has a narrow scope.[24]

(i) a Paris Convention State or (ii) a State that is not a party to the Paris Convention, if it is a party to the 1963 Vienna Convention/1997 revised Vienna Convention and the 1988 Joint Protocol or it is a non-nuclear State (it has no nuclear installations on its territory) or it is a nuclear State (it has nuclear installations on its territory) but offers reciprocal benefits in its nuclear liability law, which is based on the same principles as the Paris Convention (Art.2(a)(iv) and Points 7(a) to 12 of the Exposé des Motifs).

21 The 1963 Vienna Convention does not expressly define its geographic scope. According to the 1964 Standing Committee on Civil Liability for Nuclear Damage, its geographic scope covers nuclear damage suffered within the territory of a Vienna Convention State and on or over the high seas and excludes nuclear damage suffered within the territory of a State that is not a party to the Vienna Convention. However, during the negotiations of the 1997 revised Vienna Convention, it was pointed out that the view expressed by the 1964 Standing Committee is not binding and that the 1963 Vienna Convention may instead be interpreted as also covering damage suffered in States that are not a party to the Vienna Convention. (IAEA, *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 (Rev. 2), Vienna: IAEA 2020, pp. 29–30, https://www-pub.iaea.org/MTCD/Publications/PDF/P1906_web.pdf, point 2.2.3 Geographical Scope [access: 28 October 2024]).

22 The 1997 revised Vienna Convention applies to nuclear damage wherever it is suffered, unless national law excludes damage suffered in a nuclear State (it has nuclear installations on its territory) that does not offer reciprocal benefits (this exception cannot be made for damage suffered on board of a ship/aircraft) (Art. IA).

23 Art II. However, either the Paris Convention or the Vienna Convention (1963 or 1997 revised version) applies to a nuclear incident to the exclusion of the other (Art. III).

24 Given that the Convention on Supplementary Compensation (CSC) is complementary to the 2004 revised Paris Convention, the 1963 Vienna Convention, the 1997 revised Vienna Convention and States that follow identical principles as said conventions set

The geographic scope of the conventions is particularly important when it comes to SMRs because they are movable and because they are not located on traditional sites like ordinary nuclear installations, but on less usual sites, e.g. in territorial seas, exclusive economic zones or continental shelves. Legal issues will likely arise in case of marine SMRs or SMRs on artificial islands, and even more so when the 1963 Vienna Convention applies, given that its geographic scope is not crystal-clear (e.g. the already operative floating Russian SMR, Akademik Lomonosov, may raise legal issues because it is a floating SMR and because Russia is a party to the 1963 Vienna Convention but neither to the 1997 revised Vienna Convention nor the 1988 Joint Protocol).

Practical example 1. Damage is suffered on the high seas by a French passenger ship because nuclear substances are released by an explosion of a Dutch SMR operated on a fixed installation site in Dutch territorial seas. The 2004 revised Paris Convention applies to this scenario[25] (France and the Netherlands are Paris Convention States). However, if the Dutch SMR is replaced by an SMR in a nuclear State without reciprocity, the 2004 revised Paris Convention does not apply. The French passenger ship could then claim damages from the SMR vendor or designer under ordinary tort law.

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out in the Annex of the CSC, its geographic scope is logically mainly restricted to CSC States. Its geographic limitation is two-fold in parallel with its two-tier system. It applies to nuclear damage for which an operator of a CSC State is liable under the 2004 revised Paris Convention, the 1963 Vienna Convention, the 1997 revised Vienna Convention and the national law of States that follow identical principles as said conventions set out in the Annex of the CSC for the 1st tier. The 2nd tier is restricted to damages suffered in the territory of CSC States. This includes damages suffered in or above maritime areas beyond the territorial sea of a CSC State (i) on board or by a ship/aircraft registered in a CSC State, or on or by an artificial island, installation or structure under the jurisdiction of a CSC State, or (ii) by a CSC State national, but expressly excludes damage suffered in or above the territorial sea of States that are not a party to the CSC. The 2nd tier also includes damages suffered in or above a CSC State's exclusive economic zone or on a CSC State's continental shelf in connection with the exploitation or the exploration of the natural resources of that exclusive economic zone or continental shelf (Art. II(2) and Art. V).

[25] Given that the Brussels Supplementary Convention is complementary to the Paris Convention, its geographic scope is logically restricted to its contracting states. This might impede its application when damage arises in non-contracting states. The Paris Convention would then apply but the Brussels Supplementary Convention would not apply to a nuclear transport incident causing damages in non-contracting states (Art. 2).

2.3.2 Possible scenarios

(a) Nuclear transport from a Convention State to a Convention State

The rule under the international nuclear liability conventions is that nuclear transport liability is borne by the nuclear power plant operator and not by the transporter or carrier.

The international nuclear liability conventions allow parties to contractually determine when the liability is transferred from one operator to another operator in a written agreement.[26] If there is a written agreement, the sending operator is liable until the agreed moment of liability transfer to the receiving operator.[27]

However, the international nuclear liability conventions rule that, if there is no written agreement, transport liability is channelled towards the sending operator until the receiving operator takes charge of the nuclear substances (including transit in transit States).[28]

Practical example 2. Spent nuclear fuel is sent from a French nuclear power plant to a Dutch reprocessing plant by a French carrier and there is no written agreement. Given that France and the Netherlands are Paris Convention States, the French operator will be liable for incidents during transport by the French carrier (including for transit through Belgium) until the Dutch operator of the reprocessing plant takes charge of the nuclear substance. However, the French operator and the Dutch operator could have concluded a written agreement whereby liability is transferred from the French operator to the Dutch operator at an earlier stage, e.g. as soon as the French carrier enters Belgian territory.

Practical example 3. Spent nuclear fuel is sent from a French nuclear power plant to a Slovak reprocessing plant by a French carrier and there is no written agreement. France is a Paris Convention State, whereas Slovakia a Vienna Convention State (1963 Vienna Convention). However, given that the 1988 Joint Protocol entered into force in both States, the

[26] Art. 4 of the 2004 revised Paris Convention. Art. II(1)(b) and (c) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 3(1) of the Annex to the Convention on Supplementary Compensation.

[27] The 2004 revised Paris Convention conditions this to the fact that the receiving operator has a direct economic interest in the nuclear substances (Art. 4(c)).

[28] Art. 4 of the 2004 revised Paris Convention. Art. II(1)(b) and (c) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 3(1) of the Annex to the Convention on Supplementary Compensation.

French operator will be liable for incidents during transport by the French carrier (including for transit through Germany and Czechia) until the Slovak operator of the reprocessing plant takes charge of the nuclear substance.

(b) Can companies deviate from the rule?

Under the international nuclear liability conventions, companies are allowed to deviate from the rule that transport liability is channelled towards the nuclear power plant operator. The transporter or carrier can be held liable if the transporter or carrier so requests, if the sending or receiving nuclear power plant operators consent to the deviation and if the possibility of this exception to channelling is expressly provided for by national legislation (e.g. Belgian law allows for carrier liability).[29] Transporters usually only invoke this possibility when risks are small and as a commercial tool to attract customers.

Practical example 4. Nuclear fuel is sent from a Belgian fuel production facility to a French nuclear power plant by Belgian rail transport. At his request, the Belgian rail carrier may bear the liability for incidents during transport if the French operator agrees to it, given that Belgian legislation expressly provides for this possibility.

(c) Nuclear transport from a Convention State to a Non-Convention State

The rule under the international nuclear liability conventions is maintained that nuclear transport liability is borne by the nuclear power plant operator and not by the transporter or carrier.

The international nuclear liability conventions provide that the sending operator is liable until unloading by the carrier in the Non-Convention State (including transit in transit States).[30] The definition of 'unloading' is therefore key. Different points of transfer may be identified. However, 'unloading' is not defined in the international nuclear liability conventions. Is it, for example, when the ship arrives at the shore, when the crane unloads the ship or when the shipment reaches the outer gate of

[29] Art. 4(e) of the 2004 revised Paris Convention, which adds that the deviation from channelling require a decision by the competent public authority. Art. II(2) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 3(2) of the Annex to the Convention on Supplementary Compensation.

[30] Art. 4 of the 2004 revised Paris Convention. Art. II(1)(b) and (c) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 3(1) of the Annex to the Convention on Supplementary Compensation.

the nuclear power plant? This legal gap may cause exposure for the nuclear transporter or carrier. Clear contractual arrangements in this regard are therefore fundamental.

Practical example 5. Nuclear fuel is shipped from a French production facility to a Chinese nuclear power plant by a French maritime carrier. Given that France is a Paris Convention State but that China is not a party to any international nuclear liability convention, the French operator will be liable for incidents during transport by the French maritime carrier (including for transit through numerous transit States) for the entire journey until the French carrier unloads the nuclear substances in China.

Practical example 6. Nuclear fuel is sent from a Spanish production facility to a Slovak nuclear power plant by a Spanish road carrier. Spain is a Paris Convention State, whereas Slovakia is a Vienna Convention State. Given that Spain has not ratified the 1988 Joint Protocol, Slovakia is considered as a 'Non-Convention State' for transport liability purposes in relation to Spain. Therefore, the Spanish operator will be liable for incidents during transport by the Spanish truck (including for transit through France, Germany and Czechia) for the entire journey until the Spanish truck unloads the nuclear substances in Slovakia.

(d) Nuclear transport from a Non-Convention State to a Convention State

The rule under the international nuclear liability conventions is maintained that nuclear transport liability is borne by the nuclear power plant operator and not by the transporter or carrier.

The international nuclear liability conventions provide that the receiving operator is liable after uploading by the carrier in the Non-Convention State (including transit in transit States).[31] Again, the definition of 'uploading' is crucial but is not provided by the international nuclear liability conventions, creating a grey zone for legal interpretations. Clear contractual arrangements in this regard are therefore fundamental.

Practical example 7. Nuclear fuel is sent from a Chinese production facility to a French nuclear power plant by a Chinese maritime carrier. Given that France is a Paris Convention State but that China is not a party to any international nuclear liability convention, the French operator will be liable for incidents during transport by the Chinese maritime carrier (including for transit through numerous transit States) for the

[31] Ibid.

entire journey as soon as the Chinese carrier has uploaded the nuclear substances in China.

(e) What about mixed loads?

The international nuclear liability conventions provide that if various nuclear power plant operators send nuclear substances with a single carrier, both operators are jointly and severally liable. This implies that victims can either sue one or the other operator indistinctly. However, the maximum total amount for which a single operator is jointly and severally liable cannot exceed his maximum individual liability.[32]

Practical example 8. Nuclear spent fuel is sent from two French nuclear power plants A and B to a Spanish reprocessing plant by a French rail carrier. France and Spain are Paris Convention States. French operator of nuclear power plant A and French operator of nuclear power plant B are jointly and severally liable for incidents during transport by the French rail carrier until the Spanish operator of the reprocessing plant takes charge of the nuclear substances. Victims can choose to sue French operator A for the transport incident. Alternatively, victims can choose to sue French operator B for the transport incident. The maximum amount of joint and several liability of A or B is capped at their respective maximum individual liability.

(f) What about temporary or incidental storage?

According to the international nuclear liability conventions, a temporary or incidental storage facility does not constitute a nuclear installation. Indeed, temporary or incidental storage facilities are assimilated to means of transport. Hence, when a sending or receiving nuclear power plant operator is liable because transport liability is channelled towards him, this liability also covers incidents at temporary or incidental storages.[33]

Practical example 9. Nuclear spent fuel is sent from a French nuclear power plant to a Spanish reprocessing plant by a French road carrier but

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[32] Art. 5(d) of the 2004 revised Paris Convention. Art. II(3)(a) and (b) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 7(2) of the Annex to the Convention on Supplementary Compensation. Except for the 2004 revised Paris Convention, the other international nuclear liability conventions state that this applies in so far as the damage attributable to each operator is not reasonably separable.

[33] Art. 1(a)(ii), Art. 4, Art. 5(b) and (d) of the 2004 revised Paris Convention. Art. I(1)(j)(iii), Art. II(1) *in fine*, Art. II(3)(b) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. 1(1)(iii), Art. 3 *in fine*, Art. 7(2) of the Annex to the Convention on Supplementary Compensation.

is temporarily stored in a French facility close to the Spanish border. Given that France and Spain are Paris Convention States, unless otherwise agreed in writing, the French operator will be liable for incidents during transport by the French road carrier (including for its temporary storage at the Spanish border) until the Spanish operator of the reprocessing plant takes charge of the nuclear substances.

(g) What about incidents of transportable small modular reactors (SMRs)?

The international nuclear liability conventions do not contain specific provisions on liability for transport of SMRs.[34] The only certainty provided by the international nuclear liability conventions is that, when SMRs produce energy during transport for the very purpose of enabling the transport, they are excluded from the conventions: i.e. they do not fall within the scope of the liability rules applying to nuclear power plants under the conventions and do not fall within the scope of the liability rules applying to transport of nuclear substances under the conventions. SMRs that are used to propel a means of transport or to produce energy for any purpose related to their transport are excluded from the conventions.[35] This implies that, in such cases, liability is not channelled towards the operator. The transporter or carrier is liable and ordinary tort law applies.

For all other SMRs, there is a variety of scenarios because there is a variety of SMRs. The NEA SMR Dashboard identifies 98 SMR technologies around the world.[36]

SMRs will usually be transported from the production site to the installation site or, after their operating life, from the installation site to the decommissioning site.

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[34] SMRs are smaller, both in terms of power output and physical size, than conventional gigawatt-scale nuclear reactors. SMRs are nuclear reactors with power output less than 300 megawatts electric (MWe), with some as small as 1-10 MWe. SMRs are designed for modular manufacturing, factory production, portability, and scalable deployment. SMRs use nuclear fission reactions to create heat that can be used directly or to generate electricity. NEA, *The NEA Small Modular Reactor Dashboard: Second Edition*, Paris: OECD Publishing 2024, p. 18, https://www.oecd-nea.org/jcms/pl_90816/the-nea-small-modular-reactor-dashboard-second-edition [access: 28 October 2024].

[35] Art. 1(a)(ii) of the 2004 revised Paris Convention and Point 18(a) of its Exposé des Motifs. Art. I(1)(j) of the 1963 Vienna Convention and the 1997 revised Vienna Convention. Art. I(1)(b)(i) of the Convention on Supplementary Compensation.

[36] NEA, *The NEA Small Modular Reactor Dashboard…*, p. 11.

In my opinion, 3 main liability scenarios relating the transport of SMRs need to be distinguished:

(1) A SMR does not contain nuclear substances during transport

The international nuclear liability conventions do not apply. The transporter is liable under ordinary tort law for an incident occurring during transport.

It is important to note that, when such SMR has been installed and fuelled on the installation site and remains fixed on the site to produce energy, it is assimilated to a nuclear installation. The official interpretations of the international nuclear liability conventions[37] state that, when SMRs remain fixed and produce electricity for land-based uses—even after having been transported by truck, train or ship—they are assimilated to nuclear installations. This would be the case, even if the SMR is incorporated in a truck, train or ship and is not unloaded from that truck, train or ship in order to produce energy, as long as transport has stopped and the SMR is fixed on an installation site. The SMR is considered fixed on an installation site, even when it is installed as a platform at sea, immersed and anchored to the seabed or moored to shore and connected to shore by power cables.[38] The SMR produces energy for commercial uses in the same way as an ordinary nuclear power plant. Hence, in such cases, liability is channelled towards the SMR operator according to the liability rules for nuclear installations of the international nuclear liability conventions.

Practical example 10. Non-fuelled SMR parts are transported from a Belgian production site to a Spanish installation site, where they will

[37] 18th meeting (15–17 May 2018) and 19th meeting (14–16 May 2019) of IAEA's International Expert Group on Nuclear Liability (INLEX) referred to in footnotes 85 and 91 of IAEA, *The 1997 Vienna Convention on Civil Liability… See* also, S. McIntosh, *Nuclear Liability and Post-Fukushima Developments*. In: IAEA, *Nuclear Law: The Global Debate*, The Hague: Asser Press, Berlin: Springer Verlag 2022, 12.4.3 Transportable Nuclear Power Plants, pp. 260–261, https://www.researchgate.net/publication/357505888_Nuclear_Law_The_Global_Debate_The_Global_Debate [access: 28 October 2024].

[38] 18th meeting (15–17 May 2018) and 19th meeting (14–16 May 2019) of IAEA's International Expert Group on Nuclear Liability (INLEX) referred to in footnotes 85 and 91 of IAEA, *The 1997 Vienna Convention… See* also, A. Popov, *Russian Vision of the Problems and Prospects of the International Legal Framework in the Context of Small Modular Reactors and Transportable Nuclear Power Units*. In: IAEA, *Nuclear Law…*, 3.6 Floating SMRs and Civil Liability for Nuclear Damage, p. 51, https://www.researchgate.net/publication/357505888_Nuclear_Law_The_Global_Debate_The_Global_Debate [access: 28 October 2024].

be assembled and fuelled to produce energy.[39] No energy is produced during transport. Whilst the SMR parts are being transported and not yet installed and fixed, an incident occurs. Nuclear transport liability rules of the conventions do not apply. Liability is not channelled towards the Spanish SMR operator. The Belgian transporter is liable according to ordinary tort law. However, if the incident occurs once the SMR has been installed on the Spanish installation site and fuelled, the SMR will be assimilated to a nuclear installation. In such case liability is channelled towards the Spanish SMR operator according to the liability rules for nuclear installations of the international nuclear liability conventions.

(2) A SMR contains nuclear substances during transport (e.g. fuel or spent fuel) but produces no energy during transport

The nuclear transport rules of the international liability conventions apply. Liability is channelled towards the operator. The transporter or carrier is exonerated from liability. As set out above in section (e), the conventions address the issue of liability of various operators for nuclear transport incidents. A specific problem arises when SMRs, that have not been designed to be unloaded from their means of transport, are sent to Non-Contracting States, given that the act of 'unloading' determines who bears liability for nuclear transport incidents.

Similarly to scenario (1), when such fuelled SMR has been installed on the installation site and remains fixed there to produce energy, it is assimilated to a nuclear installation and liability is channelled towards the SMR operator according to the liability rules for nuclear installations of the international nuclear liability conventions.

Practical example 11. A factory-fuelled SMR is sold and sent from its Belgian production site to a Spanish installation site buying the SMR for the production of energy.[40] Given that Belgium and Spain are Paris Convention States, unless otherwise agreed in writing, the Belgian SMR producer will be liable for incidents during transport of the SMR by the Belgian transporter until the Spanish SMR client takes charge of the SMR. As set out above in section (b), at his request, the Belgian transporter may bear the liability for incidents during transport if the Belgian SMR

[39] This scenario also encompasses the scenario where a SMR without nuclear substances is transported from its installation site to a decommissioning site.

[40] This scenario also encompasses the scenario where a SMR containing nuclear substances (e.g. spent fuel) is transported from installation to decommissioning site.

producer agrees to it, given that Belgian law expressly provides for this possibility.

Practical example 12. A floating fuelled SMR is sold and sent from its Chinese production site to a UK installation site buying the SMR for the production of energy. Given that the UK is a Paris Convention State and that China is not a party to any international nuclear liability convention, the UK SMR producer will be liable for incidents during transport of the SMR as soon as the SMR is uploaded on the ship. As set out above in section (d), it is fundamental that the term 'uploading' is clearly defined in contractual arrangements.

Practical example 13. A floating fuelled SMR is sold and sent from its UK production site to a Chinese installation site buying the SMR for the production of energy. Given that the UK is a Paris Convention State and that China is not a party to any international nuclear liability convention, the UK SMR producer will be liable for incidents during transport of the SMR by the UK ship until unloading. As set out above in section (d), it is fundamental that the term 'unloading' is clearly defined in contractual arrangements. A problem arises if such SMR is designed to remain on the ship when it is fixed in China and produces energy, given that, in such case, the SMR will strictly speaking never be 'unloaded' in China.

(3) A SMR contains nuclear substances during transport and produces energy during transport

It is presently unclear under the international nuclear liability conventions whether a fuelled SMR that produces energy during its transport qualifies as a nuclear installation and the liability rules applicable to nuclear installations apply, or whether nuclear transport rules of the international liability conventions apply. It seems clear, however, that ordinary tort rules do not apply and that liability is channelled towards the operator under either rules.

The international nuclear liability conventions are ambiguous in their wording. The 2004 revised Paris Convention offers the possibility to cover other installations, which could be interpreted to comprise SMRs.[41]

[41] Art. 1(a)(ii) of the 2004 revised Paris Convention. It defines nuclear installations as reactors other than those comprised in any means of transport; factories for the manufacture or processing of nuclear substances; factories for the separation of isotopes of nuclear fuel; factories for the reprocessing of irradiated nuclear fuel; facilities for the storage of nuclear substances other than storage incidental to the carriage of such substances; installations for the disposal of nuclear substances; any

However, the 1963 Vienna Convention does not foresee to extend the concept of nuclear installations to other installations.[42] Similarly, the Convention on Supplementary Compensation does not provide the possibility to include other installations in the definition of nuclear installations.[43] Yet the 1997 revised Vienna Convention adds the possibility to cover other installations, which could be interpreted to cover SMRs.[44] What is sure is that, to date, fuelled SMRs producing energy during transport

such reactor, factory, facility or installation that is in the course of being decommissioned; **and such other installations in which there are nuclear fuel or radioactive products or waste as the Steering Committee for Nuclear Energy of the Organisation (hereinafter referred to as the 'Steering Committee') shall from time to time determine**; any Contracting Party may determine that two or more nuclear installations of one operator which are located on the same site shall, together with any other premises on that site where nuclear fuel or radioactive products or waste are held, be treated as a single nuclear installation.

[42] Art. I(1)(j) of the 1963 Vienna Convention. A nuclear installation is defined as
(i) any nuclear reactor other than one 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; (ii) any factory using nuclear fuel for the production of nuclear material, or any factory for the processing of nuclear material, including any factory for the re-processing of irradiated nuclear fuel; and (iii) any facility where nuclear material is stored, other than storage incidental to the carriage of such material; provided 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.

[43] Art. 1(1)(b) of the Annex to the Convention on Supplementary Compensation. It defines nuclear installation as follows:
(i) any nuclear reactor other than one 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; (ii) any factory using nuclear fuel for the production of nuclear material, or any factory for the processing of nuclear material, including any factory for the re-processing of irradiated nuclear fuel; and (iii) any facility where nuclear material i stored, other than storage incidental to the carriage of such material; 26 provided 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.

[44] Art. I(1)(j) of the 1997 revised Vienna Convention. It adds the following to the definition of nuclear installation of the 1963 Vienna Convention: '(iv) **such other installations in which there are nuclear fuel or radioactive products or waste as the Board of Governors of the International Atomic Energy Agency shall from time to time determine'.**

have not been excluded from the international nuclear liability conventions even though the conventions expressly foresee this possibility.

3. Where is a company liable for an incident during nuclear transport?

Once it is clear which company is liable for a nuclear transport incident, the question arises in which country this company is liable, i.e. before which courts victims can sue this liable company. Again, the answer to the jurisdictional question of 'where a company is liable' for transport incidents involving nuclear substances from one State to another State (possibly through one or more transit States) is to be found in the international nuclear liability conventions.

Again, the response to this jurisdictional question will differ when the nuclear transport incident occurs in a Convention State, on the one hand, and when the nuclear transport incident occurs in a Non-Convention State, on the other hand.

Importantly, again, by providing a bridge between the Paris Convention States with the Vienna Convention States (both the 1963 Vienna Convention and the 1997 revised Vienna Convention), the 1988 Joint Protocol prevents conflicts of jurisdiction by ensuring that only one convention is applied to any one nuclear incident, either the Paris or the Vienna Convention (in its original and revised version).[45] If a Paris Convention SMR causes nuclear damage in a Vienna State and *vice versa*, if a Vienna Convention SMR causes nuclear damage in a Paris State, the 1988 Joint Protocol determines the competent court and the applicable law provided the 1988 Joint Protocol is in force in the States involved. It applies both to nuclear damage caused by incidents occurring on site of nuclear installations and during the transport of nuclear substances between them.

The scenarios below summarise the common rules regarding jurisdiction in case of a nuclear incident during transport.

(a) Nuclear transport incidents in Convention States

The rule under the international nuclear liability conventions is that, when a nuclear transport incident occurs in a Convention State, the

[45] Art. III.

Convention State where the nuclear transport incident occurs has jurisdiction.[46]

Importantly, nuclear transport incidents 'in a Convention State' comprise incidents that occur in that Convention State's territorial sea and in its exclusive economic zone.

Practical example 14. Nuclear spent fuel is sent from a French nuclear power plant to a Dutch reprocessing plant by a French truck. The French truck has an accident in the Netherlands. Dutch courts have jurisdiction. The French operator is liable for the incident during the road transport by the French transporter before Dutch courts.

(b) Nuclear transport incidents in Non-Convention States

The rule under the international nuclear liability conventions is that, when a nuclear transport incident occurs in a Non-Convention State, the State where the nuclear installation is located has jurisdiction.[47]

Importantly, nuclear transport incidents 'in a Non-Convention State' comprise incidents that occur outside a Convention State's exclusive economic zone, on high seas or when it is not possible to determine with certainty the place of the nuclear incident (e.g. when the incident is due to continuous radioactive contamination in the course of the transport). However, issues are likely to arise in cases where no transport is involved but where SMRs are operated to produce energy from a fixed installation on artificial islands or other structures outside of the territory of any State, as it will be difficult to determine which State is the SMR installation State for jurisdictional purposes.

Practical example 15. Nuclear fuel is sent from a Chinese uranium supplier to a French nuclear power plant by a Chinese maritime carrier. The Chinese carrier has an accident on the high seas. French courts have jurisdiction. The French operator is liable for the maritime incident caused by the Chinese carrier before the French courts.

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[46] Art. 13 of the 2004 revised Paris Convention. Art. XI of the 1963 Vienna Convention and the 1997 revised Vienna Convention. 18th meeting (15–17 May 2018) and 19th meeting (14–16 May 2019) of IAEA's International Expert Group on Nuclear Liability (INLEX) referred to in footnotes 85 and 91 of IAEA, *The 1997 Vienna Convention…* Art. XIII of the Convention on Supplementary Compensation.

[47] Ibid.

Conclusion

Nuclear transport is likely to increase in the forthcoming years. Corollary to such transport, risks of nuclear transport incidents are likely to increase too.

Nuclear new build, especially the deployment of SMRs, depends on the commercial appetite of investors. This appetite is partly conditioned by the level of legal risks.

The international nuclear liability conventions play an invaluable role in providing legal certainty on the two main questions related to risks of nuclear transport liability, namely '***Who*** is liable in case of an incident during nuclear transport?' and '***Where*** is this company liable in case of an incident during nuclear transport?'. These conventions also appear to allow for the necessary flexibility in order to include new risks created by the transportable SMRs. Risks will depend on whether or not SMRs contain nuclear substances during transport and, if SMRs do contain nuclear substances during transport, whether they produce energy after transport has stopped or whether, by contrast, they produce energy during transport. Only the latter scenario, i.e. when SMRs produce energy during transport, seems to be a cause for legal uncertainty.

PART IV

RADIOACTIVE WASTE MANAGEMENT

Chapter 8

PROGRESS AND EMERGING ISSUES IN THE GEOLOGICAL DISPOSAL OF HIGH-LEVEL NUCLEAR WASTE IN JAPAN

Fumito Tomooka
Professor at Nihon University College of Law, Tokyo Japan
Head of Researchers at Japan Energy Law Institute, Tokyo Japan
tomooka.fumito@nihon-u.ac.jp
ORCID: 0009-0007-1957-1777

Abstract

This paper discusses the progress and emerging issues in the search for a repository for the geological disposal of high-level nuclear waste in Japan. There are currently three municipalities that have indicated their willingness to accept the first phase ('Literature Survey'). This is the result of a change in government policy after the Fukushima accident in 2011. In 2017, the 'Nationwide Map of Scientific Features' was published to show the favourable and unfavourable areas that can be identified under 'scientific knowledge'. In this way, all municipalities could have changed their minds in favour of accepting the first phase of a geological disposal site in Japan. I would like to discuss this change from a legal point of view. On the one hand, some of the implications of the evidence from Toyo Town before the accident and, on the other hand, the difficulties that still exist between the municipality that has shown its will to accept and other neighbouring municipalities.

1 Introduction

The geological disposal of high-level nuclear waste (hereinafter: 'HLW') has been a major problem, a deadly difficult problem to solve for the nuclear power policy in Japan. Since Japan's waste disposal policy is not based on ocean or space disposal, which is prohibited by international treaty,[1] the only choice is 'geological disposal'. And so, in view of the internationally achieved and confirmed technology of disposal of these wastes, the remaining issues would be to find the candidates for deep disposal sites within our Japanese islands.

In fact, Japan is made up of a large number of islands, with densely populated cities on the flat land of the main islands, and high and low mountains surrounding them.[2] And above all, Japan is famous for earthquakes, and indeed sometimes huge, catastrophic earthquakes occur.[3] As a result, as with the construction of new nuclear power plants, it is extremely difficult to find suitable geological disposal sites, probably more difficult than in any other country in the world.

These physical conditions were very similar before and after the Fukushima accident in 2011. But the situation is changing as two districts in Hokkaido (the northern island of Japan) have shown their acceptance as candidates for disposal sites, which is the first phase of the decision-making process.[4] And another municipality (Genkai Village) in Saga Prefecture has also decided to follow the two candidates in May

1 The legal history on this issue is treated in my book (in Japanese): Fumito Tomooka, *The Structure of Nuclear Law and Special Knowledges*, Tokyo: Shinzansha 2024. 友岡史仁『原子力法の構造と専門知制御』（信山社、2024年）.

2 Population is 135 million people living only within the 30% of Japanese islands. *See* the report by the Ministry of Land, Infrastructure, Transport and Tourism, *Vulnerability of the National Territory*, p. 2, https://www.mlit.go.jp/common/000997376.pdf, 国土交通省『国土の脆弱性』[access: 11 May 2026].

3 Very recent big earthquake hit the Noto peninsular in Ishikawa on the 1st January in 2024. The Shika nuclear power plant run by Hokuriku Electricity Power Company (HEPC) is situated about 70 km from the epicentre. *See* the report on the current situation of the Shika NPP relating to the 'Noto Peninsular Earthquake' at HEPC website, https://atom.pref.ishikawa.lg.jp/resource/genan/ankan/kpdf/haihu20240327_1-1.pdf, 北陸電力株式会社『令和６年能登半島地震志賀原子力発電所の状況（地震動、断層、津波、地盤）』[access: 11 May 2026].

4 Three main processes are the legally stated in the Act. *See* 3.1 in detail.

2024.[5] This is a remarkable thing compared to the previous situation where no local government officially expressed its will to accept.

In this paper, I would like to focus first on the Japanese government's changing approach to this issue. The new approach adopted by the government is based on 'special knowledge' such as 'scientific evidence' that can explain how the candidate site would be more suitable than others. And secondly, I would like to focus on the current legal statute, which has not clarified the processes of acceptance of the disposal sites by the relevant local decision makers. However, the *Designated Radioactive Waste Final Disposal Act* (hereinafter: 'the Act') only stipulates that there should be three phases in the decision-making process ('Literature Survey', 'Preliminary Investigation' and 'Detailed Investigation'). There is no written, authoritative or public detailed guidance for local communities to participate in the decision-making process. Thus, all processes are on a 'voluntary basis', with no place for the municipalities themselves to make enforceable decisions. But a national issue such as the disposal of HLW would become a very heavy, or rather too heavy, burden for small towns and villages to deal with, and it is beyond their powers to make struggles between other municipalities and their own residents. I will come back to these issues from a legal point of view.

2 Has the Fukushima Accident Changed Minds? – Accessing Specialist Knowledge Behind the Scene

2.1 What Has Changed with the Fukushima Accident in Terms of Geological Disposal?

2.1.1 Regulatory Regime

Many nuclear policies in Japan were changed after the Fukushima accident in 2011. One notable point in the policy changes is that the regulatory system has been dramatically changed to be independent of any administrative departments of the government. The innovative central organisation in the system, the Nuclear Regulation Authority (hereinafter: 'NRA'), has all the legal responsibilities for nuclear safety based on the regulations made

[5] *See* Mainichi Shinbun, *Japan city assembly Oks request for nuclear waste site survey*, "The Mainichi" Apr. 26th 2024.

by the NRA itself. The NRA's responsibilities also include the assessment of repository sites from various safety perspectives, but this new authority is not expected to directly search and find out where the suitable candidate sites would exist on its own. It is the Nuclear Waste Management Organisation of Japan (hereinafter: 'NUMO') that is responsible for these latter tasks. NUMO is an organisation established in 2000 under the authority of the Ministry of Economy, Trade and Industry (hereinafter: 'METI').

2.1.2 Public Confidence

Of all the factors, the public's distrust of the policy of geological disposal of HLW in Japan is of great importance when considering the problem. In fact, as the NUMO survey shows, since the Great East Japan Earthquake that caused the Fukushima accident, the proportion of those who agree or somewhat agree with the policy has declined significantly.[6] This backward trend in public opinion has prompted NUMO to refrain from any activities related to the search for potential disposal sites for the time being.

2.2 Previous Cases before the Fukushima Accident

Before the Fukushima accident, NUMO had started an 'open call' for all willing municipalities to apply for the screening tests for suitability as a disposal site in 2002 after the law was enacted. Since then, many municipalities have been considering their applications for 'Literature Survey', the first phase of the screening process. Finally, the only town in Kochi Prefecture, Toyo, submitted a formal application in 2007, but withdrew it shortly afterwards. What happened in between[7] was as follows.[8]

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[6] *See* Ayako Arai et al., *Communication activities through dialogue in Japanese geological disposal project of High-Level radioactive waste*, 6th East Asia Forum on Radwaste Management Conference (November, 27-29, 2017, Osaka, Japan), http://eaform2017.aesj.or.jp/file/PapersList/Session2/(2C-2)%20_A.Araki_(NUMO).pdf [access: 11 May 2026].

[7] Various analyses of this case not only from legal but sociological views can be seen. *See* e.g., Takahiro Saigo, Shunsaku Komatsuzaki and Hideyuki Horii, *Decisive factors of the dispute regarding high-level radioactive waste repository sitting at Toyo-cho, Kochi, Japan: An analysis of political process and possible solutions*, "Shakai-Gijutsu-Kenkyu-Ronbunshu" 2010, Vol. 7, p. 87 et seq., https://www.jstage.jst.go.jp/article/sociotechnica/7/0/7_0_87/_pdf, 西郷貴洋＝小松崎俊作＝堀井秀之「高知県東洋町における高レベル放射性廃棄物処分地決定に係る紛争の対立要因と解決策」社会技術研究論文集7号（2010年）87頁以下 [access: 11 May 2026].

[8] This analysis is dealt with in detail by Keisuke Imamoto, *Direct claims, petitions, and petitions under the Local Autonomy Act and the submission of opposition resolutions and written*

1. The mayor of Toyo Town twice declared and sent to NUMO the will to accept it as a candidate site without informing the municipal assembly. This act of the mayor was not followed by any official process of approval by the town assembly.
2. On the contrary, after it became known that the mayor had sent his will of acceptance to NUMO for the first time, many unofficial discussions between proponents and opponents began, resulting in serious divisions among the inhabitants.
3. Neighbouring municipalities of larger units such as Kochi and Tokushima prefectures officially announced their opposition to the mayor's decision. The then governors of the two prefectures publicly urged METI not to accept NUMO's application for permission to begin the 'Literature Survey'.

Even after the Toyo Town case, some municipalities showed interest in becoming candidates for disposal sites. For example, the mayor of a small village (Kamikoani Village) in Akita Prefecture expressed his willingness to accept in 2007. However, in this case too, the mayor was forced to withdraw his application because of strong opposition from neighbouring municipalities and the prefecture in which the village is located.

After these cases, there was no formal written application until 2020, when two of the above-mentioned municipalities in Hokkaido Prefecture appeared.

2.3 Publication of the Nationwide Map of Scientific Features

2.3.1 Before the Publication of the Nationwide Map of Scientific Features

Even after the Fukushima accident, the basic legal model for geological disposal was not changed. However, some new policy approaches have been adopted since then. The most important progress in this regard is that

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opinions by the local assemblies: a case study on the application for the literature survey for the high-level radioactive wastes (HLW) final disposal facility in Toyo Town. In: Yoshihiro Tanaka (ed.), *Nuclear Policy and Public Participation: Japan's Experience and Lessons from East Asia*, Tokyo: Daichi Hoki 2022, pp. 195 et seq. (in Japanese), 今本啓介「地方自治法上の直接請求・請願・陳情と地方議会による反対決議・意見書提出」田中良弘編著『原子力政策と住民参加――日本の経験と東アジアからの示唆』（第一法規、2022年）195頁以下.

the Japanese government has focused on disclosing 'scientific evidence' to local communities, trying to enable them to make decisions on acceptance more easily.

In 2013, two years after the accident, the Ministerial Meeting on Permanent Nuclear Waste Disposal was held, and a year later the Strategic Energy Plan was adopted. According to this plan, the government revised the previous basic policy on the way of selecting the candidate disposal sites, and several revised points were publicly shown in 2015, as follows:[9]

1. Responsibility of current generations and potential for reversibility and retrievability for future generations to choose from;
2. Promotion of national public understanding and regional understanding;
3. Activities led by the national government;
4. Support for the region's contribution to the project;
5. Improvements in related organisational structures.

The 2015 report was an interim summary for the revised new geological disposal policy. Therefore, in 2016, OECD/NEA published its international peer review[10] to approve this 2015 policy by the Japanese government. Then in 2016, the Japan Atomic Energy Commission (JAEC) published the report on the review of the activities of the Geological Disposal Technology Working Group.[11] And in 2017, the final report was published, revealing the requirements and criteria for the establishment of the 'Nationwide Map of Scientific Features'.[12]

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[9] Cabinet Decision on the 22nd May 2015. *See* also Ministry of Economy, Trade and Industry, Radioactive Waste Management Policy Division, *Geological Disposal of High-Level Radioactive Waste in Japan* (English summary), p. 6.

[10] *See* OECD/NEA, *The Nuclear Management Organization of Japan's Pre-siting Safety Case Based on the Side Descriptive Model: An International Peer Review of the NUMO Safety Case*: NEA/RWM/R(2022)2, January 2023.

[11] Japan Atomic Energy Commission, Evaluation Report on Situations of Administrative Institutions' Activities related to Final Disposals（最終処分関係行政機関等の活動状況に関する評価報告書）.

[12] Advisory Committee for Natural Resources and Energy Subcommittee on Electricity and Gas Industry, Nuclear Energy Subcommittee Geological Disposal Technology Working Group, *Results of the Study on the Requirements and Standards for Presenting Areal Scientific Features Related to Geological Disposal* (published on 15th May 2017).

2.3.2 The Content of the 2017 Report

The requirements of the 2017 Report are as follows:

1. Characteristics and long-term stability of the geological environment (volcanic/igneous activity, faulting, uplift/erosion, geothermal activity, volcanic thermal fluids and deep fluids, and mineral resources).
2. Construction and operation of the facilities with respect to volcanic eruption and unconsolidated geological formations.
3. Transport.

The important feature of the map is to show a clear classification of the assumed areas in two ways – favourable or unfavourable. For unfavourable areas, there are several considerations such as: the long-term stability of the deep geological environment, the risk of future accidental human intrusion. The map shows that 'safe waste transport' should be added as a preferred option to the assumed favourable areas.

2.3.3 Significance of the Map

The Nationwide Map of Scientific Features changes the mind in favour of accepting the first phase of geological disposal siting in Japan.

Firstly, it has led the government to make it easier for local authorities to make decisions on accepting the first phase. So it could be said that the government's previous approach was weak. This can also be seen from the regime that most of the responsibilities were due to NUMO, and the government only supervised what NUMO did on a case-by-case basis under the regulations. Therefore, in the case of Toyo Town, the government just waits for the will of the city. So from their case, the policy was changed so that another way of applying for the 'Literature Survey' (when the state offered it to the municipality) was now available. But the way of 'voluntary basis' by the municipalities still exists.[13]

Secondly, as mentioned above, all the inhabitants can visibly find out where the supposedly favourable areas for geological disposal are. Moreover, these favourable and unfavourable areas can be identified under 'scientific' evidence. After the Fukushima accident, nations and even potential candidate communities lost confidence in nuclear power itself.

[13] This process has been added after Toyo Town case. *See* the Cabinet Decision on 22nd May 2015.

But 'scientific' evidence could persuade people, not politically, why that place would be favourable.

Therefore, it could be said that the local candidates in the 'unfavourable areas' from a scientific point of view would possibly be excluded and not entitled to apply for the official 'Literature Survey'. But from a legal point of view, the map doesn't oblige any local community not to put itself forward as a candidate, even if it is included in the 'presumed unfavourable area'. The map gives us only 'geological areas', not 'administrative areas'. At the moment, both areas of Hokkaido (Suttu Town and Kamoenai Village) appear to be included in the presumed favourable areas. But Kamoenai is on the very edge of the 'presumed disadvantaged area'.[14] NUMO accepted the official applications for the 'Literature Survey' from two communities, and the interim report states that both are in favourable areas.

Of course, there may still be some questions about the interpretation of the map. The map has been made with the best considerations at the time of publishing the report in 2017. But there may be other considerations in the future from a 'scientific' point of view. And the map doesn't force local governments to change their previous non-acceptance of landfills. For example, a prefecture like Hokkaido, where two municipalities currently applying for the 'Literature Survey' are located, has been opposed to any acceptance of nuclear waste since 2000. This dilemma will be discussed in detail later (see 3.2).

3. Some Issues Related to Disposal Process Schemes – Local Authorities and the Act

3.1 Disposal Process Schemes under the Act

As mentioned above (see 1), the Act sets out three phases for the construction of a permanent nuclear waste repository. Throughout the phases up to the final construction of the final site, NUMO is responsible for ensuring

[14] With regard to the 'area subject to the Literature Survey', it is noted that 'whilst Kamemai Village contains an "area presumed to have unfavourable characteristics due to volcanic and igneous activity" (orange), the remaining areas are classified as "areas where favourable characteristics are relatively likely to be confirmed", specifically "areas favourable in terms of transport" (green coastal areas)'. *See* the NUMO, *Documentary Survey Plan for Kamoenai Village, Furuu District, Hokkaido* (17th November 2020), p. 3, https://www.numo.or.jp/press/bunken_keikakusho_kamoenai.pdf, [access: 11 May 2026].

the proper procedures at each phase and obtaining the relevant administrative approval from the Minister of METI and the applicant local authority.

The Act states as a basic policy that democratic decision-making should take place during the 'Preliminary Investigation'.[15] As mentioned earlier, there are three phases in the process of selecting and deciding on the final disposal sites. 'Literature Survey' is the starting point of 'Preliminary Investigation', with only one clause[16] and no separate articles in the Act to regulate this phase. Therefore, it is obvious that the first phase is on a 'voluntary basis', guided by the economic benefits to be begotten by the applicant municipality. However, it is a truth that the official approval of a competent local authority is a matter of the utmost importance in order to facilitate the whole process.

One of the alternatives to the current status quo in the permitting process, which could achieve the democratic decision-making mentioned above, would be elections at every level of public organisation: from the local governor and the legislature down to the mayor and the local council. In the end, the citizens of the areas concerned can express their opinion by electing their representatives to be sovereign in the siting process. The other alternative is a local referendum. The problem with the first alternative would be the violent and sharp divisions between two camps in the affected areas. The problem with the second is that the Japanese legal system doesn't provide for either a national or a local referendum.

In 2015, the Cabinet decision mentioned that the way to get consensus from the residents of the candidate municipalities is for NUMO to 'try' to create opportunities for open discussion during the 'Preliminary Investigation' phase. The government says that local discussion or democratic processes are important. But it still insists that the central government should only direct and regulate NUMO,[17] not take any initiatives.

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[15] *See* article 4, paragraph 5 of the Act: The Minister of METI 'shall hear the opinions of the prefectural governor and the mayor of the city, town or village having jurisdiction over the location of said Preliminary Investigation area, etc. and shall give due respect thereto.'

[16] *See* article 6, paragraph of the Act: When NUMO 'intends to select a preliminary investigation area, it must conduct a survey using literature and other materials (referred to as 'Literature Survey' in the following paragraph) in advance on the matters listed below in accordance with the final disposal plan.'

[17] These tendencies of the government have consistently existed even after it revised the cabinet decision in April 2023. However, it added sentences such as: 'based on the

3.2 Practical Issues between Municipalities

As far as inter-municipal issues are concerned, there's no legal basis for the approval of the prefecture in which the candidate region is located. For example, when Hokkaido Prefecture, where two regions have officially accepted the 'Literature Survey' in 2020, shows its opposing intention not to accept any final decision on geological sites in its prefecture, citing the local law (*Ordinance on Specified Radioactive Waste in Hokkaido*) of 2000 as the reason for its consideration.[18] A similar case of interference occurred at the level of local municipalities. Since the acceptance of the 'literature study', the neighbouring municipalities (Shimamaki Village, Kuromatsu Town) have enacted their own ordinances to show their opposition to the introduction of nuclear waste into their neighbouring areas.[19] But these local ordinances only work to send their political messages to others, and do not legally bind other municipalities to take or not to take any decisions.

One solution to these antagonistic movements or collisions between municipalities is something like joint applications by neighbouring municipalities. Although such a case has never occurred in Japan, as evidenced by Toyo Town and other previous cases mentioned earlier, we must seek this solution. In order for small towns or villages, including prefectures, to carefully and prudently consider and find their ways for cooperation, it is necessary to have honest and fair discussions of

recognition that selection with emphasis on ensuring-safety is important, the government shall endeavor to obtain the understanding and cooperation of the public and relevant residents through 'Map of Scientific Features' that indicates areas considered to be scientifically suitable (scientifically favourable areas).' *See* the Cabinet Decision on 28th April 2023.

[18] *Ordinance on Specified Radioactive Waste in Hokkaido* (Ordinance No. 120, 2000). However, this ordinance states that 'At present, … disposal methods have not been fully established' and so 'under these circumstances, the bringing-in of specific radioactive waste that should be handled with utmost caution is unacceptable.' This could be interpreted to mean that the prefecture can never give permission for the construction of a geological HLW repository, even though the scientific characteristics of the level of safety that should be a condition for approval have been demonstrated.

[19] *Ordinance to Prevent Radioactive Materials from Bringing into Shimamaki Village* (Ordinance No. 2, 2020) and *Ordinance to Prevent Radioactive Materials from Bringing into Kuromatsunai Town* (Ordinance No. 1, 2021).

pros and cons based on 'scientific evidence' without particular ideologies and prejudices.

3.3 Other Remaining Issues

There are other issues to consider. The first is the relationship between the state and the prefecture. Candidate municipalities are usually towns or villages of very small population and economic size. However, as mentioned above, the prefectures where the candidates are located usually express their opposition. Ordinances to this effect have a strong impact on the public, even though they don't have the legal force of political messages, and the administrative procedure after the application by the municipalities continues unhindered according to the provisions of the law, so that from a legal point of view it makes no difference whether the will of the local governments is expressed or not. However, the political messages they send contribute to the formation of public opinion, which tends to oppose the acceptance of nuclear waste.

This is the case in Kamoenai, Hokkaido. In spite of the Hokkaido Prefectural Ordinance, which states that Hokkaido refuses to accept any nuclear waste in its prefectural area, the mayor of Kamieinai has accepted the state's offer for the first phase, 'Literature Survey', and it is feared that sharp contradictions and struggles will arise and continue among them in the future.

Secondly, moving on to the second phase ('Preliminary Investigation') could be an issue after NUMO has completed its 'Literature Survey'. For example, Suttsu Town has enacted a local referendum ordinance for the decision to move to the second phase,[20] but Kamoenai hasn't. This shows that at the beginning of the next phase, similar collisions will be repeated and the issue of the first phase will remain unresolved.

Finally, how to create more incentives for municipalities not only to apply for the 'Literature Survey' but also to proceed to the final phase if the legal requirements are met is still a big problem to solve. For example, to give the municipalities as much subsidy as possible to enable them to develop economically.[21] And, of course, the grant is also a gift for being

[20] *Ordinance for a Referendum on Opinions regarding the Preliminary Investigation and Detailed Investigation for the Final Disposal of Specified Radioactive Waste in Suttsu Town* (Ordinance No. 16, 2021).

[21] The legal basis for giving grant is under the 'Power Plant Location Subsidization Programme' organized by METI.

accepted as a candidate for a landfill site. In Toyo Town, however, it is reported that the mayor has been told that he has no intention of going to the next step – just accepting the grant from the state. The same may be true of the town and village in Hokkaido and Genkai in Saga Prefecture.

4. Conclusion

Under the present system based on the Act, the 'Nationwide Map of Scientific Features' has been very effective at present for local communities to decide whether or not to apply for the first phase of selecting the candidate for the final disposal site of HLW.

On the contrary, the case of Toyo Town shows that there are still many difficulties in obtaining the consensus of the local residents of the region concerned. In addition, as I mentioned earlier, how can the surrounding neighbouring communities (including prefectures), which show strong opposition, be persuaded and the contradictions between them be resolved? This is one of the biggest problems in the issue of nuclear waste siting in Japan.

And the degree and method of involvement of the national government is also a big problem. The law states that the Minister of METI shall supervise and regulate NUMO from time to time. But this is not specifically aimed at gaining positive local consensus. This may be the reason why NUMO is the institution run by the nuclear power producers as a non-neutral position. That is, the positive role is expected from NUMO, an organisation composed of the nuclear generators, which is semi-public and at the same time semi-private. Therefore, even the main actors in the acceptance of storage sites are still the local communities, which have to take on the role of neutralising the anti-nuclear sentiment. In view of this status quo, we must consider how the state would come to the fore as the main actor to ensure that arrangements are made to coordinate the confrontations between local bodies and residents in order to find the way to the final objectives.

Chapter 9

SMR AND AMR RADIOACTIVE WASTE: A COMPARATIVE LEGAL ANALYSIS[1]

Nuria Prieto Serrano, coord.[2]
Contributing authors: Istiak Ahmed, Jerry Bonanno, Charles Bressant, Katarína Duchoňová, Stephen Tromans KC, Alexandra Van Kalleveen and Federico Winsens[3]

Acronyms used:

- AMR: Advanced Modular Reactor
- ARN: Autoridad Regulatoria Nuclear (Argentina)
- BAT: Best Available Techniques
- CNEA: Comisión Nacional de la Energía Atómica (Argentina)

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[1] Paper prepared for the conference 'Nuclear Inter Jura 2024: Nuclear Build Renaissance – in search of new approaches to legal challenges and regulatory effectiveness', Warsaw (Poland) 3–7 November 2024.

[2] Nuria Prieto Serrano, Department of International Coordination and R&D, Enresa (Madrid).

[3] Istiak Ahmed, Lawyer in Bangladesh, Lawyer licensing candidate in USA, Barrister candidate in Canada;
Jerry Bonanno, Deputy General Counsel at Nuclear Energy Institute (Washington, DC);
Charles Bressant, Associate, Pinsent Masons France LLP (Paris);
Katarína Duchoňová, SMA advokátska kancelária s.r.o. (Bratislava);
Stephen Tromans KC, 39 Essex Chambers (London);
Alexandra van Kalleveen, Secretary of Working Group 5 Waste management, INLA;
Federico Winsens, Legal Assistance CAREM Project National Atomic Energy Commission (Buenos Aires).

- CoRWM: Committee on Radioactive Waste Management (United Kingdom)
- DGR: Deep Geological Repository
- DOE: Department of Energy (USA)
- EPR: European Pressurized Reactor
- GDA: Generic Design Assessment
- HLW: High Level Waste (*)
- LILW: Low and Intermediate Level Waste (*)
- LWR: Light Water Reactor
- NRC: Nuclear Regulatory Commission (USA)
- PWR: Pressurized Water Reactor
- SMR: Small Modular Reactor
- VLLW: Very Low Level Waste (*)
- SF: Spent Nuclear Fuel

(*) Note on the waste categories HLW, LILW, VLLW: generic concepts not corresponding to any particular national definition.

A. Introduction: Reasons for Drafting This Report. The Current Situation Regarding SMR and AMR Development Worldwide

The interest of INLA WG5 in the waste generated by SMR dates back to February 2023. At that time, an online meeting was organized with members of Working Group 5, and within the context of discussions on the work program for the next two years, a list of topics of interest for joint analysis was put to a vote. Compared to other topics such as 'societal participation in site selection of repositories' or 'legal considerations on the possible development of multinational repositories,' the topic of SMR waste caught the group's significant attention. A clarification suggested by the UK member is included here: the scope of study not only covers radioactive waste and spent fuel arising from SMR but also that arising from advanced reactors as defined by 'AMR' in this country.[4]

[4] For clarification of these terms, we keep the definitions used by the UK government, by which Generation IV reactors are considered AMR: GOV UK, Department for Energy Security & Net Zero, *Advanced Nuclear Technologies*, https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies [access: 15 November 2024].

It is no surprise that the WG is interested in this topic. Currently, there are more than 50 SMR technologies in development worldwide, with 98 technologies identified at various stages of development. These projects are distributed across 18 countries. In particular, the second edition of the 2024 NEA SMR Dashboard includes 56 SMR under active development. The countries with organizations developing these technologies include the United States, Canada, France, Japan, China, and Russia, among others (Figure 1).[5] The first SMR will be built this decade, with accelerated deployment in the 2030s.

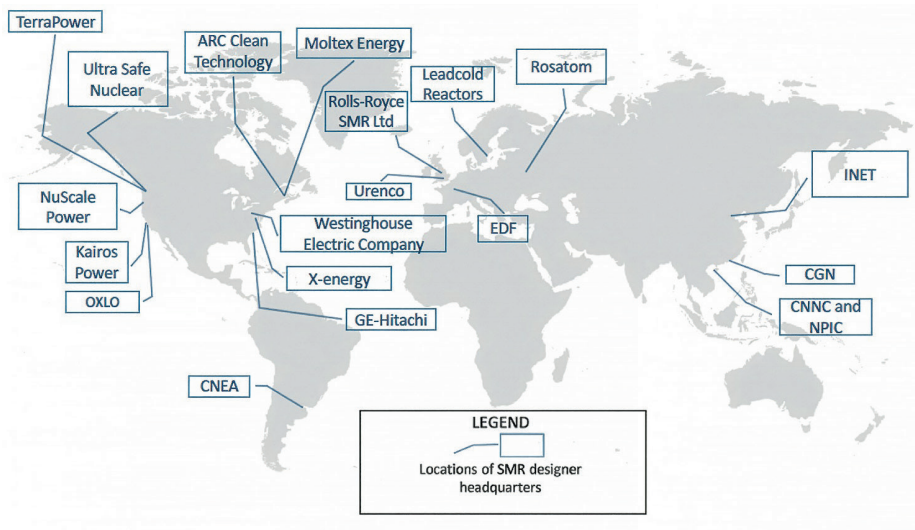

Figure 1. Location of SMR designers headquarters of a selection of SMR

Source: NEA, *NEA Small Modular Reactor Dashboard*, N 20 EA No. 7650, OECD 2023, https://www.oecd-nea.org/jcms/pl_78743/the-nea-small-modular-reactor-dashboard [access: 15 November 2024].

International organizations are closely monitoring this evolution. Within the OECD-NEA, significant work has been done on compiling

[5] The first two volumes of the first edition track the progress of 42 SMR worldwide. Volume I was launched in March 2023 during the NRC Regulatory Information Conference, and Volume II was published in July 2023 during the 14th Clean Energy Ministerial in Goa, India. The 2024 edition will evaluate 56 SMR globally. NEA, *NEA Small Modular Reactor (SMR) Dashboard*, https://www.oecd-nea.org/jcms/pl_73678/nea-small-modular-reactor-smr-dashboard [access: 15 November 2024].

and updating the status of SMR technology and its implementation worldwide, evaluating aspects such as licensing, siting, financing, supply chain, public participation, and fuel supply. The NEA SMR Dashboard reveals substantial progress towards the deployment and commercialization of SMR in both OECD and non-OECD countries, especially in the past two years.

According to the description provided by the OECD-NEA on its website, SMR are expected to play an essential role in supporting net-zero emissions goals, especially in hard-to-decarbonize industrial sectors. These new reactors offer potential benefits such as enhanced and passive safety systems, more attractive financing options due to shorter construction times, fewer components, and smaller plant footprints.

However, there are still many uncertainties regarding the type and quantity of radioactive waste/spent fuel they will generate, what challenges they will pose to existing regulatory frameworks, or if they are suitable for disposal in existing and planned waste repositories. This depends, of course, on the characteristics of the waste produced, for which there is no single answer. As a class of reactors, SMR are defined by their reduced size, but there is a wide variety in terms of power, temperature, technology, and fuel cycle, with sizes ranging from 1 MWe to over 300 MWe and temperatures from 285°C to over 850°C (Figure 2).

To conduct this study, the conventional approach was followed: a task group of dedicated WG members was formed to help draft a questionnaire with what are considered the most relevant questions in this regard. Once the questionnaire was agreed upon, each member of the task group provided answers from the perspective of their country's situation. The task group included representation from the OECD-NEA, which was very useful in contextualizing the problem and providing us with additional information.

The countries that participated in this questionnaire were Argentina, Bangladesh, the USA, Slovakia, the United Kingdom, and France. Before starting to describe the results obtained, I must express my gratitude to those who have greatly contributed to this study: Federico Winsens from Argentina, Stephen Tromans KC from the United Kingdom, Istiak Ahmed with responses from Bangladesh and the USA, Jerry Bonanno from the USA, Charles Bressant from France, and Katarína Duchoňová from Slovakia. I would also like to extend special

thanks to Kaan Kuzeyli for his collaboration in comparing responses and always to our group's Secretary, Alexandra Van Kalleeven, for her enthusiasm and support throughout the entire process. Thanks also to Soufiane Mekki from the OECD-NEA for the valuable information provided.

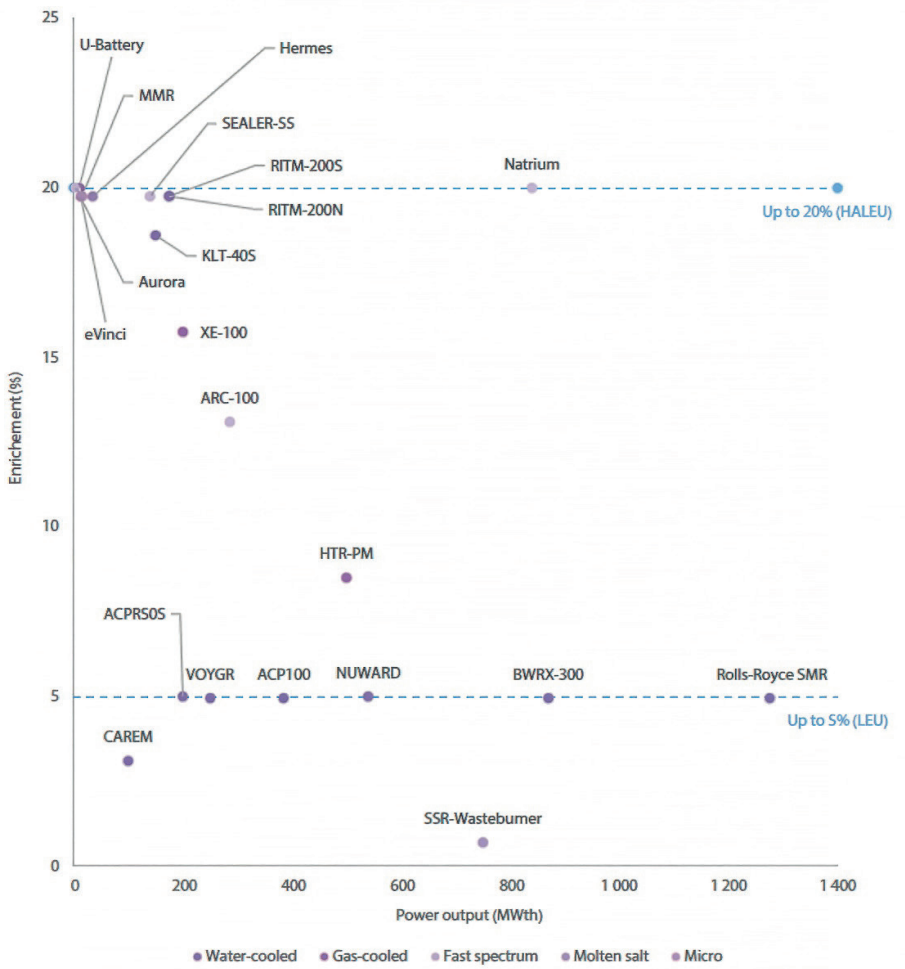

Figure 2. SMR concepts by type, thermal power and enrichment

Source: NEA, *NEA Small Modular Reactor Dashboard…*

B. Questionnaire Content

1. Plans and policies for the development of SMR. Consideration of the waste generated by them (questions 1a and 1b):

The first question of the questionnaire addresses the plans and policies for the development of SMR and to what extent the radioactive waste generated is considered in them.

In **Argentina**, with Decree 1107/2006, the construction of the CAREM-25 reactor has been promoted, and the state-owned National Commission for Atomic Energy (CNEA) has been tasked with the design and construction of its prototype. The response from this country mentions specific plans and a legal framework since 2006, highlighting some support measures for this project, such as tax benefits or a special customs control regime. The Argentine nuclear regulator, ARN, has already granted a construction license for the prototype, imposing a series of requirements. As for the waste that this reactor is expected to generate, it is anticipated to be LILW and initially stored temporarily within the site. The waste will be characterized in due course and treated according to the established general regulatory framework. It should be noted that CAREM-25 is currently achieving its approval as a prototype, but thereafter each individualized implementation project will need to obtain its respective authorization.

The response from **Bangladesh** indicates that a nuclear power plant with two reactors is under construction, although these will not be SMR. The development of SMR is under consideration, and the country is participating in international working groups to analyze the feasibility of developing this type of reactors within its territory. Regarding the new nuclear power plant under construction, which is being built in collaboration with ROSATOM, it is expected to conclude a take-back agreement with the Russian Federation for the removal of spent nuclear fuel from the plant.

Slovakia is one of the countries that has expressed interest in participating in the Phoenix project (9/2023) for the development of SMR.[6]

[6] PROJECT PHOENIX was announced by U.S. Presidential Envoy for Climate John Kerry at the UN Climate Change Conference in Sharm El-Sheikh, Egypt (COP27). The project will be carried out under the U.S. Department of State's Foundational

Under the umbrella of this project, potential sites are being studied in areas where nuclear power plants already exist, as well as cost analyses and predictable schedules; all within the framework of the country's industry decarbonization policy. The grant application to participate in this Project was submitted jointly by a consortium of partners who signed a Memorandum of Cooperation in June 2023. To present this grant application, State representatives, private companies, and research organizations have joined forces.

Furthermore, in this country, Memorandums of Understanding have also been signed in 2023 with EDF and Westinghouse to cooperate in the implementation of future SMR development projects.

At present, there is no schedule for the start of operation of this type of reactors, nor has a decision been made on their location. However, 'considering that Jaslovske Bohunice V1 NPP is under decommissioning and the brownfield should be ready in 2029, it is highly probable that the first SMR/AMR will be located in this area.'

Also in the **United Kingdom**, the government supports the development of SMR with a number of reactor types undergoing evaluation. Government funds have been allocated to support nuclear developments, including a specific fund for SMR developments and research related to AMR. In the near future, it is expected that 25% of the country's energy demand will be covered by new nuclear developments, but at the time the questionnaire was answered, it was not yet known what proportion of that figure would be occupied by SMR or AMR.

In 2023, the development of these new reactors was entrusted to the government-owned entity Great British Nuclear, equipped with a fund to select the best technologies. Great British Nuclear will be subsumed into the wider body, Great British Energy, announced by Sir Keir Starmer's Labour Government after the July 2024 general election. The Generic

Infrastructure for the Responsible Use of Small Modular Reactor Technology (FIRST) Program in cooperation with the U.S. Department of Commerce's Small Modular Reactor Public-Private Program (SMR PPP), which aims to promote transatlantic cooperation to deploy SMR in Europe and Eurasia. Project Phoenix aims to accelerate the global clean energy transition by providing technical assistance to support decision making on pursuing the conversion of one or more coal-fired power plants to secure and safe zero-carbon small modular reactor (SMR) nuclear energy generation. Project PHOENIX, https://www.smr-first-program.net/project-phoenix/ [access: 15 November 2024].

Design Assessment (GDA) process, a non-statutory and voluntary process initiated in 2008, will provide an important means by which new reactor designs can be assessed generically by the nuclear safety and environmental regulators. Currently, there are three SMR designs undergoing that process. The government will select which further designs will be able to enter the process. No licensing applications for SMR have been submitted yet and realistically are some way off. New types of reactors will also need to apply for regulatory justification approval.

Within these plans, decisions on the disposal routes for the radioactive waste/spent fuel have not yet been made. It is expected that the spent fuel and the most hazardous radioactive waste generated by these reactors will be disposed of in the future DGR facility, but for this to be possible, the waste management agency Nuclear Waste Services will need to conduct an assessment of their suitability for this type of disposal. The environmental studies required to license SMR must include information on the radioactive waste produced and a Best Available Technique (BAT) requirement for their optimization.

Among the spent fuel/radioactive waste expected to be generated by SMR and AMR, three categories are distinguished: those that will be similar to those generated in LWRs (Light Water Reactors); an intermediate category with many similarities to 'traditional' waste, but which may present some differences in its characterization; and those for which there is currently very little information and which may require decades of research to ensure their proper management.

France's energy strategy includes the development of 14 new nuclear reactors, both EPR and SMR, to increase the country's nuclear capacity and contribute to long-term climate goals. A notable example is the grant approved by the European Commission to support Nuward, a subsidiary of EDF, in its SMR research and development efforts. This project aims to design and construct small reactors (up to 300 MWe), intending to complete the research and development phases by 2027. Additionally, in 2021, President Macron announced a significant investment specifically for SMR.

Within the planned 14 new reactors, 6 should be EPR II, among which 4 should be settled in the North of France (two in Gravelines, with estimated commercial operation date by 2038, and two in Penly, by 2035) and 2 in the Centre of France (in Bugey, with commercial operation date by 2042). The overall cost for the 6 new EPR is estimated at 52 bn euros, and these projects should create 30,000 new jobs.

All this investment is accompanied by a legal framework that supports the development of these new facilities. A recent law from June 2023 establishes measures to accelerate the administrative licensing procedures for new nuclear installations, including SMR, if they are located on sites where nuclear installations already exist.

In June 2024, the first application for a construction license for an SMR was submitted in this country by a start-up called Jimmy.[7]

Currently, there is no data available in this country regarding the generation of radioactive waste in these new types of reactors. In any case, following the general rule adopted for all Basic Nuclear Installations in France, any construction application must be accompanied by estimates of waste generation and cost calculations.

In the **United States**, several State policies support the development of SMR and AMR. The Department of Energy (DOE), through its Office of Nuclear Energy, promotes the advancement of nuclear technology and science to meet the country's energy and environmental needs. Among the DOE's programs and projects, the Advanced Reactor Demonstration Program (ARDP)[8] stands out with three pathways to support the demonstration of advanced reactors through public-private partnerships.

- Pathway 1: Advanced Reactor Demonstrations, with projects such as TerraPower's Natrium reactor and X-energy's Xe-100 reactor, aiming to operate within 5-7 years.
- Pathway 2: Risk Reduction for Future Demonstrations, supporting projects like Kairos Power's KP-FHR, Holtec's SMR-300, Westinghouse's eVinci, BWX Technologies' BANR, and Southern Company's Molten Chloride Fast Reactor.
- Pathway 3: Advanced Reactor Concepts 2020 (ARC 20), with projects such as General Atomics' Fast Modular Reactor, Advanced Reactor Concepts' Advanced Sodium-Cooled Reactor Facility, and Mass. Institute of Technology's Horizontal Compact High-Temperature Gas Reactor.

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[7] franceinfo, *Une start-up dépose la première demande d'autorisation pour un mini-réacteur nucléaire en France*, https://www.francetvinfo.fr/societe/nucleaire/une-start-up-depose-la-premiere-demande-d-autorisation-pour-un-mini-reacteur-nucleaire-en-france_6515660.html [access: 15 November 2024].

[8] U.S. Department of Energy, *Advanced Reactor Demonstration Program*, https://www.energy.gov/ne/advanced-reactor-demonstration-program [access: 15 November 2024].

Another program promoted by DOE is the Advanced SMR RD&D Program. Initiated in 2019, this program supports the research and deployment of SMR technologies. This program supported development of the NuScale VOYGR project.[9] The DOE has offered several additional funding opportunities, including funding assistance for multiple projects across the U.S. under the 2018 Funding Opportunity for Advanced Technology Development;[10] and loan guarantees offered by the DOE's Loan Program Office (LPO) which support advanced nuclear projects, including SMR.[11]

The nuclear regulator (Nuclear Regulatory Commission, NRC) is also involved in the development process of these new reactors. The NRC has issued design approvals and certifications for the NuScale US600.[12] The NRC has also issued a construction permit for the Kairos Hermes low-power test reactor and is currently reviewing a construction permit application for the Kairos Hermes-2 project.[13]

The response from the United States also provides abundant information about additional applications that are currently under review by NRC, pre-application activities and interactions between NRC and potential applicants, rulemaking and policy work underway at NRC, and siting decisions that have been announced by private entities. These efforts reflect a coordinated approach between the government and the private sector to advance SMR technology,

[9] https://www.energy.gov/ne/advanced-small-modular-reactors-SMR [access: 15 November 2024], https://www.nuscalepower.com/en/news/press-releases/2023/uamps-and-nuscale-power-agree-to-terminate-the-carbon-free-power-project [access: 15 November 2024].

[10] For more information on awards, U.S. Department of Energy, *Map: Nuclear Energy Industry FOA Awardees with Data Table*, https://www.energy.gov/ne/map-nuclear-energy-industry-foa-awardees-data-table [access: 15 November 2024].

[11] Loan Programs Office, *Building a Bridge to Bankability*, https://www.energy.gov/sites/default/files/2022-05/DOE-LPO22-PPTv02_LPO-Overview-Slides.pdf, [access: 15 November 2024]; idem, *Advanced Nuclear Energy. Loan Guarantees*, https://www.energy.gov/sites/default/files/2020/01/f70/DOE-LPO-Nuclear-Energy-Jan2020.pdf [access: 15 November 2024].

[12] https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/nuscale.html [access: 15 November 2024].

[13] U.S. NRC, *Hermes – Kairos Project Status Dashboard*, https://www.nrc.gov/reactors/non-power/new-facility-licensing/hermes-kairos/dashboard.html [access: 15 November 2024].

contributing to energy independence and environmental sustainability in the United States.

Regarding the consideration of radioactive waste generated in all these new projects, in any case, the new SMR projects must comply with regulations that minimize waste generation and facilitate future decommissioning. The disposal of LILW is the responsibility of the states, while the disposal of SF and HLW is a federal responsibility according to the Nuclear Waste Policy Act.

2. Consideration of Specific Financial Mechanisms (question 1c)

Within the first set of questions, the questionnaire inquires whether national policies include specific provisions for financing the costs associated with radioactive waste generated by SMR:

In **Argentina**, the costs associated with the storage of radioactive waste must be included in the total cost estimate for the development of the SMR. This means that they must be considered in the financial analysis to decide if the prototype is economically viable. Regarding the costs of disposal, it has not yet been decided whether these will be covered by the waste management funds provided by the operators or if a special charge will be created for the SMR operator.

In **Bangladesh**, there is no specific national policy for SMR, and therefore the costs associated with this type of waste have not been estimated. For the two new projected nuclear plants (which are not SMR), the national policy for the management of radioactive waste and spent nuclear fuel from 2019 requires producers to store the spent fuel for a minimum of 10 years. The financing system in place includes a radioactive waste management fund to cover long-term obligations, with contributions from the waste generators. These provisions are likely to be applicable to SMR waste management, if the country approves their development.

The response from **Slovakia** indicates that there is no special information or plan regarding the generation of SMR waste, nor have specific plans been developed for these costs.

In **France**, this type of information is not yet available either, with the general rule being the polluter pays principle. Operators of Basic Nuclear Installations are required to contribute financially to the management of the waste they generate, intended to finance the operations of the National Agency for Radioactive Waste Management (Andra). However, Andra has the right to refuse to manage this type of waste, which would

be a major problem since this agency has a monopoly on radioactive waste disposal in the country.

A similar response is offered by the **United Kingdom**, where the current policy does not include specific cost estimates for SMR waste. Under the Energy Act 2008, a nuclear power plant operator needs to provide and grow a separated fund which will pay for the decommissioning costs, and the waste and spent fuel management costs of the plant. A plan for doing this must be approved by the UK Government before construction can start. To date, no Funded Decommissioning Programme has been put forward for an SMR or AMR, and so currently, the possible destination and associated costs of LILW generated during the operation of new SMR are being investigated by prospective reactor vendors and operators. The price that would have to be paid for transferring spent fuel to the future DGR, assuming there are no industry proposals for reprocessing, is also being studied.

In the **United States**, LILW generated during the operation of nuclear power plants is the responsibility of the license holder. Applicants for licenses who are not considered 'electric utilities' must demonstrate their financial qualifications to cover estimated operating costs. Commercial power rector licensees must also provide NRC with reasonable assurance that funds will be available for decommissioning. All current commercial power reactor licensees have established Nuclear Decommissioning Trusts as the main source of funding for decommissioning. In the specific case of decommissioning financing for SMRs and AMRs, the NRC has indicated that it would manage such issues in the near-term on a case-by-case basis using design-specific decommissioning cost estimates with possible exemptions to the general requirements. The above refers to the management costs of LILW during operation and decommissioning of the nuclear facilities. Regarding the costs of disposal of SF and HLW, U.S. law authorizes the DOE to sign contracts with entities that generate or possess spent nuclear fuel for its transportation and final disposal. Historically, utility companies have paid fees to the Nuclear Waste Fund to cover the costs of disposing of SF and HLW. The financing for SMR and AMR would, in principle, not be different from that established for other nuclear power plant owners.

The DOE is working on two reports: one public report on strategies for the disposal of SF and waste from advanced reactors, and another for internal use, based on information received from vendors, with technical

assessments of the feasibility of storage, transportation, and disposal of SF from advanced reactors and its economic implications.[14]

In conclusion, no country has detailed specific provisions regarding the costs associated with radioactive waste generated by SMR. In some cases, it is indicated that, as a general rule, estimates should be provided with the initial budgets; however, there does not appear to be confidence in the accuracy of this information. Only the United States emphasizes in its response that the management of SMR/AMR waste is being addressed on a case-by-case basis.

3. Expected Inventory and Characteristics of Radioactive Waste from SMR (question 2, a, b, and c)

Information about inventories of existing waste and of estimates for the short and medium term is commonly made available in countries with nuclear power, and certainly in those participating in the questionnaire. An open and easy source for this are the national reports to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (hereinafter, Joint Convention).[15] Finding estimates on SMR and AMR radioactive waste generation in those inventories is a different matter. The questionnaire included questions about SMR radioactive waste inventory estimates as well as the overall radioactive waste inventory. This approach aimed to use the general radioactive waste data to contextualize the proportion of waste derived from SMR in relation to the total.

In **Argentina**, the radioactive waste generated in CAREM-25, according to the available information, will consist of LILW and VLLW which is being considered under the existing regulatory frameworks. No information is currently available about the expected amounts of SF. The inventories of the operating plants are specified in the national report for the Joint Convention.[16] Quantitative estimates of waste generated in SMR

[14] For a summary of these projects *see* N. Larson, *Back-End Management of Advanced Reactors (BEMAR)*, https://www.nwtrb.gov/docs/default-source/meetings/2023/august/ned-larson.pdf?sfvrsn=4 [access: 15 November 2024].

[15] International Atomic Energy Agency (IAEA), Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, adopted in 1997.

[16] This includes the two units of Atucha Nuclear Power Plant and one unit of Embalse Nuclear Power Plant, as specified on page 41 of the 2020 national report: Argentina.

are not yet mentioned, but this report indicates the temporary storage facilities at the CAREM site among its planned facilities. When asked if the physic-chemical and radiological characteristics of the waste expected to be generated are known, the respondent indicates that there will be no difference from other PWRs in the case of SMR based on this prototype.

In **Bangladesh**, there is no expected inventory for SMR.

The response from **Slovakia** refers to the facilities that currently exist for the two operating nuclear power plants, which consist of a surface disposal facility for LILW and a storage facility of SF. There are no specific provisions yet for SMR waste, and they will need to be included in the national program that covers all radioactive waste under the country's jurisdiction. The existing comprehensive storage and disposal infrastructure could include SMR waste. No inventory estimates are provided at this time.

The inventories in the **United Kingdom** are made public on the website[17] (as in the case of France, spent fuel is not currently counted as radioactive waste). Current plans do not include estimates of radioactive waste from SMR or AMR.

In **France**, Andra is responsible for compiling and publishing the national inventory of radioactive materials and waste located on French territory every year. Every five years, Andra also publishes a report on the estimated management capacities and a proposal on the investments needed for efficient management. The last report (2023) does not include any information about SMR. However, since the pluriannual energy program requires the conduction of studies on that matter, Andra judges that the prospects of the use of SMR in France need to be defined more precisely in order to project an estimation of their waste disposal. The next prospective report, due in 2028, should then include provisions on SMR & AMR.

In the **United States**, there is abundant information on the waste inventories of reactors operational to date, based on the reports that nuclear facility operators submit annually to the NRC. The DOE has

gob.ar, *Informe Nacional a la Convención Conjunta*, https://www.argentina.gob.ar/arn/informe-nacional-la-convencion-conjunta [access: 15 November 2024].

[17] GOV UK, *UK Radioactive Waste and Material Inventory 2022*, https://www.gov.uk/government/publications/uk-radioactive-waste-and-material-inventory-2022 [access: 15 November 2024].

undertaken several projects to understand the quantity and characteristics of the SF that will be generated by SMR and AMR. For example, the ONWARDS Project (Optimizing Nuclear Waste and Advanced Reactor Disposal Systems) comprises eleven individual projects aimed at reducing waste volume in AMR. Another example of a project promoted by DOE is 'Nuclear Waste Attributes of SMR Scheduled for Near-Term Deployment – Nuclear Fuel Cycle and Supply Chain' (DOE, ANL/INL): this study compared the waste from three small reactors scheduled for near-term deployment (VOYGR, Natrium, and XE-100) with that of a large reference Pressurized Water Reactor (PWR). It was found that SMR waste showed similarities to the large reference reactor and some potentially significant differences. Overall, this study concluded that 'assuming appropriate waste management and system design and operational optimization, there appear to be no major challenges to the management of SMR wastes compared to the reference [reactor].'[18]

The DOE and NRC have conducted investigations to better understand the issues associated with the storage and management of SF generated by advanced reactors. These investigations include different types of fuel, such as metallic fuel, tristructural isotropic (TRISO) fuel, and molten salt reactor (MSR) fuel.

4. Specific Provisions for Radioactive Waste from SMR, Different from Those Applicable to Other Radioactive Waste (questions 3, 4a, and 4b)

Question 3 of the questionnaire refers to specific binding provisions that have been developed in laws (question 3) or regulatory standards (question 4) related to SMR and different from those existing for other nuclear facilities.

Argentina does not specify unique provisions for SMR waste.

Bangladesh mentions the IAEA Country Nuclear Power Program but does not provide specific details.

Slovakia has not yet developed specific binding provisions that regulate the safety of SMR, but it is following the conclusions and recommendations of organizations such as the OECD-NEA with interest.

[18] T. K. Kim, L. Boing, W. Halsey, B. Dixon, *Nuclear Waste Attributes of SMRs Scheduled for Near-Term Deployment. Nuclear Fuel Cycle and Supply Chain*, November 18, 2022 ANL/NSE-22/98, Revision 1, p. 8, https://share.google/TwKb19sbGNmL5D7Wu [access: 15 November 2024].

Among the plans announced by the government to increase the country's electrical capacity, including the possible development of SMR, is the 'improvement of administrative processes for connecting new sources to the electricity system', which may include the development of new regulatory standards.

The response from the **United Kingdom** indicates that there is currently no specific legislation distinct from the general regulations regarding SMR or AMR, neither at the level of laws or regulations nor regulatory standards.

France has an identical response, clarifying that 'the French legal framework was designed for Basic Nuclear Installations and is not (yet) adapted to SMR. It is therefore possible that it will evolve to take into account specific characteristics of SMR.'

The **United States** indicates, like other countries, that general provisions on the management of radioactive waste will also apply to SMR and AMR. Although exclusive standards for SMR and AMR have not been developed, the NRC uses the existing regulatory framework and can apply specific requirements through license conditions, orders, and exemptions from current regulations. The requirements for SMR and AMR waste management can be included in the current regulations through modifications and updates, ensuring that the challenges these reactors may present are adequately addressed.[19] If additional or more specific requirements are needed for the management of SMR and AMR waste, these will be achieved through specific licensing requirements or new regulations promulgated by the NRC.

5. Public Information and Participation Campaigns Regarding Radioactive Waste from SMR (questions 5a, b, c, and d)

The fifth set of questions in the questionnaire refers to public information and participation campaigns, both regarding the development of SMR and AMR and their waste. Again, the question focuses specifically on the waste from SMR and not on the generality of radioactive waste generated in existing or decommissioned facilities.

Argentina indicates that abundant information has been disseminated about the CAREM-25 project, although these campaigns have not

[19] More information available in https://www.nrc.gov/reactors/new-reactors/smr/policy-development/resolved-policy.html [access: 15 November 2024].

specifically focused on the backend. It is noted that, according to existing legislation, neither the province nor the municipality has jurisdiction to decide on the location of radioactive waste storage and disposal facilities.

This is also the case in **Bangladesh**. The response from this country highlights the general support for the project to build a new nuclear power plant, although it is not an SMR, and describes the steps of public information and communication about this project.

In **Slovakia**, public participation is mandatory for new nuclear projects; however, no special plans for SMR/AMR are available. It is interesting to note that Slovakia is being consulted regarding the development of an SMR in Poland, within the framework of the transboundary environmental assessment. Additionally, the development plans for SMR in Slovakia have been widely discussed in news and press releases, and it is presumed that the existing site at Bohunice NPP will likely host the new facilities. The municipality is familiar with the operation of the plant and, in principle, accepts the new nuclear developments.

In the **United Kingdom**, although the energy policy and the location of the future DGR are being publicly debated, public information and participation campaigns are not yet explicitly addressing the issue of radioactive waste from SMR and AMR. CoRWM, a committee that provides independent scrutiny and transparent advice to the UK governments on the long-term management of HLW, has raised the issue in its 2024 Position Paper on Waste from SMR and AMR.

France has a solid infrastructure for public debate, with the Commission Nationale du Débat Public (created in 1997 to supervise consultations, transparency, and conciliation), which is expected to eventually promote and supervise a debate on the development, project per project, of SMR & AMR and the proposed management of the waste generated. As mentioned, very recently (June 2024), a start-up submitted the first application for the construction of an SMR, receiving wide media coverage.

In the **United States**, a consent-based approach strategy is being implemented to select a DGR site for civil SF and HLW. Since 2023, the DOE has allocated special funds to work with communities interested in hosting the site. The DGR would accommodate SF and HLW from reactors already in operation and eventually from future SMR and AMR.

The DOE has carried out communication campaigns directed both at the general public and potential host communities to explain the

development of SMR and the management of the waste they generate. These campaigns aim to raise awareness about the specific nature of SMR and AMR waste. Notable among these is the initiative in which the DOE has awarded funding to the Energy Communities Alliance Inc. and the American Nuclear Society to disseminate knowledge about advanced reactors to the public.

6. Other Relevant Aspects (question 6)

A last question is introduced to allow the respondents express opinions not included in the previous parts. Here is a summary of their comments:

Argentina points out that there is no substantial difference of the CAREM project with other reactors. The same management principles and methods apply.

In **Bangladesh**, the demand for electricity is very high considering the country's growth and demographic characteristics. The nuclear power plant under construction will be the first experience in introducing nuclear power, and experts suggest waiting for the results of this new plant before making further decisions to develop SMR.

In **Slovakia**, according to the respondent, the main challenge will be to adapt the existing standards for operational plants to the specific characteristics of SMR. For now, it seems that the official bodies' position is strict considering that SMR should be treated like any other nuclear installation.

The representative from the **United Kingdom** indicates that the main problem is that the characteristics and amounts of radioactive waste and spent fuel from SMR and AMR are still unknown, which makes it very difficult to debate whether they can all be accommodated in the DGR, at least without special processing. CoRWM has published a Position Paper to flag the issue and promote debate.

In **France**, the primary issue for SMR & AMR would be whether their waste could actually be processed and managed with the infrastructures hosting 'traditional' reactors' waste, or whether Andra would accept responsibility over them.

In the **United States**, the respondents indicate that the legal and policy challenges are similar to those associated with the management of SF in general and focus on the need to find a suitable site for the DGR.

C. Some Conclusions

We are satisfied with the picture reflected by the questionnaire. It would have been desirable to have a greater number of participating countries, particularly more from Eastern Europe, Scandinavian countries or Canada. Nevertheless, the data collected provides a good, though incomplete, picture of the countries planning to license SMR and AMR in the coming years.

Conceptually, we observe how legislators can favor the development of SMR and AMR through measures such as tax incentives (as cited by Argentina) or streamlining the licensing process in some cases (as in France). In the Argentine case, it appears that licensing a CAREM-25 prototype will pave the way for the more agile commissioning of commercial reactors. The chosen model (CAREM-25) seems to generate radioactive waste that is easier to manage as compared to other models available on the market, given the similarities to a PWR. Other countries, however (notably the USA), are expanding the range of reactors under consideration.

Not all responses reflect the same degree of certainty and confidence in the knowledge about SMR and AMR waste. The responses from France or the United Kingdom reflect these doubts and difficulties more intensely than, for example, those from the USA or Argentina. In the American case, there is confidence in being able to address challenges on a case-by-case basis, while the confidence shown by the Argentine respondent derives from the fact that only one model reactor is being evaluated, already with some knowledge about its similarities to a PWR.

In any case, the decision on the technology to be adopted should consider economic and supply factors, but also (in our opinion, very especially) factors related to the management of the expected waste. Therefore, it seems that designs generating waste and spent fuel for which there is greater knowledge today or that are suitable for existing disposal systems should be favored.

The questionnaire also reflects the necessary symbiosis between public support formulas for the development of SMR and AMR and mixed public-private cooperation formulas.

Regarding this, and particularly referring to the responses from France, an important issue is whether existing radioactive waste management

agencies should take responsibility for the waste from SMR and AMR. This is especially relevant for agencies that have been funded by contributions from 'traditional' nuclear power plants, and whose funds could now be diverted to managing waste from new producers. It is assumed that there should be an economic adjustment so that new producers compensate for using capacities that were not created for them. This adjustment should address questions such as who should bear the cost if an existing design for a DGR needs to be adapted to accommodate this new type of waste; or even who should bear the cost incurred by the authorities when new regulations are necessary.

Concerning the financing of SMR and AMR waste management, all respondents agree on applying the polluter-pays principle. However, there seem to be different approaches on whether an initial guarantee should be required from new SMR to cover future waste management and decommissioning costs, or if their financing can 'join' existing systems by requiring new operators to make periodic contributions to the fund, without needing a substantial initial guarantee. Ultimately, this boils down to a matter of trust: will we treat new producers the same way we treat current NPP licensees, or will we demand high additional guarantees from them? Judging by the responses given, the dilemma is usually resolved in favor of trusting new producers, reflecting State support for these projects.

An added problem is how to calculate the costs to manage an inventory that is still unknown. Generally, all countries are deliberating the same issue. The only respondent who has provided some specificity is from the USA, stating that, initially, contributions should be imposed case-by-case for both operational waste management expenses and decommissioning.

As we have noted, inventory estimates are still lacking. Several countries have indicated that upcoming national policies (Slovakia) or the next edition of inventories (France) should already include this data.

To the question of whether there is legislation or regulation specifically aimed at SMRs and AMRs, the common response is negative. The respondent from the USA repeatedly explains that any specific requirements in addition to the existing, generally applicable regulations will initially be defined through the licensing terms, adopted case-by-case. This could make the USA a pioneer in regulating SMRs and AMRs when reactors with the same technical characteristics start to be built worldwide.

In this regard, it is important to highlight the efforts of public agencies, particularly the NRC, to follow the technical developments occurring in the private sector. If those who know the technical characteristics of the new reactors best are their proponents (the industry), it is essential that the regulator does not lag too far behind in its capacity to evaluate these proposals from a nuclear safety perspective.

Finally, the public debate around SMR waste is generally underdeveloped. There are two necessary debates: the first, which is occurring to varying degrees in all countries, is about the advisability of developing SMR and AMR; the second is about the disposability of their radioactive waste.

Regarding the selection of sites for SMR and AMR, the responses from Slovakia and France are symptomatic, pointing out the preference for choosing locations with existing nuclear facilities where local populations already trust the activities being carried out. Additionally, it is interesting to note Slovakia's comment about its participation as a consulted country in the evaluation of its neighbor Poland.

Regarding the fate of waste from SMR and AMR, the responses from France and the United Kingdom reflect gaps in information about the nature and quantities of the radioactive waste and spent fuel that could be disposed of in a DGR. In the UK's case, the most urgent debate in the respondent's opinion is about determining whether radioactive waste / spent fuel from SMR and AMR would be suitable for disposal in the planned DGR. Understanding what is included in the inventory for disposal will be important for communities in the UK Government's consent-based siting DGR process prior to deciding whether they wish to host a DGR in their area. In the French case, this is complicated by the decision that needs to be made about whether Andra will take responsibility for these new types of waste.

The country that has already begun active information campaigns about the nature and possible management routes for SMR and AMR waste is the United States.

We can conclude that there are still many steps to take. First, sufficient knowledge must be acquired about the waste that can be generated in this new type of reactors; this knowledge should allow us to refine our inventory estimates and consequently the associated costs of their treatment and final disposal. Second, the regulatory framework specifically addressing SMR and AMR needs to be improved. In this sense, an

approach like the US one suggests that it is preferable to go step by step and establish safety conditions for each case that arises, rather than trying to establish a one-size-fits-all regulatory framework a priori.

It has been a satisfaction to compose this study, and I believe all participants have learned from it. Surely, in the coming years, similar studies will be conducted that will reflect a greater maturation of all these issues.

ANNEX
USA responses[20]

INLA WG 5, Task Group "SMR & AMR waste"
Draft July 26, 2023
Name, country and affiliation of the respondent:
Jerry Bonanno
United States of America
Nuclear Energy Institute
Date: 21 March 2024

1. Plans and policy for the development of Small Modular Reactors (SMR) and Advanced Modular Reactors (AMR)

1a) Please, describe the plans in your country to develop SMRs & AMR.
Please provide, if possible, the following information:

- ***The estimated time schedules and steps in those plans, such as generic design approval, justification, pre-licensing and licensing activities (estimate years of site selection, start of construction, start of operation, estimates for operation and closure & decommissioning);***
- ***Changes (if any) to timelines for projects which have been proposed;***
- ***Origins of this information, i.e., are timelines set out in regulation or are they based on statements by industry/designers/the regulator?***

In the United States, private entities are the applicants for commercial SMR/AMR projects. The Nuclear Regulatory Commission (NRC) licenses and regulates the civilian use of radioactive materials to provide

[20] The task group has determined that, given its level of detail and the interest of this information for other countries developing SMR/AMR, it is appropriate to include the responses given by the U.S. to the questionnaire as an annex to the report.

reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment (https://www.nrc.gov/about-nrc.html). This includes the licensing and regulation of commercial reactors used to generate electric power, as well as reactors used for research, testing, and training. The Department of Energy's (DOE) Office of Nuclear Energy's mission is to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs (https://www.energy.gov/ne/about-us). Several states in the U.S. are also implementing or considering policies that will support the development of new nuclear deployment, including SMR/AMRs. (For more on state policies *see* https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/Compendium-January-2023.pdf).

The information below describes examples of several projects or initiatives underway by DOE, NRC, and private entities to support commercial deployment of SMR/AMRs in the United States. This list is not all encompassing but is meant to give the reader a sense of the scope and scale of projects and initiatives that are underway.

DOE

Advanced Reactor Demonstration Program: DOE's Advanced Reactor Demonstration Program (ARDP) supports the demonstration of advanced reactors through private-public cost-share partnerships (~50/50 cost shares). The ARDP provides support through three pathways:

- *Pathway 1 – Advanced Reactor Demonstrations*: The goal of this pathway is to test, license, and build operational reactors within 5-7 years. This pathway of the ARPD program is supporting the commercial deployment and demonstration of the TerraPower Natrium reactor and the X-energy Xe-100 reactor.
- *Pathway 2 – Risk Reduction for Future Demonstrations*: The goal of this pathway is to solve technical, operational, and regulatory challenges to support demonstration within 10-14 years. Projects under this pathway include Kairos Power's KP-FHR (fluoride salt-cooled high-temperature reactor), Westinghouse Nuclear's eVinci (heat pipe-cooled microreactor), BWXT's BANR (high-temperature gas-cooled microreactor), Holtec International's SMR-160 (advanced light-water small modular reactor), and Southern Company's Molten Chloride Fast Reactor.

- *Pathway 3 – Advanced Reactor Concepts 2020 (ARC 20)*: The goal of this pathway is to solidify concept to mature technology for potential demonstration by mid-2030s. ARC 20 projects include Advanced Reactor Concepts,[21] Advanced Sodium-Cooled Reactor Facility, General Atomics' Fast Modular Reactor, and Mass. Institute of Technology's Horizontal Compact High-Temperature Gas Reactor.

For more information on ARDP *see* https://www.energy.gov/ne/advanced-reactor-demonstration-program.

Advanced SMR RD&D Program: The DOE's Advanced SMR R&D program was initiated in FY2019 and supports research, development, and deployment activities to accelerate the availability of U.S.-based SMR technologies into domestic and international markets by the late 2020s or early 2030s. This program supported the commercial deployment and demonstration of the NuScale VOYGR (NuScale Power and Utah Associated Municipal Power Systems). For more information *see* https://www.energy.gov/ne/advanced-small-modular-reactors-smrs. Although the NuScale project with UAMPS Carbon Free Power Project was recently terminated, NuScale's announcement indicates that the lessons learned from the project will carry forward into the company's future development work. For more information *see* https://www.nuscalepower.com/en/news/press-releases/2023/uamps-and-nuscale-power-agree-to-terminate-the-carbon-free-power-project.

Funding Opportunity for Advanced Technology Development: In 2018, DOE issued a multi-year cost-shared funding opportunity to support innovative, domestic nuclear industry-driven concepts that have high potential to improve the overall economic outlook for nuclear in the U.S. Multiple projects across the U.S. have been awarded assistance under this broad funding opportunity. For more information on awards please *see* https://www.energy.gov/ne/map-nuclear-energy-industry-foa-awardees-data-table.

Loan Program Office: The DOE Loan Program Office (LPO) has $10.9 billion in loan guarantees available for advanced nuclear projects. The loan guarantees can be for advanced nuclear reactors including small modular reactors, uprates and upgrades at existing facilities and front-end

[21] Since issuance of the ARC 20 support Advanced Reactor Concepts has changed its name to 'arc clean technology' (https://www.arc-cleantech.com/).

of the fuel cycle projects (conversion, enrichment and fuel fabrication). LPO can offer 100% guarantee of U.S. Treasury's Federal Finance Bank (FFB) loans or partial guarantees of commercial loans. The following are links to a slide deck providing an overview of LPO and a fact sheet on the advanced nuclear energy loan guarantees.

- https://www.energy.gov/sites/default/files/2022-05/DOE-LPO22-PPTv02_LPO-Overview-Slides.pdf
- https://www.energy.gov/sites/default/files/2020/01/f70/DOE-LPO-Nuclear-Energy-Jan2020.pdf

NRC

Completed licensing/certification/approval activity

- Standard Design Approval issued for NuScale US600 small modular reactor issued (9/11/2020).
- Standard Design Certification issued for NuScale US600 small modular reactor issued by final rule (1/19/2023). Information on this review can be found here https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/nuscale.html.
- Kairos Power Construction Permit issued (12/14/23) for Hermes low-power test reactor to support development of Kairos Power's fluoride salt-cooled, high-temperature reactor technology in Oak Ridge, TN. Progress and timelines on this review can be found here https://www.nrc.gov/reactors/non-power/new-facility-licensing/hermes-kairos/dashboard.html.

Applications under review / approvals issued

- Abilene Christian University Construction Permit Application under review for Molten Salt Research Reactor in Abilene, TX. Progress and timelines on this review can be found here https://www.nrc.gov/reactors/non-power/new-facility-licensing/msrr-acu/dashboard.html.
- Kairos Power Construction Permit Application under review for Hermes 2 test reactor in Oak Ridge, TN. Progress and timelines on this review can be found here https://www.nrc.gov/reactors/non-power/new-facility-licensing/hermes2-kairos/dashboard.html.
- NuScale Standard Design Approval under review US 460 light water SMR. Progress and timelines on this review can be found

here https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/current-licensing-reviews/nuscale-us460.html.

Pre-Application Activities/Interactions Between NRC and Potential Applicants

- General Atomics – Energy Multiplier Module (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/genatom.html)
- General Atomics – fast modular reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/general-atomics)
- Kairos Power – fluoride salt-cooled high temperature reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/kairos.html)
- Westinghouse – eVinci micro reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/evinci.html)
- TerraPower/GE Hitachi – Natrium sodium fast reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/natrium.html)
- TerraPower – molten chloride fast reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/mcfr.html)
- Terrestrial Energy – Integral Molten Salt Reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/imsr.html)
- X-energy – Xe-100 pebble-bed, high-temperature gas-cooled reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/xe-100.html)
- ARC Clean Technology – ARC-100 Sodium-Cooled Fast Reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/arc-100.html)
- Oklo – Aurora Powerhouse reactor, liquid metal-cooled, metal-fuel fast reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/okla-aurora-powerhouse.html)
- University of Illinois Urbana-Champaign – Ultra Safe Nuclear Corporation's Micro Modular Reactor (MMR), high-temperature

gas-cooled research reactor (https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/university-of-illinois-at-urbana-champaign.html)

Rulemaking / Policy Development

- Risk Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors ('Part 53 Rulemaking'): The NRC staff provided a proposed rule on March 1, 2023 (SECY-23-0021, https://www.nrc.gov/docs/ML2116/ML21162A093.html) for Commission approval that offers a voluntary, performance-based alternative regulatory framework for licensing future commercial nuclear plants, including non-light-water reactors (non-LWRs) and LWRs. The Commission recently directed the NRC staff to modify and publish the proposed rule for comment (SRM-SECY-23-0021, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML24064A047). Once finalized, the Part 53 Rulemaking would be available in addition to the existing licensing frameworks provided in 10 CFR Parts 50 and 52.
- Alignment of Licensing Processes and Lessons Learned from New Reactor Licensing Rulemaking: This rulemaking would amend the NRC's regulations for the licensing of new reactors. The rule would align requirements between the two licensing processes provided in the NRC's regulations to ensure that all new reactor applications conform to the NRC's policies and requirements, regardless of the selected licensing approach. The rule would address lessons learned from NRC reviews conducted for combined licenses, design certifications, early site permits, and operating licenses (https://www.nrc.gov/reading-rm/doc-collections/rulemaking-ruleforum/active/ruledetails.html?id=27).
- Physical Security Rulemaking: The NRC staff has developed preliminary proposed rule language to amend its physical security requirements for small modular reactors and other advanced reactor technologies. The goal of the rulemaking is to provide regulatory stability, predictability, and clarity in the licensing process and minimize or eliminate uncertainty for applicants who might otherwise request exemptions from the regulations (https://www.nrc.gov/reading-rm/doc-collections/rulemaking-ruleforum/active/ruledetails.html?id=76).

- Emergency Preparedness Rulemaking: The Commission recently approved publication of a final rule that would amend the agency's existing regulations to include new alternative emergency preparedness requirements for small modular and advanced reactors (https://www.nrc.gov/docs/ML2120/ML21200A055.html).
- Advanced Nuclear Reactor Generic Environmental Impact Statement: The NRC staff has provided a proposed rule (SECY-21-0098) for Commission approval that would codify the findings of the draft Advanced Nuclear Reactor Generic Environmental Impact Statement (https://www.nrc.gov/docs/ML2122/ML21222A044.html).
- Fuel Qualification for Advanced Reactors: In 2022, the NRC issued NUREG-2246 'Fuel Qualification for Advanced Reactors.' The purpose of this report is to identify criteria that will be useful for advanced reactor designers through an assessment framework that would support regulatory findings associated with nuclear fuel qualification (https://www.nrc.gov/reactors/new-reactors/advanced/rulemaking-and-guidance/fuel-qualification.html).
- Industry-Led Licensing Modernization Project: In 2020, the NRC issued Regulatory Guide 1.233 'Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors.' This regulatory guide endorsed the methodology described in NEI 18-04, Revision 1, 'Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development,' as an acceptable approach for informing the licensing basis and determining the appropriate scope and level of detail for parts of applications for licenses, certifications, and approvals for non-LWRs (https://www.nrc.gov/reactors/new-reactors/advanced/rulemaking-and-guidance/industry-led-licensing-modernization-project.html).
- Non-Light Water Reactor Design Criteria: In 2018, the NRC issued Regulatory Guide 1.232 'Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors.' The guidance provided in this Regulatory Guide was the result of a joint initiative between the NRC and DOE (https://www.nrc.gov/reactors/new-reactors/advanced/rulemaking-and-guidance/nrc-doe-joint-initiative-non-lwr-design-criteria.html).

- American Society of Mechanical Engineers Section III Division 5: In 2023, the NRC issued Revision 2 of Regulatory Guide 1.87 'Acceptability of ASME Section III, Division 5, High Temperature Reactors.' This regulatory guide endorses, with exceptions and limitations, the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Code (ASME Code) Section III, 'Rules for Construction of Nuclear Facility Components,' Division 5, 'High Temperature Reactors,' and Code Cases N-861, N-862, N-872, and N-898. The document describes an approach that is acceptable to the NRC staff to assure the mechanical/structural integrity of components that operate in elevated temperature environments and that are subject to time-dependent material properties and failure modes (https://www.nrc.gov/reactors/new-reactors/advanced/rulemaking-and-guidance/asme-bpv-code-section3-div5.html).
- American Society of Mechanical Engineers / American Nuclear Society RA-S-1.4 Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants: In 2021, ASME/ANS issued the advanced non-light water reactor PRA standard, ASME/ANS RA-S-1.4-2021, 'Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants.' In 2022, the NRC endorsed the standard as Trial Regulatory Guide (RG) 1.247 'Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities.' This new guidance describes one acceptable approach for determining whether the acceptability of the probabilistic risk assessment (PRA) used to support a PRA application is sufficient to provide confidence in the results for non-light water reactors (non-LWRs) and risk-informed activities.
- International Cooperation: Information on NRC's collaborative projects with Canada can be found here: https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/international-cooperation.html.

Private Entities

Siting Decisions

- In May 2023, Dow and X-Energy Reactor Company announced that Dow has selected its Seadrift Operations manufacturing site

in Texas for a proposed small modular reactor nuclear project. The project is focused on providing the site with power and steam, as existing assets near their end-of-life (https://corporate.dow.com/en-us/news/press-releases/dow-s-seadrift--texas-location-selected-for-x-energy-advanced-sm.html).

- In May 2021, Kairos Power and the Tennessee Valley Authority (TVA) jointly announced the deployment of its Hermes low-power demonstration reactor in the East Tennessee Technology Park (ETTP) in Oak Ridge, Tennessee.
- In November 2021, TerraPower formally selected Kemmerer, Wyoming as the site of its Natrium demonstration reactor.

1b) Please, describe the consideration of waste and waste estimates in those plans.

E.g.: Is a requirement set to optimize waste? Are management and disposal routes for waste contemplated in those plans?

Waste Disposal

Low-Level Radioactive Wastes (LLRW)

In the United States, the disposal scheme for LLRW is set out in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA). The LLRWPAA defines LLRW as radioactive material that –

- is not high-level radioactive waste, spent nuclear fuel, or byproduct material (as defined in section 11e.(2) of the Atomic Energy Act of 1954); and
- the Nuclear Regulatory Commission, consistent with existing law and in accordance with paragraph (A), classifies as low-level radioactive waste.

The NRC describes LLRW as:

[A] general term for a wide range of items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. Radioactive materials are present at nuclear power plants undergoing decommissioning as the result of plant operations prior to permanent shutdown and as the result of decommissioning activities. Examples include radioactively contaminated equipment, piping, tanks, hardware, and tools; concrete debris and soil; liquid radioactive waste (radwaste) treatment residues; and radioactively contaminated protective shoe covers and clothing; cleaning rags, mops, and

filters. The radioactivity in these wastes can range from just above natural background levels to much higher levels, such as seen in components from inside the reactor vessel of a nuclear power plant. LLW from decommissioning activities is typically shipped to a disposal site specifically licensed for disposal of LLW (NUREG-1307, Rev. 19, https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1307/r19/index.html).

The LLRWPAA makes states responsible for disposal of LLRW generated within their borders and establishes a framework for states to form 'compacts' to establish regional LLRW disposal facilities. There are currently four commercial LLRW disposal facilities operating in the United States located in Barnwell, South Carolina; Richland, Washington; Clive, Utah; and Andrews, Texas. The Barnwell and Richland sites accept waste from states within their respective compacts, the Clive site accepts waste from all regions of the United States, and the Andrews site accepts waste from generators within the Texas Compact and from other generators with the permission of the Compact (*see* https://www.nrc.gov/waste/llw-disposal/licensing/locations.html).

Each year, commercial power reactor licensees submit Radioactive Effluent Monitoring Reports to the NRC. These reports contain information on waste form, waste volume, isotopic content, and shipping of dry active wastes and irradiated components (*see* https://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html).

Spent Nuclear Fuel and High-Level Wastes

In the United States, the Nuclear Waste Policy Act (NWPA) makes spent fuel (SNF) and high-level waste (HLW) disposal a federal responsibility. Specifically, the NWPA assigns responsibility for SNF and HLW disposal to three Federal agencies:

- *Department of Energy (DOE)* – has responsibility for developing permanent disposal capability for SNF and HLW.
- *Environmental Protection Agency (EPA)* – has responsibility for developing environmental protection standards for disposal of SNF and HLW.
- *Nuclear Regulatory Commission (NRC)* – has responsibility for developing regulations to implement the regulations developed by EPA; licensing the construction, operation, decommissioning, and closure of SNF/HLW repositories; and certifying packages used to transport SNF and HLW to licensed repositories (*see* 10 CFR

Part 60 'Disposal of High-Level Radioactive Wastes in Geologic Repositories' and Part 63 'Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada)'.

The NWPA also:

- Authorizes DOE to enter contracts (i.e., 'Standard Contract') with any person who generates or holds title to HLW or SNF of domestic origin for the acceptance of title, subsequent transportation, and disposal of such waste or spent fuel.
- Prohibits NRC from issuing or renewing a license to any person to use a utilization or production facility unless such person has entered such a contract or DOE affirms in writing that such person is actively and in good faith negotiating with DOE for such a contract.
- Prohibits spent fuel and HLW disposal in a DOE repository unless the generator or owner has entered a contract with DOE by the later of June 30, 1983, or the date on which the generator or owner commences generation of or takes title to such fuel or waste.

For information regarding DOE's management of the 'Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste' *see* https://www.energy.gov/gc/office-standard-contract-management.

For a background and history of the Yucca Mountain program and license application see the Fourth, Fifth, and Sixth U.S. National Reports for the IAEA Review Meetings of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste/documents).

Waste Optimization and Management

Optimization

The NRC's Standards for Protection Against Radiation (10 CFR Part 20) require applicants for licenses to construct and operate new reactors under 10 CFR Parts 50 and 52 to describe how the design and procedures for operation of the facility will minimize contamination, facilitate eventual decommissioning, and minimize the generation of radioactive wastes (*see* 10 CFR 20.1406, https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1406.html). NRC provides guidance on waste minimization in Regulatory Guide 4.21 'Minimization of Contamination and

Radioactive Waste Generation: Life-Cycle Planning' (https://www.nrc.gov/docs/ML0805/ML080500187.pdf).

NRC has also issued a Policy Statement entitled 'Low-Level Waste Management and Volume Reduction,' recognizing the 'substantial progress made by licenses in reducing volumes of LLRW shipped for disposal' and highlighting a continuing emphasis on waste minimization, short-term decay and storage, long-term storage, as well as use of waste processing technologies and alternate disposal methods (https://www.nrc.gov/docs/ML1502/ML15023A098.pdf). The NRC has pointed out that the cost of LLRW disposal at licensed commercial burial sites has prompted licensees to use process controls and volume reduction to reduce the amount and volume of waste generated (https://www.energy.gov/em/articles/seventh-national-report-joint-convention-safety-spent-fuel-management-and-safety).

Apart from the general requirement in 10 CFR Part 20 described above, there are more specific requirements governing applications for various types of approvals for new commercial nuclear power plants that require the applicant to provide a description of the design objectives, performance requirements, and procedures governing radioactive waste handling systems (*see* 10 CFR 50.34(b), 50.34a.(b)-(e), 52.47(a), 52.79(a), 52.137(a), 52.157(c)).

For example, the NRC's January 19, 2023, final rule certifying the NuScale small modular reactor design incorporated Chapter 11 'Radioactive Waste Management' of the NuScale design certification application by reference. In turn, Chapter 11 provides detailed information on radioactive source terms; liquid, gaseous, and solid waste management systems; the process and effluent radiation monitoring instrumentation and sampling system; and the instrumentation and control design features for process and effluent radiological monitoring, and area radiation and airborne radioactivity monitoring.

Management

The existing regulatory framework for managing low-level radioactive wastes in the U.S. is provided in the NRC's regulations at Subpart K to 10 CFR Part 20 and associated guidance, as well as in state requirements.

Management of spent fuel generated at operating reactors is addressed in the NRC's regulations 10 CFR Part 72. The regulations in this part establish requirements, procedures, and criteria for the issuance of

licenses to receive, transfer, and possess power reactor spent fuel, power reactor-related Greater than Class C (GTCC) waste, and other radioactive materials associated with spent fuel storage in an independent spent fuel storage installation (ISFSI) and the terms and conditions under which the Commission will issue these licenses. The regulations in this part also establish requirements, procedures, and criteria for the issuance of licenses to the Department of Energy (DOE) to receive, transfer, package, and possess power reactor spent fuel, high-level radioactive waste, power reactor-related GTCC waste, and other radioactive materials associated with the storage of these materials in a monitored retrievable storage installation (MRS). The term Monitored Retrievable Storage Installation or MRS, as defined in § 72.3, is derived from the Nuclear Waste Policy Act (NWPA) and includes any installation that meets this definition. The regulations in this part also establish requirements, procedures, and criteria for the issuance of Certificates of Compliance approving spent fuel storage cask designs.

1c) Please, explain whether the national policy includes an estimated cost of management for this type of waste and the financing mechanism foreseen to cover this cost.

Low-Level Radioactive Waste Generated During Operation

Management and disposal of LLRW generated during plant operation is generally the responsibility of the NRC licensee and financed by the licensee through operating funds. The NRC requires applicants for licenses to operate commercial power reactors that are not 'electric utilities' to demonstrate their financial qualifications to cover estimated operating costs of the facility. *See* 10 CFR 50.33(f) (https://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0033.html).[22] The NRC's regulations also require a demonstration of financial assurance when licensees will cease to be an 'electric utility' (*see* 10 CFR 50.76), and in the event of a license transfer to a different entity (*see* 10 CFR 50.80).

LLRW burial fees associated with decommissioning of commercial power reactors are examined and periodically updated by the NRC in

[22] Historically, entities that meet the definition of 'electric utilities' (i.e., 'any entity that generates or distributes electricity and which recovers the cost of this electricity, either directly or indirectly, through rates established by the entity itself or by a separate regulatory authority' *see* 10 CFR 50.2), have relied upon rates set by the States to recover costs of reactor construction and operation.

a guidance document entitled 'Report on Waste Burial Charges: Changes in Decommissioning Waste Disposal Costs at Low-Level Waste Burial Facilities,' NUREG-1307, Rev. 19 (Feb. 2023) (www.nrc.gov/docs/ML2304/ML23044A207.pdf). Estimated costs of disposing of LLRW via land burial are factored into the NRC's requirements for decommissioning funding assurance described below.

Decommissioning of Commercial Power Reactors

The NRC defines the term 'decommission' as follows:

[T]o remove a facility or site safely from service and reduce residual radioactivity to a level that permits –

(1) Release of the property for unrestricted use and termination of the license; or

(2) Release of the property under restricted conditions and termination of the license.

10 CFR 50.2. Commercial power reactor licensees must provide the NRC with reasonable assurance that funds will be available to decommission the facility at the time of licensing and throughout the life of the facility. This funding assurance is provided through a series of regulatory requirements provided in 10 CFR 50.75. Funding for the decommissioning of power reactors may also be subject to the regulation of Federal or State Government agencies (e.g., Federal Energy Regulatory Commission (FERC) and State Public Utility Commissions) that have jurisdiction over electricity rate regulation. The NRC's requirements are in addition to, and not substitution for, other requirements. As a facility approaches the end of its licensed life (i.e., at or about 5 years prior to projected end of operations), the NRC's regulations require the licensee to submit a site-specific decommissioning cost estimate. This cost estimate should include an 'up-to-date assessment of the major factors that could affect the cost to decommission' the facility. 10 CFR 50.75(f)(3).

The acceptable methods of providing decommissioning funding assurance are provided in 10 CFR 50.75(e) and include:

- Prepayment
- External sinking fund
- Surety methods, insurance, or other guarantee method
- Contractual obligations
- Other methods approved by the NRC.

Although the NRC regulations provide flexibility with respect to the methods available to provide decommissioning funding, all current commercial power reactor licensees have established Nuclear Decommissioning Trusts (NDTs) as the primary source of decommissioning funding. These NDTs are used to implement either the prepayment or external sinking fund methods of decommissioning funding assurance, depending on whether the licensee has access to rate recovery or a non-bypassable charge to fund decommissioning. The NRC's regulations generally restrict the use of funds set aside for decommissioning until after permanent shutdown and defueling of the reactor. *See* 10 CFR 0.82(a)(8)(ii). The NRC requires licensees to file biennial Decommissioning Funding Status Reports, which are due in March of odd-numbered years (*see* https://www.nrc.gov/docs/ML1934/ML19346E375.html and https://www.nrc.gov/waste/decommissioning/finan-assur/bi-decom-reports.html).

Where necessary to account for the unique design features of SMRs and AMRs that may affect decommissioning funding assurance, the NRC has indicated that it would manage such issues in the near-term on a case-by-case basis using design-specific decommissioning cost estimates and exemptions to the requirements of 10 CFR 50.75. (*see* SECY-11-0181 https://www.nrc.gov/docs/ML1126/ML112620358.pdf).

Spent Nuclear Fuel Disposal

As described above in response to Question 1.b, United States law:

- Authorizes DOE to enter contracts (i.e., 'Standard Contract') with any person who generates or holds title to HLW or SNF of domestic origin for the acceptance of title, subsequent transportation, and disposal of such waste or spent fuel.
- Prohibits NRC from issuing or renewing a license to any person to use a utilization or production facility unless such person has entered such a contract or DOE affirms in writing that such person is actively and in good faith negotiating with DOE for such a contract.
- Prohibits spent fuel and HLW disposal in a DOE repository unless the generator or owner has entered a contract with DOE by the later of June 30, 1983, or the date on which the generator or owner commences generation of or takes title to such fuel or waste.

All entities that are currently licensed by the NRC use utilization or production facilities in the U.S. have entered contracts with DOE for the

disposal of SNF. Historically, utilities that have DOE contracts were also required to pay fees into the Nuclear Waste Fund to cover costs associated with SNF and HLW disposal. This statutory fee was set at $0.001 per kilowatt-hour of electricity generated using nuclear power and was required to be evaluated annually. The fee remained in place until 2014, when it was adjusted to zero pursuant to a court ruling. The court determined that the fee could be reinstated when DOE either resumes compliance with the NWPA and develops the Yucca Mountain repository, or Congress enacts an alternative program. The current balance of the NWF is approximately $46 billion (https://www.energy.gov/sites/default/files/2022-12/FY22%20-%20NWF%20Annual%20Financial%20Report%20Summary.pdf). The fund continues to earn interest at a rate of approximately $1.6 billion annually.

DOE is currently working on one public and one proprietary report, which will address different aspects of the management of spent fuel from advanced reactors. The first report, which will be made public once completed is titled 'Advanced Reactors Fuel and Waste Streams Disposition Strategies: Spent Fuel and Waste Disposition.' This report will leverage DOE's experience with SNF from prior similar reactors to gain insights into issue like: degradation rate behavior constraints, potential for criticality over repository time scales, thermal output per waste package, secondary waste streams (from operations and treatment), potential impacts of alternative fuel cycles. The second set of reports will be proprietary and involve collecting advanced reactor data by engaging the advanced reactor vendors that are voluntarily working with DOE. The objectives of this report are to: (1) make a technical assessment of feasibility of storage, transportation, and disposal advanced reactor SNF; and (2) develop order-of-magnitude cost estimates for storage, transportation, and disposal. These proprietary reports will be used by the DOE General Counsel to inform them of necessary changes to Standard Contract for SMR/AR. For a summary of these projects *see* https://www.nwtrb.gov/docs/default-source/meetings/2023/august/nedlarson.pdf?sfvrsn=4.

2. Expected inventory and characteristics of SMR & AMR waste in your country

2a) Briefly describe the current inventory and characteristics of nuclear waste inventory in your country.

This question refers to radioactive waste not generated at SMR & AMR. Reference can be made to the waste inventory as set out in your national program or in public documents such as the Joint Convention national reports.[23] ***If so, please facilitate the link and page, or a screenshot of those pages.***

Each year, commercial power reactor licensees submit Radioactive Effluent Monitoring Reports to the NRC. These reports contain information on waste form, waste volume, isotopic content, and shipping of low-level dry active wastes and irradiated components (*see* https://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html).

The U.S. nuclear power industry has generated approximately 84,000 metric tons (MT) heavy metal (MTHM) of spent fuel as of the end of 2019. Of this, 39,000 MTHM is in dry storage at NPP sites. Most of the U.S. commercial spent fuel will remain stored at NPPs until a disposition path is identified. Some spent fuel is also being stored away from NPPs. DOE's inventory of spent fuel is approximately 2500 MTHM (https://www.energy.gov/sites/default/files/2020/10/f80/7th-JC-RM-United-States-NR-Final-Oct-2020.pdf).

2b) Do you know the forecasts for SMR & AMR waste generation in your country?

If yes, please make a short description, adding, if possible, the estimated time schedule linked to this estimated inventory. Please indicate the source of this information.

2c) Characteristics of the inventory. Do you have information regarding the physic-chemical and radiological characteristics of the waste expected to be generated in SMRs & AMRs?

Please, make a short description (it does not need to be technically detailed), explaining as far as you can the differences between this type of waste and radioactive waste generated at conventional reactors.[24] ***Please indicate the source of this information.***

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[23] National reports to the Joint Convention on the Safety of Spent Fuel Management and on the Safety on Radioactive Waste Management, https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste [access:].

[24] By 'conventional reactors', we understand reactors belonging up to Generation III. The scope of this questionnaire extends to SMR and AMR waste; for a clarification of

DOE has undertaken several projects to understand both the amount and attributes of spent fuel that will likely be generated by SMR/AMRs, for example:

- **ARPA-e Optimizing Nuclear Waste and Advanced Reactor Disposal Systems (ONWARDS) Project:** Consists of 11 individual projects 'To enable the growth of advanced nuclear energy, ONWARDS seeks to develop and demonstrate breakthrough technologies that will facilitate a 10x reduction in AR waste volume generation or repository footprint. In addition, ONWARDS aims to advance development of high-performance AR waste forms while maintaining exemplary safeguards standards and global back-end costs in the accepted range of $1/megawatt-hour', https://arpa-e.energy.gov/technologies/programs/onwards. Specific ONWARDS projects include:
  - ◊ Brigham Young University (BYU) – Two-Step Chloride Volatility Process for Reprocessing Used Nuclear Fuel from Advanced Reactors (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/two-step-chloride-volatility-process-reprocessing-used-nuclear-fuel-advanced-reactors)
  - ◊ Citrine Informatics – Novel Phosphate Waste Forms to Enable Efficient Dehalogenation and Immobilization of Salt Waste (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/novel-phosphate-waste-forms-enable-efficient-dehalogenation-and-immobilization-salt-waste)
  - ◊ Deep Isolation – UPWARDS: Universal Performance Criteria and Canister for Advanced Reactor Waste Form Acceptance in Borehole and Mined Repositories Considering Design Safety (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/upwards-universal-performance-criteria-and-canister-advanced-reactor-waste-form-acceptance-borehole-and-mined-repositories-considering-design-safety)
  - ◊ General Electric (GE) Global Research – Resonance Absorption Densitometry for Materials Assay Security Safeguards (RADMASS) (https://arpa-e.energy.gov/programs-and-initiatives/search-

these terms, we keep the definitions used by the UK government, by which Generation IV reactors are considered AMRs, GOV UK, Department for Energy Security & Net Zero, *Advanced Nuclear Technologies...*

all-projects/resonance-absorption-densitometry-materials-assay-security-safeguards-radmass)
  - ◊ Idaho National Laboratory (INL) – Traveling Molten Zone Refining Process Development for Innovative Fuel Cycle Solutions (https://arpa-e.energy.gov/sites/default/files/2025-10/Day1_Performer_INL_Childs.pdf)
  - ◊ Oklo – Enabling the Near Term Commercialization of an Electrorefining Facility to Close the Metal Fuel Cycle (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/enabling-near-term-commercialization-electrorefining-facility-close-metal-fuel-cycle)
  - ◊ Orano Federal Services – Off-Gas Treatment Process for Conditioning and Recycling Facilities (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/gas-treatment-process-conditioning-and-recycling-facilities)
  - ◊ Rensselaer Polytechnic Institute (RPI) – Metal-Halide Perovskites as Innovative and Cost-Effective Fluoride Salt Waste Forms (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/metal-halide-perovskites-innovative-and-cost-effective-fluoride-salt-waste-forms)
  - ◊ Rutgers University – Pioneering a Cermet Waste Form for Disposal of Waste Streams from Advanced Reactors (PACE-FORWARD) (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/pioneering-cermet-waste-form-disposal-waste-streams-advanced-reactors-pace-forward)
  - ◊ Stony Brook University – MATRICY: Matrix Engineered TRISO Compacts Enabling Advanced Reactor Fuel Cycles (https://arpa-e.energy.gov/sites/default/files/2025-10/Nicholas%20Brown%20-%20UTK.pdf)
  - ◊ TerraPower – Chloride-Based Volatility for Waste Reduction and/or Reuse of Metallic-, Oxide- and Salt-Based Reactor Fuels (https://arpa-e.energy.gov/programs-and-initiatives/search-all-projects/chloride-based-volatility-waste-reduction-andor-reuse-metallic-oxide-and-salt-based-reactor-fuels)
- **Nuclear Waste Attributes of SMRs Scheduled for Near-Term Deployment – Nuclear Fuel Cycle and Supply Chain (DOE, ANL/INL):** This study focused on nuclear waste attributes of three small reactors (SMR) scheduled for near-term-deployment,

VOYGR™ (NuScale Power), Natrium™ (TerraPower), XE-100 (X-energy). Compares those wastes to those of a reference large PWR, examining front-end wastes (e.g., fuel manufacture), back-end waste (e.g., spent fuel management), and end-of-life or decommissioning wastes. The study found that waste attributes of the SMRs showed both 'similarities to the reference LWR and some potentially significant differences.' Overall, the study concluded that 'assuming appropriate waste management system design and operational optimization, there appear to be no major challenges to the management of SMR wastes compared to the reference LWR,' https://fuelcycleoptions.inl.gov/SiteAssets/SitePages/Home/SMR_Waste_Attributes_Report_Final.pdf.

- **Several additional DOE studies on advanced reactor waste** – 'Advanced Reactors Fuel and Waste Streams Disposition Strategies: Spent Fuel and Waste Disposition' (June 28, 2023); 'Storage, Transportation, and Disposal of Advanced-Reactor Spent Nuclear Fuel and High-Level Waste: Spent Fuel and Waste Disposition,' https://www.nwtrb.gov/docs/default-source/meetings/2023/august/brady-hanson.pdf?sfvrsn=4.

3. Consideration of SMR & AMR waste in laws and regulations
Is there any provision in your national set of laws and regulations specifically addressed to waste from SMRs & AMR?
Please note that the focus of this question is on SMR & AMR wastes. Answers referencing general provisions for radioactive waste management should briefly explain how those provisions are relevant to managing SMR and AMR waste.
See existing framework described above in response to questions 1 and 2, which would generally apply to wastes generated by SMR/AMRs licensing in the U.S.

4. Regulatory requirements concerning SMR & AMR waste
4a) Has your nuclear regulatory authority developed specific standards for SMR & AMR waste management? If yes, please shortly quote and describe them.
The standards referred to may address aspects such as conditioning, treatment, packaging, storage, transport and disposal of SMR & AMR waste. Please note that the focus of this question is on SMR & AMR wastes.

Answers referencing general regulations for radioactive waste management should briefly explain how those provisions are relevant to managing SMR and AMR waste.

4b) Has your nuclear regulatory authority announced plans for developing specific standards for SMR & AMR waste?

Please, quote and describe shortly these plans.

See existing framework described above in response to questions 1 and 2, which would be applicable to wastes generated by SMR/AMRs licensed in the U.S. For a complete list of policy issues relevant to SMRs and non-light water reactors that have been considered and resolved by NRC *see* https://www.nrc.gov/reactors/new-reactors/smr/policy-development/resolved-policy.html. Any additional or more specific requirements necessary to address wastes generated by SMR/ANRs could be achieved through specific licensing requirements or new/amended regulations promulgated by the NRC (in addition to license conditions, orders, and exemptions from existing requirements).

5. SMR & AMR waste and the rights of public information and participation

5a) Please, explain to what extent decision-making in rule-making and policy setting in your country has been subjected to the principles of transparency and public participation: a) as regards the development of SMR & AMR; and b) as regards the management of waste generated by SMR & AMR.

This question focuses on specific measures for transparency and public participation, beyond the general rules for public participation in rule-making and policy setting. Examples may include a public referendum about the development of SMR & AMR, specific consultation campaigns being conducted (nation-wide or in the potential hosting communities for SMR & AMR), etc.

5b) Please, provide examples or describe the communication campaigns addressed in your country to the general public: a) as regards the development of SMR & AMR, and b) as regards the management of waste generated by SMR & AMR.

This question refers to communication campaigns rather than public participation in decision-making.

5c) Please, provide examples or describe the communication campaigns addressed in your country specifically to the potential host communities of SMR & AMR: a) as regards the development of SMR & AMR, and b) as regards the management of waste generated by SMR & AMR.

This question refers to communication campaigns rather than public participation in decision-making. A specific question in this regard is: Are potential host communities generally aware of the specific nature of SMR & AMR waste?

5d) Is any negotiation being carried out with local communities who are proposed as hosts for a disposal site for conventional waste in your country? If this is the case, has the issue of SMR & AMR waste arisen in the dialogue? For example, related to a possible extension of the inventory to be emplaced in the site.

[I am interpreting this question to focus primarily on national policy (i.e., actions by the Federal government), rather than activities that may be undertaken by private entities interested in pursuing licenses to manufacture, construct, and operate commercial reactors and waste facilities, or current licensees that are operating such facilities.]

DOE is committed to a consent-based approach to finding sites to store and dispose of spent nuclear fuel. DOE's approach centers on broad public participation, equity, and environmental justice. DOE's efforts to develop a consent-based siting process by working collaboratively with members of the public, communities, stakeholders, and governments at the Tribal, state, and local levels began in 2015. DOE requested public comment on the process in both 2017 (www.energy.gov/sites/prod/files/2017/01/f34/Draft%20Consent-Based%20Siting%20Process%20and%20Siting%20Considerations.pdf) and in late 2021 (https://www.federalregister.gov/documents/2021/12/01/2021-25724/notice-of-request-for-information-rfi-on-using-a-consent-based-siting-process-to-identify-federal).

In 2023, DOE awarded $26,000,000 in funding to 13 geographically an institutionally diverse awardees consisting of university, nonprofit, and private-sector entities to work with communities interested in consent-based siting of spent fuel storage and disposal facilities. The awardees—representing 12 states and the District of Columbia—will constitute a consent-based siting consortium and collectively help DOE

facilitate engagement activities and dialogue. DOE and the consent-based siting consortia will collaborate to build equity and environmental justice principles into the community engagement processes. The preliminary project teams receiving awards are:

- American Nuclear Society (IL) as the lead, with South Carolina Universities Research and Education Foundation (SC), Northern Arizona University (AZ), University of New Mexico (NM), South Carolina State University (SC), and City College of New York (NY) as partners.
- Arizona State University (AZ).
- Boise State University (ID) as the lead, with the National Tribal Energy Association, Arizona State (AZ), Colorado State (CO), Idaho State (ID), Montana State (MT), University of Idaho (ID), University of Wyoming (WY), and University of Michigan (MI) as partners.
- Clemson University (SC) as the lead, with South Carolina Universities Research and Education Foundation (SC) as a partner.
- Energy Communities Alliance (DC).
- Good Energy Collective (CA) as the lead, with the University of Notre Dame (IN) as a partner.
- Holtec International (NJ) as the lead, with University of Florida (FL), McMahon Communications (MA), Agenda Global (DC), American Nuclear Society (IL), and Nuclear Energy Institute (DC) as partners.
- Keystone Policy Center (CO) as the lead, with Social and Environmental Research Institute, GDFWatch (UK), and the National Association of Regional Councils (DC) as partners.
- Missouri University of Science & Technology (MO) as the lead, with University of Missouri – Columbia (MO), University of Illinois (IL), Taylor Geospatial Institute (MO), and St. Louis University (MO) as partners.
- North Carolina State University (NC) as the lead, with the yak titᵛu titᵛu yak tiłhini Northern Chumash Tribe of San Luis Obispo County and Region (CA), Mothers for Nuclear (CA), and the Tribal Consent Based Coalition – Diablo Canyon Nuclear Power Plant (CA) as partners.
- Rensselaer Polytechnic Institute (NY) as the lead, with Schenectady Foundation (NY) as a partner.

- Southwest Research Institute (TX) as the lead, with Deep Isolation (CA), Westra Consulting (NE), Community Transition Planning (MI), Prairie Island Indian Community Tribal Nation (MN), Xcel Energy (MN), and Decommissioning Plant Coalition (DC) as partners.
- Vanderbilt University (TN) as the lead, with Rutgers University (NJ) and Oregon State University (OR) as partners.

(*See* https://www.energy.gov/articles/doe-awards-26-million-support-consent-based-siting-spent-nuclear-fuel.) For more information on DOE's consent-based siting process generally, *see* https://www.energy.gov/ne/consent-based-siting.

Apart from its consent-based siting efforts, in December 2022 DOE awarded $800,000 to the Energy Communities Alliance, Inc. and the American Nuclear Society to expand engagement with energy communities, educational institutions, and underserved communities. These efforts are aimed at establishing education and outreach opportunities, focusing on localities impacted by or interested in deploying advanced reactors. (*See* https://www.energy.gov/ne/articles/us-department-energy-selects-partners-engage-communities-nuclear-energy.)

While it does not have promotional responsibilities, the NRC has a long-standing policy of 'provid[ing] the public with substantial information on its activities, to conduct business in an open manner, and to balance openness and transparency with the need to exercise regulatory and safety responsibilities without undue administrative burden.' *See* Commission Policy Statement on Enhancing Participation in NRC Public Meetings, 86 Fed. Reg. 14964; March 19, 2021 ('The NRC has had a formal policy regarding open (public) meetings since 1978.'). The NRC's organizational values and Principles of Good Regulation also stress 'openness' as a core value. The Principles of Good Regulation describe the principle of 'Openness' as 'Nuclear regulation is the public's business, and it must be transacted publicly and candidly. The public must be informed about and have the opportunity to participate in the regulatory processes as required by law. Open channels of communication must be maintained with Congress, other government agencies, licensees, and the public, as well as with the international nuclear community.' (*See* https://www.nrc.gov/about-nrc/values.html.)

The NRC has also recently undertaken efforts to update and further improve its Environmental Justice ('EJ') policies. The NRC describes its

EJ efforts as being aimed at 'identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of an agency's programs, policies, and activities on minority and low-income populations.' (*See* https://www.nrc.gov/about-nrc/regulatory/licensing/nepa/environmental-justice.html.) The NRC has had an EJ strategy in place since 1995, and the agency's recent systematic assessment involved 'extensive outreach effort to stakeholders, including environmental justice communities and Tribal nations, NRC staff, other federal agencies, industry groups, nuclear safety organizations and the public at large. Over the course of the assessment, the Team held several public meetings and received approximately 2,500 written comments.' (*See* https://www.nrc.gov/about-nrc/regulatory/licensing/nepa/environmental-justice/assessment.html.) The NRC staff's assessment and recommendations can be accessed here https://www.nrc.gov/docs/ML2203/ML22031A063.html.

6. Challenges related to SMR & AMR waste. Other considerations

6a) In summary and in your view, what new challenges do AMR & SMR waste pose to existing radioactive waste frameworks or disposal plans in your country?

The specific technical challenges associated with management and disposal of AMR & SMR are being addressed most directly through the multiple efforts underway at DOE (described above).

The legal and policy challenges associated with AMR & SMR waste in the U.S. are largely coextensive with the challenges associated with spent fuel management more broadly. As described above, the legal framework for used fuel management in the U.S. is provided in the NWPA, which created a structured program in which the federal government was required to begin removing used fuel from reactor sites in 1998. The federal government has failed to meet its obligations under the NWPA and effectively cancelled efforts to license at permanent repository at Yucca Mountain.

DOE's current efforts are focused on using a consent-based siting approach for a centralized interim storage facility. DOE has emphasized that it will take a stepwise, iterative, and adaptive approach process to determine whether and how potentially hosting a facility aligns with state and local community goals. According to DOE planning documents, this process would take roughly 10 years to complete for an interim

storage facility but would likely take longer for siting a repository (https://www.energy.gov/sites/default/files/2023-05/Consent-Based%20Siting%20Process%20Report-0424%203.pdf).

In the meantime, used fuel must be safely managed and stored by reactor owners until transported offsite for either interim storage or final disposal, with costs for fuel management and storage being borne by reactor owners. To address this issue, operating reactors have re-racked their used fuel pools to increase the pools' storage capacity and licensed and constructed onsite dry storage facilities. Although adopting those kinds of measures is costly, those costs are largely offset by operating reactors' ongoing recovery for DOE's failure to begin picking up the fuel.

There may be different business impacts associated with used fuel management and storage for new reactors because new reactor owners will have to enter an amended standard contract. The amended standard contract attempts to manage DOE's ongoing liability by, for example, extending the timeframe used fuel must be stored by new reactor owners and providing for limited damages if DOE fails to perform.

6b) Please, add any other consideration you might have in regard to the planning, regulation and public communication and participation in the management of this type of waste.

Chapter 10

ACHIEVING PERMANENT DISPOSAL OF HIGHER LEVEL RADIOACTIVE WASTES

Stephen Tromans KC
39 Essex Chambers, London
Member of UK Committee on Radioactive Waste Management[1]

'You don't build a house without a toilet.'[2]

'The tragedy of nations is perhaps this: that even the best rulers use up a piece of their people's future.'[3]

Abstract

Any country which has pursued a programme of nuclear power generation, or is considering doing so, must inevitably face the issue of disposing of the spent fuel and radioactive wastes from these activities. Such

[1] The Committee (CoRWM) is an expert independent Committee appointed by the Secretary of State to advise the UK Government and Devolved Administrations on the management of radioactive waste. The views in this paper are personal and should not be taken as representing the view of CoRWM. I am most grateful to Sir Nigel Thrift (Chair of CoRWM) and Mark Kirkbride (fellow-member of CoRWM and chair of Sub-Group 2 on site evaluation) for their review and helpful comments on an earlier version of this paper.

[2] Jitsuro Terashima, President of the Japan Research Institute think tank and member of an expert panel advising the national government on energy policy after the Fukushima disaster. R. Maeda, *INSIGHT – Japan's Nuclear Crisis Goes Much Further Than Fukushima*, Reuters, Feb 26, 2021, https://www.reuters.com/article/business/insight-japan-s-nuclear-crisis-goes-much-further-than-fukushima-idUSL4E8DQ0FP/ [access: 29 May 2026].

[3] Rainer Maria Rilke, *Early Journals*.

waste will, in many cases, present a radiological and potentially toxicological hazard over many thousands of years, timescales which are barely conceivable in terms of human history.

This paper looks at the issues around the topic and considers progress by reference to geological disposal projects in Finland and France. It reviews the failure of siting policy in the US, and the current state of play in the UK, considering the technical, legal, social and political issues.

What is clear is that very significant funding, time and expertise will need to be invested in the process of finding solutions for permanent disposal solutions for spent fuel and higher activity wastes if a global expansion of nuclear energy is to occur. In those countries where the process has been or is being successful, it can be observed what level of scientific, financial and social collaboration will be needed. In other countries such as the US and UK, history teaches what a fraught and uncertain process it can be. However, the risks for present and future generations of creating high level waste which will sit in surface or near surface stores indefinitely should not be regarded as tolerable.

Introduction

Any country which has pursued a programme of nuclear power generation, or is considering doing so, must inevitably face the issue of disposing of the spent fuel and radioactive wastes from these activities. Such waste will, in many cases, present a radiological and potentially toxicological hazard over many thousands of years, timescales which are barely conceivable in terms of human history.

As a result, any disposal facility must be designed to contain the relevant radionuclides and isolate them from the biosphere; it must retard their dispersion and provide isolation from aggressive phenomena over the necessary timescales, by a combination of the waste packaging, engineered barriers and surrounding geology.[4] In the case of the most challenging wastes, which will pose a significant hazard over very long periods of time, this means that the only viable solution is deep

[4] IAEA Safety Standards, *Disposal of Radioactive Waste*, Specific Safety Requirements No. SSR-5, Vienna: IAEA 2011, para. 3.32.

geological disposal in a facility located underground within a stable geological formation.[5]

Practical experience of such facilities has been very limited, but this is now advancing as some states progress towards construction and operation of such facilities, and feasibility studies, underground research facilities, site specific safety cases and operational experience have strengthened confidence in the safety of geological disposal.[6] Whether to pursue the option of geological disposal remains a decision for individual states, taking account of national policy, the national waste inventory, and economic and social factors. Needless to say, the development of such facilities, to provide passive safety over millennia, comes at a high cost[7] and will of necessity take place over many decades.

The key problem in developing geological disposal facilities is not fundamentally a technical one, challenging though this is. Provided suitable host rock strata exists, underground tunnelling and mining technology can allow a geological disposal facility to be safely constructed and the waste packages emplaced. The Site Specific Safety Case will need to demonstrate the appropriate degree of isolation of the waste over the timescales necessary to ensure sufficient radioactive decay. Rather, the issue is one of siting and the political and community opposition which can arise from a proposal in a given area of population. This makes the siting process extremely sensitive and potentially unpredictable, even if geological disposal is supported by robust national policy. This may also be exacerbated by the fact that siting is a staged process which occurs over a protracted period of time, as areas of search are identified, potential sites are screened, and the site-specific information to support a safety case and the ultimate siting decision are gathered.

Siting involves not only consideration of geological information,[8] but also social, human and environmental factors and the potential effects on these, for example transportation of the waste to the facility, the disposal of large quantities of excavated spoil and the population

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[5] IAEA Safety Standards, *Geological Disposal Facilities for Radioactive Waste*, Specific Safety Guide No. SSG-14, Vienna: IAEA 2011, para. 1.2.

[6] Ibid. para. 1.5. *See* further IAEA, *Design Principles and Approaches for Radioactive Waste Repositories*, IAEA Nuclear Energy Series No. NW-T-1.27, Vienna: IAEA 2020, covering the full range of repository types.

[7] The estimated cost of Olkiluoto in Finland, discussed below, is around €818 million.

[8] Including geology, hydrogeology, geomechanics, geochemistry & seismicity.

fluctuations and demands on local services during the construction phase. These aspects have caused proposals to misstep and fail, perhaps notably in the US.

In the UK, these challenges have been recognised through a policy of voluntarism, such that a facility should only proceed with the agreement of the relevant 'community', though this is not proving a straightforward proposition to implement.

The approach of top down decision making, where radioactive waste facilities are imposed on unwilling communities, sometimes referred to as 'decide and defend', has been tried in the 1980s and 1990s and has largely been discredited.[9] The NEA's preferred approach is one of partnership if a licensable disposal facility is to be achieved, the key components being voluntarism, collaboration with local stakeholders, the agreement of community benefits packages, and some form of possible veto (whether formal or informal) by the local community.[10] Finland and Sweden are exemplified by NEA as proponents of this approach.

Imperatives to provide geological disposal facilities

In general, radioactive waste awaiting transportation to a geological disposal facility will be in an immobilised form, either within dry casks, or in some cases, within drums following a vitrification process, in which radioactive waste is blended with glass precursor materials and heated to above 1,000 degrees C to melt the components.

Storage may be at the nuclear reactor site, or at a centralised facility. This storage can be via dry casks suitable for interim storage on site, or a more robust shielded container suitable for transportation which meets IAEA Safety Standards.[11] The storage systems may be above ground or excavated to below ground level (e.g. near surface vaults). The quantity

[9] A. Blowers and G. Sundqvist, *Radioactive Waste Management – Technocratic Dominance in an Age of Participation*, "Journal of Integrative Environmental Sciences" 2010, Vol. 7, Issue 3, pp. 149–155.

[10] NEA, *Partnering for Long-Term Management of Radioactive Waste: Evolution and Current Practice in Thirteen Countries*, NEA No. 6823, Paris: OECD 2010.

[11] IAEA Safety Standards, *Regulations for the Safe Transport of Radioactive Material*, Series No. SSR-6 (Rev. 1), Vienna: IAEA 2018. In the UK for example a number of organisations have adopted the use of Robust Shielded (RS) packages for higher activity waste,

of dry storage casks in use is indicated by the market in the Americas, where demand is highest, which was estimated at $1 billion in 2020.[12]

Delays in the provision of geological disposal facilities mean that the intended lifetimes of interim storage facilities will, in some cases, need to be extended. Conventional stores (as currently used) will usually require replacement and repackaging at not more than 200-year intervals.

It is debatable how acceptable the prolongation of interim storage can be. As an article in "Chemical & Engineering News" in 2020 pointed out,[13] more than 250,000 metric tonnes of highly radioactive wastes are in storage adjacent to nuclear power stations and weapons production facilities worldwide, with over 90,000 metric tonnes within the USA alone.

Much of this radioactive waste is now decades old, with a legacy going back to the 1940s, such that age is taking its toll on the containment, noting that these wastes will remain dangerous for many thousands of years. It also points out that even the well-established process of vitrification has uncertainties about how the steel canister protecting the glass may corrode, and what effect water ingress could have on the glass in terms of possible ion exchange and leaching of radioactive materials. This may include issues arising in damp repository conditions, particularly if cracks in steel canisters allow water into the microscopic gap between the waste and steel, triggering potentially unexpected reactions in the confined space.

Even for the more easily dealt with solid spent fuel assemblies, stress fractures may occur at weld seams, leading to corrosion affecting the stainless steel used in dry casks. This may be further exacerbated by the coastal locations of many nuclear power plants, with exposure to sea-salt aerosol which would be highly likely to accelerate corrosion.

Facilities currently storing radioactive waste will predominantly have been sited and designed in an era predating the recognition of the potential effects and risks posed by climate change, such as sea level rise,

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which are thick-walled, ductile cast iron containers weighing up to 35 tonnes. Work is under way to develop a transport version of this package meeting IAEA standards.

[12] *Storage and Disposal of Radioactive Waste*, https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste [access: 29 May 2026].

[13] M. Jacoby, *As Nuclear Waste Piles Up, Scientists Seek the Best Long-Term Storage Solutions*, "C&EN" March 30, 2020, Vol. 98, Issue 12, https://cen.acs.org/environment/pollution/nuclear-waste-pilesscientists-seek-best/98/i12 [access: 29 May 2026].

coastal erosion and extreme weather events. These may all impact on the safety of prolonged interim storage facilities.

Statistically, the earth is due for another extreme solar storm during this century which could inflict long term power outages that could compromise the safety of stored spent fuel.[14]

There are also concerns being voiced about the potential risks presented by terrorism and armed conflict or war. The nature of the packaging or vitrification of radioactive waste most likely indicates that in practice it would be difficult for these materials to be dispersed as a result of a terrorist attack, such as to threaten harm to life, but the necessary clean-up would be both extremely difficult and expensive. Vulnerability to certain types of missile strike may be different, as shown in a recent wargame designed by the Washington-based Nonproliferation Policy Education Center (NPEC) reported in June 2023 in the "Bulletin of the Atomic Scientists".[15] Spent fuel contains accumulated highly radioactive fission products, including iodine, caesium and strontium, which would result in a radiological emergency if released. Clearly, any such attack would be contrary to norms of international behaviour (though not explicit international law), however they have occurred in the past and may well do so again in future.[16]

Moreover, studies of history clearly demonstrate that political economies operate in cycles, with almost inevitable upheavals and societal breakdown occurring regularly; indeed Western societies such as the USA are moving, or have moved, into socio-economic conditions conducive to such disruption.[17]

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[14] M. Leyse, *Spent Nuclear Fuel Mismanagement Poses a Major Threat to the United States. Here's How*, "Bulletin of the Atomic Scientists", April 2, 2024, https://thebulletin.org/2024/04/spent-nuclear-fuel-mismanagement-poses-a-major-threat-to-the-united-states-heres-how/ [access: 29 May 2026].

[15] H. Sokolsky, *Wargame Shows Attacks on Reactors Would Cause Meltdowns and Military Paralysis*, "Bulletin of the Atomic Scientists", June 26,2023, https://thebulletin.org/2023/06/wargame-shows-attacks-on-reactors-would-cause-meltdowns-and-military-paralysis/#post-heading [access: 29 May 2026].

[16] K. Herviou et al., *What Are the Risks of Nuclear Power Plants in Wartime?*, "Polytechnique Insights", Jul 12,2022, https://www.polytechnique-insights.com/en/columns/geopolitics/how-to-protect-nuclear-power-plants-in-wartime [access: 29 May 2026]; B. Ramberg, *The Danger of Nuclear Reactors in War*, "Project Syndicate", Aug 5, 2022, https://www.project-syndicate.org/onpoint/ukraine-shows-nuclear-reactors-at-risk-during-war-by-bennett-ramberg-2022-08 [access: 29 May 2026].

[17] *See* P. Turchin, *End Times: Elites, Counter-Elites and the Path of Political Disintegration*, Penguin Random House, UK 2023.

All of these factors strengthen the imperative for swift action to be taken for the development of geological disposal facilities to move spent nuclear fuel and higher-level radioactive waste deep from surface storage into underground vaults, so that it is out of harm's way.

Progress

The World Nuclear Association website includes a helpful table showing the progress of various countries in relation to deep geological repository projects.[18] The site at Onkalo, Finland (discussed below) has a commissioning date of 2024.

Next in line is the Cigéo facility in France, where a construction licence was submitted in 2023, and Forsmark in Sweden where the application for a construction licence was approved in 2022. Both have proposed commissioning dates in the first half of the 2030s.

A site has been selected in Switzerland, at Nördlich Lägern, where general licence applications are due to be submitted to the Federal government in 2024, with approval anticipated around 2030, subject to an optional referendum, and with 2060 as a proposed commissioning date. Other countries are still at the selection stage for varying areas of search; these include Canada, China, Czech Republic, Germany, Hungary, India, Japan, Slovakia, and the UK. In the USA the process has stalled, as discussed below.

Olkiluoto

In 2020, the Director General of the IAEA described the world's first deep geological facility at Olkiluoto, off the south-west coast of Finland, as 'game changer'.[19] The commitment and drive of the Finnish government, and the companies involved in developing the project, are clearly an

[18] *Storage and Disposal of Radioactive Waste…*

[19] L. Gil, *Finland's Spent Fuel Repository a "Game Changer" for the Nuclear Industry, Director General Grossi Says*, IAEA, Nov 26, 2020, https://www.iaea.org/newscenter/news/finlands-spent-fuel-repository-a-game-changer-for-the-nuclear-industry-director-general-grossi-says [access: 29 May 2026].

example to other countries. It can be seen in the context of a country deeply committed to nuclear power as part of its energy strategy.

It is worth recalling some of the history of the project. The Nuclear Energy Act in Finland was amended in 1994 to provide that nuclear waste arising in Finland should be disposed of within Finland. From 1983 until 2000 a screening exercise was undertaken which covered the whole Finnish territory. This resulted in four sites being identified for further investigation, one of which was Olkiluoto, which has hard rock (granite) geology. The levels of public support were assessed, and two sites, Olkiluoto and Hästholmen, were found to have the highest levels of support. Of these sites, Olkiluoto had the more favourable geology, and was therefore proposed to the Finnish government as the preferred site. Approval was confirmed by the municipality where the site is located, Eurajoki, and the decision was ratified by the national government in 2001. Excavation began in 2004 and a licence to construct the final disposal facility was issued in 2015. Prior to issuing the licence to construct the repository, there were extensive underground investigations to study the characteristics of the rock. The facility, known as Onkalo, was developed by Posiva, a company owned by the two companies responsible for producing nuclear energy in Finland, Fortum Oyj and TVO (Teollisuuden Voima Oyj). The GDF is expected to receive canisters of fuel for around 100 years.

The disposal concept, known as KBS-3, shared with the proposed Swedish facility at Forsmark, utilises copper canisters for waste containment; copper is known to have a long-term resistance to corrosion from the findings of ancient copper tools and geological copper deposits.

It is interesting to consider why the process in Finland progressed in a relatively smooth manner. Perhaps a starting point lies in the origins of the Finnish nuclear power programme in the 1970s; the Three Mile Island accident in the US in 1979 focused minds on nuclear risks, and the export of waste to the then Soviet Union was seen as potentially storing up trouble for the future. Accordingly, in 1983 the Finnish Parliament required the two nuclear power companies, Fortum and TVO, to set aside funds and begin the process of planning for a disposal facility. This created a very significant State Nuclear Waste Management Fund, mandated by the Nuclear Energy Act of 1987 and overseen by its Ministry of Economic Affairs and employment. Accordingly, Posiva has for many years been well resourced in undertaking the necessary research. It has also been supported and overseen by the Finnish Research Programme

on Nuclear Waste Management (KYT), an independent body charged with assimilating Finland's overall nuclear waste management base from across a number of different organisations, including the regulatory authority STUK, the Geological Survey of Finland (GTK) and various specialist consultancies.

It is also worth noting that the preparation of the long term safety case was a wide ranging and very demanding exercise, as it was necessary to maintain public trust and confidence, which as well as including rigorous science, incorporated some imaginative and eclectic processes in seeking to look tens and hundreds of millennia ahead to the point when risks from the waste would be at their greatest, after the inevitable failure of the primary containment.[20]

One aspect of siting was identifying a location of little interest in terms of metal deposits and non-saline, usable groundwater. Plainly, the process did ultimately prove successful in engendering and maintaining trust, whilst also bucking the trend of 'deflation of expertise' which is so prevalent in contemporary Western society, defined by Ialenti in his excellent book on the Finnish programme, *Deep Time Reckoning*, as:[21]

> … what happens when political power is commonly gained through populist mockery of expert authority, experts' voices are too often drowned out by the noisy clamors of knee-jerk tweets and self-published blogs, and adepts' inquisitive spirits are frequently dulled by new corporate-managerial reforms and constrained by bureaucratic protocols.

It is therefore possible to perceive in Finland a high and sustained degree of national commitment to finding a solution to the problem of spent nuclear fuel and radioactive waste. Public trust in the Finnish Radiation and Safety Authority (STUK) is very high, and the safety issue was essentially depoliticized at a local level.[22] There has also been a move

[20] The projections include final waste canisters being deposited in 2120 and tunnels backfilled, 22,000 years as the earliest projection for Finland's next Ice Age, 26,122 years when Plutonium-239 reaches its half-life, and 2.3 million years when Caesium-135 reaches its half-life. S. Upson, *Finland's Nuclear Waste Solution*, "IEEE Spectrum", Nov 30, 2009, https://spectrum.ieee.org/finlands-nuclear-waste-solution [access: 29 May 2026].

[21] V. Ialenti, *Deep Time Reckoning: How Future Thinking Can Help Earth Now*, Cambridge: Massachusetts Institute of Technology 2020.

[22] T. Vilhunen et al., *Perceptions of Justice Influencing Community Acceptance of Spent Nuclear Fuel Disposal. A Case Study in Two Finnish Nuclear Communities*, "Journal of Risk

or evolution from technocratic management towards a more participative and communicative approach.[23] This methodology has been shared, albeit with some differences, with Sweden.

Both countries have in common a society which is consensus-driven and with high levels of trust. Whereas the Swedish approach has been characterised as 'involved partnership' which allows for challenge, and even modification of the policies and actions of the operator and authorities, the approach in Finland is more that of a 'bystander partnership' which is characterised by trust in the safety authorities, and with the primary issue of concern being community socio-economics. In both countries the host municipalities have chosen not to exercise their right of veto and are supportive of the siting of the repository in their area.

The process in Finland has been a long and sustained one. There were important milestones in the 1990s in the Eurajoki municipality, including a 1997 study on the economic competitiveness of the municipality and a 1998 analysis known as the 'Olkiluoto vision', which included a spent nuclear fuel repository.[24]

The USA

If Finland can be considered to be an exemplar of a successful siting process, then the USA can only be seen as the reverse. The history to date could possibly be described as one of 'anti-voluntarism' whereby the process has been subverted and stalled by local interests and political power play.

The US does already have a deep geological facility, the first in the world before Olkiluoto, the Waste Isolation Pilot Plant (WIPP) near Carlsbad in New Mexico. This was developed to take defence-related

Research" 2022, Vol. 25, Issue 8, pp. 1023–1046, https://www.tandfonline.com/doi/pdf/10.1080/13669877.2019.1569094 [access: 29 May 2026].

[23] M. Kari, M. Kojo and M. Lehtonen, *Role of the Host Communities in Final Disposal of Spent Nuclear Fuel in Finland and Sweden*, "Progress In Nuclear Energy" March 2021, Vol. 133, 103632. https://www.sciencedirect.com/science/article/pii/S0149197021000044 [access: 29 May 2026].

[24] NEA, *Stepwise Decision Making in Finland for the Disposal of Spent Nuclear Fuel*, Paris: OECD 2002, p. 84, https://www.tandfonline.com/doi/pdf/10.1080/13669877.2019.1569094 [access: 29 May 2026].

transuranic[25] waste, for example laboratory and industrial waste contaminated with transuranic radionuclides. Although much less dangerous than spent fuel and high level waste, such waste remains radioactive for thousands of years. At WIPP there is no reliance on waste packaging for isolation, with this being provided by the surrounding salt formations which are ~2,000 feet thick. Site characterization began in the mid-1970s, excavation commenced in the 1980s and the site began to receive radioactive waste in 1999 from defence related locations around the US. The site was selected by the US Department of Energy (the DOE, formerly the US Atomic Energy Commission) on the basis of positive interest from the local New Mexico community, and because a site previously under consideration in Kansas was facing local opposition and featured previously undiscovered oil and gas resources.

The key technique used to achieve public trust at WIPP was the New Mexico Environmental Evaluation Group (EEG), created in 1978 as an independent body charged with overseeing the project and verifying statements and studies undertaken by the DOE. It seems likely that the project would not have progressed were it not for the work of EEG, for example by investigating and instigating studies when brine deposits under pressure were found beneath the site. The US Congress authorised construction in 1979, but further approval was necessary from Congress before the facility could be used. This led to a political battle and to legislation which included provision for revised safety standards to be approved by the Environmental Protection Agency.

The WIPP site has been controversial for various reasons. Two significant accidents in 2014 (a truck fire and radioactive release from breach of a container) called its safety credentials into question and led to reduced operations.[26] According to the US Government Accountability Office, it remains unclear whether the root causes of the accidents have

[25] The transuranium elements (also known as transuranic elements) are the chemical elements with atomic numbers greater than 92, which is the atomic number of uranium. All of them are radioactively unstable and decay into other elements. With the exception of neptunium and plutonium which have been found in trace amounts in nature, none occur naturally on Earth and they are synthetic.

[26] D. M. Klaus, *What Really Went Wrong at WIPP: An Insider's View of Two Accidents at The Only US Underground Nuclear Waste Repository*, "Bulletin of the Atomic Scientists" 2019, Vol. 75, Issue 4, pp. 197–204, https://doi.org/10.1080/00963402.2019.1628516 [access: 29 May 2026].

been addressed.[27] Further, WIPP has remained the only facility of its kind for transuranic wastes, despite the understanding being at the time of construction that the burden would be shared by other sites. This has led to pressure on space and proposals for extension in time and physical extent, creating tensions with the state of New Mexico.[28]

The facility does however have very strong, though not universal, support within the local community and indeed is a source of pride, as well as jobs and economic support: it has been reported that the first trucks carrying waste containers to the facility were jeered at while passing through Santa Fe, but cheered on arrival in Carlsbad.[29]

A facility for receiving spent fuel and high-level radioactive waste, both being much more hazardous than that authorised for disposal in WIPP, is a very different proposition, and so it has proved with the stymied proposal for a high-level waste repository at Yucca Mountain, Nevada. The initial phases of the saga have been set out in various publications.[30]

The US arrangements for siting sit firmly within a legislative context. The problem of permanent disposal of high-level radioactive waste has been growing ever since the inception of the Manhattan Project in the early 1940s, but was not addressed in law until the Nuclear Waste Policy Act of 1982 (NWPA), when attention was drawn to the huge disparity of funding for developing the military and peaceful uses of nuclear power and that devoting to looking for solutions to the wastes being generated. At the time of the passage of the NWPA, much effort was expended by the legislators in seeking to preclude consideration of their own constituencies as host sites for a repository.

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[27] U.S. Government Accountability Office, *Waste Isolation Pilot Plant: Construction Challenges Highlight the Need for DOE to Address Root Causes*, https://www.gao.gov/products/gao-22-105057 [access: 29 May 2026].

[28] *See* P. Lohmann, *NM's Nuclear Waste Site Could Be Open 'Forever' Despite 2024 Closure Date, Advocate Warns*, "Source NM", Aug 8, 2022, https://sourcenm.com/2022/08/08/nms-nuclear-waste-site-could-be-open-forever-despite-2024-closure-date-advocate-warns/ [access: 29 May 2026].

[29] D. Moore and Bloomberg, *America's Nuclear Waste Capital Wants to Keep Up Their Cottage Industry Even Though New Mexico Wants the Authority to Crack Down*, "Fortune" May 2, 2023, https://fortune.com/2023/05/02/nuclear-waste-storage-new-mexico-carlsbad-wipp [access: 29 May 2026].

[30] A thorough account up to 2007 is given in R. Vandenbosch and S. E. Vandenbosch, *Nuclear Waste Stalemate: Political and Scientific Controversies*, Salt Lake City: University of Utah Press 2007.

Scientific and technical considerations could already be seen to be dominated by politics. The most debated provision of the NWPA was that allowing a selected state to veto its selection for a site, but with the ability for that veto to be overridden by a majority vote in both houses of Congress.[31] The process has been described as searching for a 'technically appropriate subsurface with a politically compliant governor on top'.[32] The exigent timescales required by the NWPA for progressing a site were somewhat antithetical to an open consultative process and were likely to contribute to 'insufficient attention to local concerns and participatory opportunities or result in inappropriate compromises'.[33]

There followed preliminary studies by the DOE at several prospective sites, which generated local protest at various sites, particularly those in the Eastern states. The choice was narrowed down to three candidate sites in the West, and in 1987 the Nuclear Waste Policy Amendments Act established Yucca Mountain as the only site to be investigated further: the Amendments Act also suspended the requirement in the NWPA for an Eastern site to be pursued in tandem.[34]

Nevada at that time had the least political influence of the three Western states with candidate sites,[35] and the Amendments Act was notoriously referred to as 'the Screw Nevada bill'.[36] The passage of the

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[31] Ibid., p. 2.

[32] Ibid., p. 53.

[33] Ibid., p. 56.

[34] The Act also directed DOE (without any technical justification) to terminate research programmes on crystalline rock (effectively granite) which was the only likely medium for a repository in Northeastern and Midwestern states: ibid., pp. 41–42, 84. As has been pointed out, the somewhat modest title of the Act belied the massive changes in nuclear waste policy which it introduced. Ibid., p. 71.

[35] The other two sites were Hanford in Washington State, and Deaf County in Texas. Hanford, as well as being located on potentially problematic basalt, has a very unhappy history of nuclear waste management from the US defence programme. Deaf County was in a very productive and prosperous agricultural area, with some of the best land in Texas, and was on a salt formation. At that time there was concern about the safety of salt domes following the 1987 accident at the Gorleben site in Germany caused by the pressure of salt creep. Moreover, the Speaker of the House of Representatives was from Texas and the House majority leader was from Washington State: Nevada was the smallest and politically weakest of the three states.

[36] Ibid., p. 3. It may also be noted that various proposals for centralised interim storage sites (monitored retrieval storage) for example in Tennessee and Utah, failed because of local opposition: ibid., p. 8.

Amendments Act also illustrated the significance of dominant political actors, in that case Senator J. Bennett Johnston (D-LA), Chair of the Senate Energy and Natural Resources Committee, who was well-informed, politically astute and had an impressive grasp of scientific and technical issues.[37] The lack of transparency in site selection was however striking: 'In the end, it was not the DOE, which had conducted extensive studies of the sites, that picked the site but, rather, a conference committee that operated behind closed doors.'[38] It could be argued that in taking the decision, Congress had placed the DOE in an untenable position of having to justify the site's suitability, rather than conducting a dispassionate analysis of its viability and whether it was the best site.

There followed a draft Environmental Impact Statement and a Science and Engineering Report by the DOE, and subsequently Presidential approval of the proposal for Yucca Mountain. Nevada then exercised its statutory veto, which was overridden by strong majorities in both houses of Congress in mid-July 2002 – a time of great national concern about vulnerability to terrorist attacks following 9/11. However, political developments intervened once again.

Opponents to Yucca Mountain found an effective champion in Senator Harry Reid (D-NV), who had a firm grasp of the legislative process and increasing political power. Underground test facilities were constructed at Yucca Mountain; work was also undertaken on projected performance by probabilistic modelling, which ran into legal difficulties when the DC Court of Appeals held that the EPA had unlawfully limited the period for assessing compliance with dose standards to 10,000 years, well before the likely peak dose (between 100,000 and 1 million years). Even within 10,000 years there was arguably a failure to provide sufficient weight to the risk of volcanic activity, which while low in terms of probability would have significant consequences for exposure to radiation.

A significant part of the public opposition to Yucca Mountain within Nevada was based on mistrust of government: those affected by fallout from the test detonation of 'Dirty Harry' in 1953 (a 32-kiloton bomb which produced the most fallout of any tested within the US mainland) did not receive any compensation until the 1990s.[39] International concerns also

[37] Ibid., p. 84.
[38] Ibid., p. 87.
[39] Ibid., p. 117.

played into the same narrative: a replica spent fuel flask was transported around Nevada and other Western States in 2000 in the 'Mobile Chernobyl' campaign to highlight the risks of mass transportation of spent fuel.

In 2006 the DOE proposed 2017 as the date the Yucca Mountain facility would begin waste acceptance. During the administration of President Obama, the project met its political nemesis in the 2011 amendments to the Department of Defence and Full-Year Continuing Appropriations Act. It was, by then, seriously contested by the public and many politicians, as well as state and local administrations, and by Senator Harry Reid who had been the leader of the Senate since 2006. By 2008 the project's budget had been significantly curtailed and attempts to find a different and less politicised approach, through the so-called Blue Ribbon Commission on America's Nuclear Future, came to nothing, and under President Trump the DOE ceased deep borehole activities.

In May 2021 the Energy Secretary Jennifer Graham announced that Yucca Mountain would not feature in the President Biden administration's plans for nuclear waste disposal. Today the site has been abandoned and nothing exists but a boarded-up tunnel entrance.[40] The site, in technical terms, has undeniable merits: its desert location, distance from centres of population (Las Vegas is 90 miles away), closed hydrologic basin and surrounding Federal land. On the other hand, Nevada highlighted some problems – its location in an active seismic region, with earthquake induced faults, potential fracture pathways in the rock, and some evidence of hydrothermal activity within the repository block. But irrespective of the science, as the Blue Ribbon Commission reported to President Obama, experience suggests that 'any attempt to force a top-down, federally mandated solution over the objections of a state or community' is likely to be expensive, time-consuming, and ultimately unsuccessful: 'The construction of a permanent nuclear waste repository will require not only the backing of scientists and politicians but also the consent of a host community.'[41] Yucca Mountain can be seen as a flawed process which failed.

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[40] YuccaMountain.org, https://www.yuccamountain.org/faq.htm [access: 29 May 2026].

[41] D. Stover, *The "Scientisation" of Yucca Mountain*, https://www.yuccamountain.org/pdf/dawn_stover_102011.pdf [access: 29 May 2026].

Canada

Some brief comments may be made on the situation in Canada, where the Nuclear Waste Management Organisation (NWMO) is considering two community locations in Ontario for a deep GDF. One site is in the municipality of South Bruce, where the local council volunteered to be a host in 2012. Since then deep test drilling has begun and according to a 2021 report the community has received over $3.2 million in community funding, used for many different purposes quite unrelated to the proposed project, including salaries of municipal employees, funding doctors, upgrading abstraction wells, and purchasing fire-fighting equipment.[42] This has led to controversy as to whether NWMO is funding basic municipal expenses in a way which might make the municipality financially dependent and therefore making it harder to disentangle itself by saying no to the project.

France

The process of developing a repository in France is managed by ANDRA (*Agence nationale pour la gestion des déchets radioactifs*). Studies on possible locations date back to the 1960s and by the 1990s the focus was on clay and granite as potential formations. Legislation in 1991 (the *Loi Bataille*) required research at a number of sites, with ANDRA narrowing down the choice from four to three. In 2019 ANDRA filed with the Nuclear Safety Authority (ASN) a request to build the Cigéo Centre (*Industriel de Stockage Géologique*) at Bure in the Meuse Département, within Kimmeridgian claystone in the Paris Basin. The project has been the subject of some protest and resistance by anti-nuclear activists, who were evicted from the forest site of the proposed air vents in 2018.

ANDRA applied for a construction licence (DAC) in 2023, which ASN will consider over a period of several years, beginning with a 30-month technical examination phase, followed by consultation and a public

[42] C. Butler, *'Goodwill' Money From Proposed Nuclear Waste Site Pours Into Declining Ontario Farm Town. What if It Stops?*, CBC News, May 07, 2021, https://www.cbc.ca/news/canada/london/nuclear-waste-disposal-site-teeswater-south-bruce-1.6013827 [access: 29 May 2026].

inquiry, probably in 2026.[43] The Meuse and Haute-Marne departments are quite sparsely populated. The *Loi Bataille* emphasises public participation, and public debates have been held. There appears to be strong local support, with the main opposition being non-local; strikingly a 2020 poll showed that 65% of those polled within 15 km of the site trusted ANDRA to manage radioactive waste in the long term.[44] There is a strong imperative to make progress since the cooling pool facilities at the La Hague reprocessing facility in Normandy will reach their capacity by the end of the decade.[45]

The United Kingdom

The UK, perhaps unfortunately, has some special features when it comes to finding a solution to higher level radioactive wastes. The first stems from the devolved nature of government in the UK, with the Scottish Government and Welsh Government having devolved authority concerning waste disposal.

There is a UK-wide policy framework for managing radioactive substances and nuclear decommissioning, recently updated in May 2024, to which the Scottish and Welsh Governments are parties.[46] Whilst it is the policy of the UK Government and the devolved administrations to manage the UK's most hazardous waste through geological disposal, the Scottish Government's policy is quite different and Scotland is not participating in the geological disposal programme.[47] This is despite the fact that spent fuel has been generated by Scotland's nuclear power stations

[43] World Nuclear News, *Application Lodged for Construction of French Repository*, Jan 18, 2023, https://world-nuclear-news.org/Articles/Application-lodged-for-construction-of-French-repo [access: 29 May 2026].

[44] C. Vestergaard, R. Price, *A Visit to the Site of France's Future High-Level Waste Repository*, Stimson, Apr 20, 2021, https://www.stimson.org/2021/visit-to-the-site-of-frances-future-high-level-waste-repository/ [access: 29 May 2026].

[45] B. Mallet, *Focus: France Seeks Strategy as Nuclear Waste Site Risks Saturation Point*, Reuters, Feb 3, 2023, https://www.reuters.com/business/environment/france-seeks-strategy-nuclear-waste-site-risks-saturation-point-2023-02-03/ [access: 29 May 2026].

[46] *UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning*, https://assets.publishing.service.gov.uk/media/6632371769098ded31fca7c1/managing-radioactive-substances-and-nuclear-decommissioning-uk-policy-framework.pdf [access: 29 May 2026].

[47] Ibid., para. 8.56.

and that exotic wastes have arisen from various experimental reactor facilities at the Dounreay site in Caithness.

Therefore, the search for a possible GDF site is proceeding in England and Wales only. Scotland has its own policy for the management of higher activity waste, which is that long-term management should be in near-surface facilities, located as close as possible to the site where the waste was produced. This policy was stated in 2007, shortly after CoRWM recommended geological disposal as the best available approach for the long term management of higher activity waste, and was said to be so that the waste could be monitorable and retrievable, and the need for transporting it over long distances is minimal.[48] The Scottish Government stated that '… we do not accept that it is right to seek to bury nuclear waste, which will remain radioactive for thousands of years, in underground sites. This out of sight, out of mind policy should not extend to Scotland'.[49]

This of course effectively precludes Scotland from any possible GDF site, in circumstances where there are large areas of suitable geology in remote locations in Scotland.[50] Whilst the Welsh Government policy is for geological disposal and has its own policy framework on working with communities,[51] it is questionable whether a repository sited in Wales to take waste from other parts of the UK would be acceptable in political or community terms, though this has not been stated explicitly, and no proposed sites in Wales are currently under consideration. If that is correct, only about 75% of the UK mainland landmass is in fact available as an area for a GDF.

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[48] Scottish Government, *Radioactive Waste Policy Statement*, https://www.gov.scot/publications/radioactive-waste-policy-statement/ [access: 29 May 2026].

[49] Ibid.

[50] There were high risk materials such a plutonium and exotic spent fuels at Dounreay which have been transferred to Sellafield under the consolidation of spent fuel and nuclear material programme. Also some highly enriched uranium was transferred from Dounreay to the USA by air. It is proposed that spent fuel currently in storage at power stations in Scotland would in due course be transferred to a GDF, presumably in England. *See* GOV UK, *Consolidation of Spent Fuel and Nuclear Materials*, https://www.gov.uk/government/case-studies/consolidation-of-spent-fuel-and-nuclear-materials [access: 29 May 2026].

[51] Welsh Government, *Geological Disposal of Higher Activity Radioactive Waste: Working with Communities*, https://www.gov.wales/sites/default/files/publications/2019-04/geological-disposal-of-higher-activity-radioactive-waste-guidance-for-communities.pdf [access: 29 May 2026].

The second peculiar national factor is the nature of the UK's waste inventory. Dealing with spent fuel from nuclear power generation, whilst not easy, is markedly more straightforward than dealing with the radioactive wastes from the UK's long, and essentially unhappy, history of reprocessing at Sellafield.[52] That waste, either high-level and heat generating, or the worst forms of intermediate level waste, now represents a major financial and technical challenge for the UK, long after the profits from taking waste for reprocessing from overseas have ceased. Much of this inventory still remains untreated and unpackaged,[53] though progress is being made on reducing the worst risks.[54] It does not seem unreasonable to suggest that it may be easier to engage positively with the public in respect of spent fuel, which has plainly benefited the public from generating electricity (as in Finland) than the complex brew of spent fuel types and reprocessing residues the UK holds.

The current UK policy is one of voluntarism, though interestingly the word does not appear in the Waste Policy: it is referred to as 'community consent-based processes'.[55] The process for identifying a suitable site for a GDF in England is at Appendix 1 and in Wales (though as explained above the political reality, at least at the present time, is most likely that no site in Wales will come forward).

The task of engaging with potentially willing communities falls to Nuclear Waste Services (NWS), a subsidiary of the Nuclear Decommissioning Authority, the statutory body charged with dealing with and cleaning up nuclear sites and their radioactive and industrial waste. A number of features of the 'working with communities' policy can be identified (largely taken verbatim from Appendix 1 of the Policy though here rearranged sequentially).

(1) A successful consent-based process needs a willing community with relevant principal local authority support. The process itself

[52] For an account, *see* S. Tromans, *Nuclear Law: The Law Applying to Nuclear Installations and Radioactive Substances in its Historic Context*, Hart Publishing 2010, pp. 14–17. For a highly critical account by an American outsider to the UK, see the Pulitzer Prize winning writer M. Robinson, *Mother Country: Britain, the Welfare State and Nuclear Pollution*, New York: Farrar, Straus & Giroux 1989.

[53] *See* the report on the 2022 Waste Inventory, GOV UK, *Consolidation of Spent Fuel…*

[54] GOV UK, *Nuclear Decommissioning Authority: Business Plan 2024 to 2027*, https://www.gov.uk/government/publications/nuclear-decommissioning-authority-business-plan-2024-to-2027/nuclear-decommissioning-authority-business-plan-2024-to-2027 [access: 29 May 2026].

[55] *UK Policy Framework for Managing…*, para. 8.71.

must be open, transparent, as flexible as possible and democratically accountable.

(2) Discussions about a proposed location for a GDF can be initiated by anyone or any group of people with an interest in the siting process, and who wish to propose an area for consideration. Examples include local authorities, landowners, businesses, community groups or interested individuals. NWS may also proactively encourage interested parties and local communities to come forward and engage. It is possible that an interested party may suggest a location for a GDF beneath the UK's territorial waters, with the surface facilities being located on land, which could be a feasible option. Government owned land may also be put forward.

(3) Once NWS and the interested party have had an initial exchange of information and agree that the proposal merits further consideration, they must jointly inform all relevant principal local authorities and open up discussions more widely in the community. Increasingly detailed investigations will be carried out by NWS over a number of years.

(4) NWS, as the delivery body, will work in partnership with communities to provide answers to their questions, so the community can make an informed decision about whether to support a facility being developed in their area.

(5) In order to begin a conversation with the people in the area, the interested party, NWS, an independent chair and an independent facilitator will form a Working Group. All relevant principal local authorities that represent the people in all or part of the area under consideration must be invited to join the Working Group. This early part of the process is essentially about fact finding, gathering information about the community and providing information to the community about geological disposal.

(6) An early task for the Working Group is to identify a Search Area. The Search Area is the geographical area within which NWS seeks to identify potentially suitable sites to host a GDF. Defining the boundaries of the Search Area is important in order to identify appropriate membership for the Community Partnership, including relevant principal local authorities, and to determine eligibility for Community Investment Funding.

(7) As it identifies the Search Area, the Working Group will start work to understand the local area and any issues or questions the community within it might have. Funding will be provided for independent support and a facilitator to support the Working Group. The independent facilitator will be a member of the Working Group and will help to bring together different views so that discussions progress in a constructive and informative manner.

(8) A Community Partnership can only be formed and continue to operate if one or more relevant principal local authorities in the Search Area agree to participate. There must be at least one relevant principal local authority representing each district or unitary authority electoral ward in the Search Area. In an area with two tiers of local government (i.e. district and county) in order to maintain flexibility, it is not a requirement that both join. All of the Search Area must be represented by a relevant principal local authority on the Community Partnership. If a relevant principal local authority decides to leave the Community Partnership with the result that part of the Search Area (or, once identified, the Potential Host Community) is no longer represented by any of the relevant principal local authorities on the Community Partnership, then it will no longer form part of the Search Area. The Community Partnership should seek to include representation from parish and town councils, though given the potentially large number of parish or town councils in any given area, it may not be feasible for them all to be members of the Community Partnership.

(9) The Community Partnership provides a vehicle for sharing relevant information and to find answers to the questions the community may have about geological disposal and its impacts, the siting process and how the community could benefit. The prospective members of the Community Partnership will develop and sign a Community Partnership Agreement. Once the Community Partnership Agreement is in place Community Investment Funding can be made available.

(10) The Community Partnership will need to engage with the community over a long period of time. Getting people actively involved on any issue can be challenging and it is possible that vocal minorities can dominate debate. It will therefore be important to open up community participation through a wide number of channels.

(11) Funding for engagement will be provided to Working Groups and Community Partnerships. The Community Partnership may also commission reports and research on specific topics from independent experts, as part of its agreed programme of activities. Given the range of advice and information available it may be that the Community Partnership receives conflicting statements from different parties. If that is the case the Government is making available a mechanism through which the Community Partnership can access independent experts for views on contested and unresolved scientific or technical issues.

(12) A GDF should have a positive effect on the local economy in terms of job creation. It is also likely to involve major investments in local transport facilities and other infrastructure and create secondary benefits within industry, local education resources and local service industries. However, these benefits will not materialise for a number of years. The Government is therefore making available Community Investment Funding to those communities that form Community Partnerships and participate in the process. During the early parts of the siting process, the UK Government has committed to make available Community Investment Funding of up to £1 million annually per community. This will rise to up to £2.5 million annually per community where deep borehole investigations take place to assess the geological suitability of a site. The funding can be used to pay for projects, schemes or initiatives that:

    a. improve community well-being, for example improvements to community facilities, enhancement of the quality of life or health and well-being of the community;
    b. enhance the natural and built environment including cultural and natural heritage, especially where economic benefits, for example through tourism, can be demonstrated; or
    c. provide economic development opportunities, for example employment opportunities, job creation, skills development, education or training, promotion of local enterprise, long-term economic development or economic diversification.

The Community Investment Funding should be administered by a third party with legal personality in order to provide additional transparency and independence from NWS, as the conduit of the funding.

(13) The Government will provide additional investment to the community that is ultimately selected to host the GDF, which will replace the Community Investment Funding. Investment could include improved local education and skills capacity, improved transport infrastructure or improved recreational facilities. This additional investment will be significant and comparable to other international GDF projects.

(14) To ensure democratic accountability, the relevant principal local authorities on the Community Partnership will take two key types of decisions. They will have the final say on:
   a. whether to seek to withdraw the community from the siting process (through invoking the Right of Withdrawal);
   b. if or when to seek the community's views on whether it wishes to host a GDF (i.e. proceed to a Test of Public Support).

(15) Although the relevant principal local authorities will have the final say in relation to these two key decisions, they should involve other members of the Community Partnership in discussions on whether they intend to seek to withdraw the community from the process and the appropriate time to launch a Test of Public Support. All relevant principal local authorities on the Community Partnership must agree before the Right of Withdrawal can be invoked or the Test of Public Support can take place. For example, in an area with two tiers of local government and where both relevant principal local authorities are on the Community Partnership then they must both agree to invoke the Right of Withdrawal and to carry out the Test of Public Support. It would not be appropriate for principal local authorities to take these decisions without being members of the Community Partnership and fully engaged in the process. They must be a member of the Community Partnership in order to have a say.

(16) The community can withdraw from the siting process at any point up until a Test of Public Support is taken. The relevant principal local authorities can either take the decision to withdraw the community from the process themselves or do so after seeking the community's views. If the relevant principal local authorities agree that the decision to withdraw the community from the process should involve the community directly, then the method for seeking the community's view on possible withdrawal from the

process will be considered by the Community Partnership as a whole.

(17) NWS can also choose to withdraw from the process. For example, NWS could withdraw for technical reasons, or other reasons which demonstrated there were no longer prospects of finding a suitable site within either the Search Area or Potential Host Community. NWS could also withdraw in order to prioritise available funds across other communities in the siting process. NWS will be transparent in its considerations to withdraw from a community.

(18) Detailed site investigations may take up to 15 years depending on the investigations necessary to understand the geology in an area and be confident that a facility can be designed to safely and securely isolate and contain the radioactive waste. When NWS has sufficient information to satisfy itself that a GDF is viable and the community has indicated it is willing to host it, NWS will need to obtain development consent to build the GDF.

(19) Eventually, if the Right of Withdrawal has not been exercised, or NWS has not withdrawn, the Search Area will be narrowed down until the Community Partnership identifies a specific site and the community which will be directly affected by the facility being on that site.

(20) The relevant principal local authorities must seek a final view from the community, through a Test of Public Support, on whether it is willing to host a GDF before NWS seeks the necessary regulatory approvals and development consent for the construction and operation of a GDF. The Test of Public Support can only take place if all relevant principal local authorities on the Community Partnership agree to it being held. The method for taking the Test of Public Support will be decided by the Community Partnership as a whole. The Community Partnership's view on what mechanisms could be used for this should be set out in the Community Partnership Agreement, which can be updated as views on this develop over time.

(21) The Potential Host Community will be defined using district, or unitary council electoral ward boundaries, depending on the administrative arrangements in place in the area. The Potential Host Community would include all of the wards in which the following would be located:

a. proposed surface and underground elements of a GDF;
b. any associated development (as defined under the Planning Act 2008 in England) and any land required to mitigate impacts;
c. transport links/routes from the GDF site to the nearest port, railhead or primary road network (i.e. out to where minor roads meet the nearest A roads);
d. direct physical impacts associated with underground investigations, construction and operation of the GDF (identified though environmental impact assessment work carried out to support NWS's engagement with communities and its development consent applications). Only residents in the area that will be directly impacted by the development should have a final say in whether they wish to host a GDF.

(22) It will be the people living in the Potential Host Community, through a Test of Public Support, that will decide whether they want to continue with the process for siting a GDF in the area. As with the Right of Withdrawal, there are currently three main mechanisms that could be used for the Test of Public Support: a local referendum, a formal consultation or statistically representative polling. The Test of Public Support would only be taken after extensive community engagement when the community has had time to ask questions, raise any concerns and learn about a GDF. There will be only one opportunity for a Test of Public Support in each Potential Host Community.

(23) The community's Right of Withdrawal will cease following the Test of Public Support. Once it has been established that the community is willing to host a facility, and NWS, has identified a preferred site, NWS, subject to the Secretary of State's agreement, will proceed with applications for the relevant planning and regulatory consents required for the underground investigations, construction and operation of a GDF.

Progress in siting in the UK

It is fair to say that progress by Nuclear Waste Services (the subsidiary of the Nuclear Decommissioning Authority which is responsible for

finding a site for and developing the GDF) has been mixed. Much of the early focus was in the North-West of England, a region with a long nuclear heritage, and consequently a relatively high degree of public acceptance of nuclear and nuclear waste related development. However, finding both a suitable geology, and winning the mind of a host community on that geology, is a challenge.

The most recent account is in NWS's *GDF Report 2024 – Protecting People and Our Environment*, detailing progress of the GDF siting process up to 31 March 2024.[56] In 2023, NWS withdrew from the community engagement process in Allerdale, Cumbria, because its analysis showed there was not likely to be enough suitable rock for a GDF. NWS has stressed the need to be transparent in its reasons for withdrawal from a community and to honour any Community Investment Funding commitments already made and in fact Allerdale benefited from funding of over £2.2 million on some 60 local projects. Discussions are proceeding with the Mid Copeland and South Copeland Community Partnerships in Cumbria, and one based around Theddlethorpe in Lincolnshire. All are considering sub-seabed inshore sites, and each have their own issues to be resolved, for example the relative complexity of the West coast geology and the other competing infrastructure projects, such as offshore wind, on the East coast. Studies are proceeding on the deep geology and on the environmental sensitivity, such as local landscape and biodiversity.

What is also mentioned in the GDF Report, albeit very briefly, is the withdrawal in February 2024 of East Riding of Yorkshire Council from the South Holderness Working Group, leading to the Working group being wound down.[57] This came just one month after the formation of the Working Group following a meeting at which local councillors voted 53-1 in favour of a motion calling on the council to withdraw.[58] A significant factor was the strong opposition by the local Conservative MP,

[56] GOV UK, *GDF Report 2024 – Protecting People and Our Environment*, https://www.gov.uk/government/publications/gdf-report-2024 [access: 29 May 2026].

[57] GOV UK, *Nuclear Waste Services Responds to Council's Withdrawal From South Holderness Working Group*, https://www.gov.uk/government/news/nuclear-waste-services-responds-to-councils-withdrawal-from-south-holderness-working-group [access: 29 May 2026].

[58] World Nuclear News, *Holderness Withdraws From UK Repository Siting Process*, Feb 22, 2024, https://world-nuclear-news.org/Articles/Holderness-withdraws-from-UK-repository-siting-pro [access: 29 May 2026].

Graham Stuart, who also then happened to be the Minister for Energy Security.[59]

Further, in the case of Theddlethorpe, proposals have come from the leaders of Lincolnshire County Council and East Lindsey District Council for an early test of public support to avoid prolonged uncertainty affecting the area.[60] There appears to be a quite concerted anti-GDF cohort of the population in the area, the demographics of which lean towards retired people and seasonal holidaymakers. "The Guardian" has reported fears the Theddlethorpe may end up on a 'shortlist of one' and apparently a gaffe in which the local seaside resort of Skegness was wrongly spelled as 'Skegross' on a map did little to engender local support.[61]

The Waste Inventory

Knowledge of the national waste inventory, and which parts of it are destined for geological disposal, are essential for the planning and design of an underground disposal facility. Decisions need to be made as to whether portions of the inventory, such as certain types of intermediate level waste, which may present a lower degree of hazard, should go into a deep repository or whether disposal at shallower depth may be also offer a safe and more cost effective solution.

A potentially difficult question is how to deal with future waste arisings from new nuclear generation facilities, particularly given the ambitions in the UK, France (and other countries) for a nuclear renaissance supporting an expansion of nuclear energy. For proposed GDFs this raises the issue of scale and whether a local community is willing to take the leap of faith of supporting a GDF of an 'as yet' unknown capacity. There is quite a difference in perception in being willing to host a facility to deal

[59] S. Harratt, *Energy Minister Graham Stuart Opposes Holderness Nuclear Waste Site*, BBC News, Feb 7, 2024, https://www.bbc.co.uk/news/uk-england-humber-68233882 [access: 29 May 2026].

[60] Lincolnshire County Council, *Leaders Call for Quicker End to Uncertainty on Theddlethorpe GDF*, https://www.lincolnshire.gov.uk/news/article/1568/leaders-call-for-quicker-end-to-uncertainty-on-theddlethorpe-gdf [access: 29 May 2026].

[61] A. Lawson, *'It'll Be a Shortlist of One!' Villagers in England Fear Nuclear Dump Proposal*, "The Guardian" Mar 3, 2024, https://www.theguardian.com/business/2024/mar/03/itll-be-a-shortlist-of-one-villagers-in-england-fear-nuclear-dump-proposal [access: 29 May 2026].

with an existing national problem of a known scale, and on the other hand an indeterminant, potentially open-ended range and quantity of wastes.

The UK Policy[62] (para. 8.63) lists the radioactive wastes and nuclear materials not yet declared to be wastes which would comprise the inventory for disposal in a GDF:

- HLW arising from reprocessed spent nuclear fuel at Sellafield;
- ILW arising from existing nuclear licensed sites, defence, medical, industrial, research and educational facilities that is not suitable for disposal in near surface facilities;
- the small proportion of LLW that is not suitable for disposal in near surface facilities;
- spent fuel from existing commercial reactors (yet to be declared waste) and from research reactors that is not reprocessed;
- spent fuel (yet to be declared waste) from new nuclear projects (including small modular reactors);
- spent fuel (yet to be declared waste) from advanced modular reactors if it is suitable for disposal in a GDF;
- ILW from new nuclear projects not suitable for disposal in near surface facilities; the plutonium inventory (yet to be declared waste) – either as spent fuel following reuse or in an immobilised form suitable for geological disposal;
- uranium stocks – including that arising from enrichment and fuel fabrication activities and reprocessing activities (yet to be declared waste); and
- irradiated fuel and nuclear materials (yet to be declared waste) from the UK defence programme.

The Policy (para. 8.64) does not anticipate that these categories will change significantly. The assumption is that there will be up to 24 GWe of new nuclear capacity generating spent fuel, through large-scale nuclear power stations, SMRs and AMRs.[63] It is recognised that communities considering hosting a GDF will want to have as clear as possible an understanding of the inventory for disposal before they take a Test of Public Support. If the list were to change significantly then it would need to be discussed with the potential host community and a process for agreeing any future material changes to the categories of waste to be

[62] *UK Policy Framework for Managing…*

[63] Ibid., para. 55.

disposed of would need to be agreed before the community took a decision on whether or not it wishes to host a GDF.

New nuclear technologies, especially advanced reactors with different forms of fuel and cooling from the existing generation of reactors, seem likely to pose uncertainties and potentially serious difficulties as to the nature of the containment, and quite possibly pre-treatment, which will be required. CoRWM addressed this issue in depth in its Position Paper, *Development of Small Modular Reactors and Advanced Modular Reactors – Implications for the Management of Higher Activity Wastes and Spent Fuel* in February 2024.[64]

Whilst the UK Government's preference is for a single GDF to take the entire inventory, it acknowledges that in a given host community there might not be sufficient suitable rock or a safety case might not be able to be made for some parts of the inventory.[65] It is not envisaged that a potential host community would be able to pick and choose the inventory it will host.

Retrievability

Disposal of waste implies finality, that there is no intention to retrieve the waste: however that is not to say that retrieval will be impossible. IAEA Safety Guidance notes that while in some states post-closure retrievability is a national requirement, it is important that provision for retrievability should not compromise safety standards, or have an unacceptable effect on the safety or performance of the disposal system and is considered as an 'exceptional condition' if occurring in the post-closure period.[66]

Section 22 of the US Nuclear Waste Policy Act requires that any repository be designed so that spent nuclear fuel may be retrieved during an 'appropriate period', which appears to equate to the 100 to 300 years prior to repository closure. By comparison, French law requires that

[64] Committee on Radioactive Waste Management, *Development of Small Modular Reactors and Advanced Modular Reactors – Implications for the Management of Higher Activity Wastes and Spent Fuel*, February 2024, https://assets.publishing.service.gov.uk/media/65c26c9ca6838e000d49d589/corwm-smr-and-amr-position-paper.pdf [access: 29 May 2026].

[65] *UK Policy Framework for Managing…*, para 8.65.

[66] IAEA Safety Standards, *Geological Disposal Facilities…*, para. 1.1.

waste must be retrievable for the first few hundreds of years, in case a use can be found for it.

There is no hard and fast rule in the UK, but the Waste Policy proceeds on the basis that the objective is disposal of waste, not storage. There may be a 'compelling case' for retrieval of emplaced waste during the operational phase of the facility, but will become difficult after permanent closure: and 'Permanently closing a GDF at the earliest possible opportunity once operations have ceased provides for greater safety, greater security, and minimises the burden on future generations.'[67]

The ability to retrieve waste for the relatively short period that the GDF is operational appears to make sense, from both a safety and resource perspective; the latter such that human knowledge may develop over a period of few hundred years. However, beyond that it can be argued that the ambition of retrievability is a misplaced human desire to control, whereas '… the involvement of deep geological formations can be characterized as a posthuman task in the sense of decentering humans as permanent 'instances of care and management' in the long run (especially with regard to such disposal systems that should be irreversibly sealed in the future).'[68]

Transportation

One of the most important factors in siting a GDF is the issue of transportation, both in connection with the construction process and also in transporting the spent fuel and radioactive waste for deposit in the facility once built. In respect of the former, the main impact is likely to be the removal for disposal elsewhere of large quantities of spoil and excavated rock. With regard to the latter, transportation of higher-level radioactive waste is subject to strict regulation, and has occurred over many decades on a regular basis by ships, road and rail, and on occasion by air.

Nonetheless, operation of a GDF, at least in the UK, would result in hundreds of repeated movements, on a frequent basis, over many

[67] UK Policy Framework for Managing…, paras 8.75–8.77.

[68] Ch. Schürkmann, *Joining Multiple Collaborations: Toward a Sociomaterial Perspective on Nuclear Waste Management Between Society, Technology and Nature*, "Worldwide Waste: Journal of Interdisciplinary Studies" 2022, Vol. 5(1), No 3, pp. 1–16, https://www.whp-journals.co.uk/WW/article/view/1059/622 [access: 29 May 2026].

decades. Those on the proposed transportation route may therefore be expected to have a legitimate concern as to the actual or potential consequences of such transportation. A number of local authorities are members of the organisation, 'Nuclear Free Local Authorities'[69] and may be expected to oppose road or rail movements of higher activity radioactive wastes through their areas: they may well be joined by others as proposed GDF transportation corridors become clearer. The question therefore arises of how such authorities or affected communities fit within the Working with Communities process. The Policy, as noted above, contemplates that the host community will include those hosting transportation links or routes from the GDF site to the nearest port, railhead or primary road network. At the time when the site at Yucca Mountain was being considered, a proposed rail corridor starting in Caliente, Nevada, was proposed and was the subject of environmental impact assessment.[70] The route avoided the most densely populated areas in the Las Vegas valley but was the most challenging route in terms of an engineering and environmental standpoint.

Conclusions

There is a very broad and rich range of literature relating to radioactive waste, social science and anthropology.[71] It is clear that there must be 'a triadic alliance of collaboration' in which society, technology and nature (the geology) are assembled, nature being an 'unruly collaborator'.[72]

The promoter of a GDF has control over its concept and design, its engineering programming, and the process for obtaining the necessary permits. What the promoter cannot control is the geology and its uncertainties. Many decades of investigation and research, both by boreholes and in underground research facilities, will be necessary to validate that the proposed host geology is sufficiently robust to make an acceptable

[69] Nuclear Free Local Authorities, *Member councils*, https://www.nuclearpolicy.info/about/member-councils [access: 29 May 2026].

[70] U.S. Department of Energy, *EIS-0369: Supplemental Yucca Mountain Rail Corridor and Rail Alignment*, https://www.energy.gov/nepa/eis-0369-supplemental-yucca-mountain-rail-corridor-and-rail-alignment [access: 29 May 2026].

[71] *See* the useful survey in Ch. Schürkmann, *Joining Multiple Collaborations…*

[72] Ibid.

environmental safety case. During that period there will inevitably be uncertainty, though hopefully this will diminish the longer investigation and analysis go on.

Also, what cannot be controlled, at least in a democratic, community-consent based process, is public sentiment, either in favour of, or against, the proposed GDF. This can be suddenly affected by political factors, either at local or national level, as seen in the USA and in the UK. It must be borne in mind that public support may have to be sustained over a number of years while confirmatory investigations take place.

Whilst financial inducements, such as support for local projects or investment in infrastructure or costal defences may assist, it may be queried whether these alone will sustain public support without a clear vision—as seems to have been the case in Finland—of the purpose and nature of the project.

It may well be that GDF promoters are naturally inclined to invest more energy and resources in the 'hard' aspects, such as engineering and project management which they can control: but it would be very risky not to invest equally deeply in communicating with potential host communities, including understanding fully the underlying social science and learning from experience, both good and bad, in other countries and on different types of infrastructure projects.

What is clear is that very significant funding, time and expertise will need to be invested in the process of finding solutions for permanent disposal solutions for spent fuel and higher activity wastes if a global expansion of nuclear energy is to occur. In those countries where the process has been or is being successful, it can be observed what level of scientific, financial and social collaboration will be needed. In other countries such as the US and UK, history teaches what a fraught and uncertain process it can be. However, the risks for present and future generations of creating high level waste which will sit in surface or near surface stores indefinitely should not be regarded as tolerable.

PART V

DECOMMISSIONING AND RADIOLOGICAL PROTECTION

Chapter 11

ENVIRONMENTAL IMPACT ASSESSMENTS FOR DECOMMISSIONING AND DISMANTLING: ANALYSIS OF EXISTING FRAMEWORKS AND RECOMMENDATIONS FOR IMPROVING EFFECTIVENESS

Guan Schaiko
Partner Stibbe law firm
guan.schaiko@stibbe.com

Ellen Vandensande
Former Nuclear policy advisor to the Belgian Minister of the Interior
ellen.vandensande@gmail.com

Extensive summary

In this paper we have examined the main legal instruments governing the final phase of a nuclear power plant, leading to decommissioning and dismantling. We have highlighted the ambiguity between nuclear safety terminology and the environmental legal framework, particularly in relation to the definitions of decommissioning and dismantling.

The paper argues that EIA legislation should apply after a plant has been shut down, when decommissioning begins. Dismantling, a critical component of this phase, requires specific authorizations beyond the operating license. The use of these terms in treaties such as the Espoo Convention, the Aarhus Convention and the EIA Directive creates confusion as to what constitutes a project requiring an EIA, particularly in

terms of transboundary consultation and public participation. A specific case law example is explained in detail.

We emphasize that projects must have significant environmental effects in order to trigger an EIA obligation, thus reinforcing the protective aim of legal texts concerning public safety and the environment. To improve legal clarity for future decommissioning projects, we recommend a consistent approach by international and European stakeholders.

In addition, we stress the importance of complying with both the EIA and Habitats Directives, which address the broad environmental and health challenges of nuclear decommissioning. This dual compliance ensures thorough risk assessment and biodiversity protection, and promotes a balanced approach to safety, environmental responsibility and legal accountability in the decommissioning process.

1 INTRODUCTION

The decommissioning and dismantling of nuclear facilities presents complex challenges that require rigorous environmental assessment. This paper focuses on the environmental challenges for the existing nuclear fleet that has been or will be decommissioned. Many countries in the EU and around the world are at the beginning of the process of decommissioning their nuclear power plants. An important tool in this process is the Environmental Impact Assessment (hereinafter: 'EIA'), which defines the environmental limits within which decommissioning will take place, as well as the procedural guidelines.

In this paper, we explore the intersection of international and European legal frameworks governing EIA for the decommissioning and dismantling of nuclear facilities. We begin by outlining the relevant international treaties, such as the Espoo and Aarhus Conventions, and the role of International Atomic Energy Agency (hereinafter: 'IAEA') standards in shaping EIA requirements. The discussion then shifts to a detailed analysis of EU legislation in this area, with a particular focus on the EIA Directive, the environmental obligations under the Euratom Safety Directives for decommissioning purposes and the Habitat Directive.

Particular attention is paid to recent case studies illustrating the practical challenges and legal disputes arising from the decommissioning

process, such as the decommissioning of nuclear installations in Belgium. These examples highlight the dynamic interplay between compliance with EIA protocols and the broader objectives of environmental protection and public health and safety concerns.

Our contribution not only deepens the understanding of existing legal frameworks, but also proposes recommendations for harmonising international and European standards to improve the effectiveness and efficiency of EIA in the nuclear sector in the context of decommissioning.

2 DECOMMISSIONING AND DISMANTLING AND ENVIRONMENTAL IMPACT ASSESSMENT

In order to provide a clear overview of the interaction between 'decommissioning and dismantling' and 'impact assessment', it is necessary to discuss the main legal instruments that define these terms.

2.1 Decommissioning and Dismantling

(a) ***IAEA***

First, we examine the IAEA's approach.

According to the IAEA's General Safety Requirements decommissioning is regarded as the final stage in the lifecycle of a nuclear power plant:

> 1.1. The terms 'siting', 'design', 'construction', 'commissioning', 'operation' and 'decommissioning' are normally used to delineate the six major stages in the lifetime of an authorized facility and of the associated licensing process. The term 'decommissioning' refers to the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility (except for the part of a disposal facility in which the radioactive waste is emplaced, for which the term 'closure' instead of 'decommissioning' is used). Aspects of decommissioning have to be considered throughout the other five major stages.
> 1.2. Aspects of decommissioning typically include planning for decommissioning, conducting decommissioning actions and terminating the authorization for decommissioning. There may be a period of transition between permanent shutdown (the term 'permanent shutdown', as used in this publication, means that the facility has ceased operation and

operation will not be recommenced) and the granting of authorization to begin decommissioning actions. (Own emphasis.)[1]

Nuclear decommissioning within the nuclear energy sector thus is

> an umbrella term given to all activities that enable nuclear facilities to be permanently shut down, decontaminated, dismantled and released from regulatory control. Decommissioning is not complete until radioactive and other hazardous materials have been removed from the site, and the buildings and land which were formerly used as nuclear facilities have been prepared for new uses. The final step (of the decommissioning process) involves extensive surveys to confirm the absence of any significant radioactivity on the site, enabling its release from regulatory control.[2]

The following infographic (Figure 1) illustrates the difference to be understood when the IAEA refers to the terminology of decommissioning and dismantling.

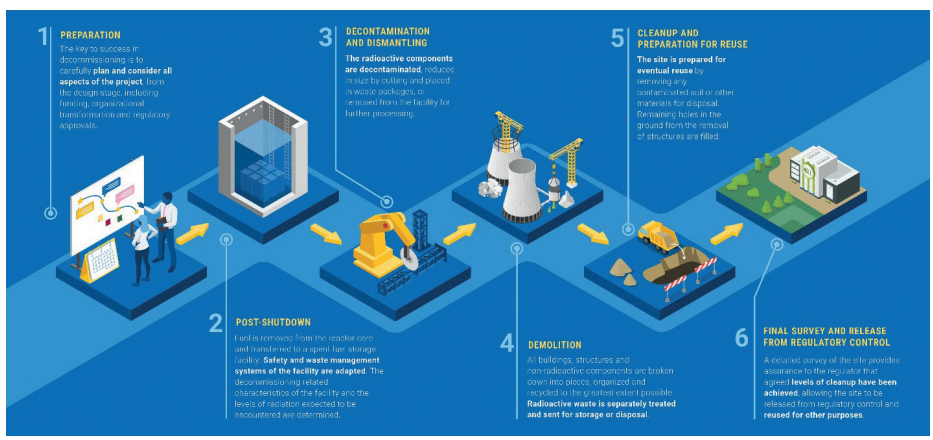

Figure 1. Nuclear decommissioning process

Source: J. Liou, *Decommissioning a nuclear power plant*, "IAEA Bulletin" April 2023, Vol. 64-1: *Nuclear decommissioning*, pp. 8–9, https://www.iaea.org/sites/default/files/2025-09/nucleardecomissioning_0.pdf [access: 5 November 2024].

[1] IAEA, *Decommissioning of Facilities*, IAEA Safety Standards Series No. GSR Part 6, Vienna: IAEA 2014, 1.1–1.2.

[2] P. O'Sullivan, *Nuclear Decommissioning. Addressing the past and ensuring the future*, "IAEA Bulletin" April 2023, Vol. 64-1: *Nuclear decommissioning*, pp. 4–7, https://www.iaea.org/sites/default/files/2025-09/nucleardecomissioning_0.pdf [access: 5 November 2024].

Decommissioning is therefore a broader concept than dismantling.

Decommissioning is the terminology used to describe the final stage in the life cycle of a nuclear power plant. Once a nuclear power plant has been permanently shut down, it moves from being a facility with operational processes for electricity production to activities associated with the preparation and implementation of decommissioning, including changes to the organisation and safety systems of the plant.

Dismantling is only a part of that phase and aims to remove and/or decontaminate equipment and structures, systems and components of a plant containing radioactive material to a level that allows the plant to be released from regulatory control for unrestricted use or with restrictions on its future use. More specifically, this is the approach in the case of immediate dismantling. In the case of deferred dismantling, after the nuclear fuel has been removed from the facility (for nuclear installations), all or part of a facility containing radioactive material is either processed or brought to a condition in which it can be safely stored and the facility maintained until it is subsequently decontaminated and/or dismantled.[3]

(b) ***EURATOM***

There are several references to decommissioning and dismantling in the EURATOM Treaty.

A specific definition is to be found in the Commission Recommendation 2010/635/Euratom of 11 October 2010 on the application of Article 37 of the Euratom Treaty.[4] In footnote 8 the Commission provides the following clarification, in line with the IAEA approach:

> Decommissioning comprises all technical and administrative procedures, activities and measures taken after the final shut-down of a facility and up to the release of the site for unrestricted or other licensed use. Within these activities 'dismantling' comprises disassembling, cutting and demolition of contaminated or activated components, systems and structures including their packaging and transfer off-site.[5]

Further references can be found in the Council Regulation (Euratom 2021/100 of 25 January 2021 establishing a dedicated financial programme

[3] IAEA, *Decommissioning of Facilities…*, 1.8–1.9.

[4] Commission Recommendation 2010/635/Euratom of 11 October 2010 on the application of Article 37 of the Euratom Treaty, *OJ* L 279, 23.10.2010, pp. 36–67.

[5] Ibid.

for the decommissioning of nuclear facilities and the management of radioactive waste, and repealing Regulation (Euratom) No 1368/2013[6] where 'decommissioning means administrative and technical measures in accordance with national law which allow the removal of some or all of the regulatory controls from a nuclear facility and which aim to ensure the long-term protection of the public and the environment, including the reduction of the levels of residual radionuclides in the materials and on the site of the nuclear facility' (Article 2 (1)).

The Commission and the IAEA thus share the same interpretation of the use of the terms decommissioning and dismantling. Let us now look at how these terms are used in the EIA framework.

2.2 Environmental impact assessment (EIA)

The subject matter of an EIA in the EU is regulated by several international and European legal instruments. The main question always is whether and to what extent a particular project or decision, in the context of a decommissioning process, must be preceded by an environmental impact assessment.

(a) *ESPOO Convention*

The Convention on Environmental Impact Assessment in a Transboundary Context, adopted in Espoo (Finland) on 25 February 1991 (hereinafter: 'ESPOO Convention'), defines the obligations of the Parties to carry out an environmental impact assessment in a Transboundary Context for the listed activities, and this prior to the decision making.[7] The Espoo Convention addresses 'the need to give explicit consideration to environmental factors at an early stage in the decision making process by applying environmental impact assessment, at all appropriate administrative levels, as a necessary tool to improve the quality of information presented to decision makers so that environmentally sound decisions

[6] Euratom 2021/100 of 25 January 2021 establishing a dedicated financial programme for the decommissioning of nuclear facilities and the management of radioactive waste, and repealing Regulation (Euratom) No 1368/2013, *OJ* L 34, 1.2.2021, pp. 3–17.

[7] In addition, the Protocol on Strategic Environmental Assessment, which entered into force on 11 July 2010, requires that a strategic environmental assessment be carried out for certain plans and/or programmes that are likely to have significant environmental effects. As the focus of this paper is on decommissioning projects, this instrument will not be further discussed.

can be made paying careful attention to minimizing significant adverse impact, particularly in a transboundary context'.[8] The convention incorporates Principle 10 of the Rio Declaration of 12 August 1992 and aims to ensure that its parties assess the environmental impact of certain activities at an early stage of planning, and notify and consult each other on the activities listed in the convention that are likely to have a significant adverse transboundary (cross-border) impact. The main principles of the Espoo Convention are the following:

- in accordance with the precautionary and prevention principles, it requires that the adverse environmental impacts be anticipated and addressed early in the planning of activities in order to prevent/mitigate and monitor their significant adverse transboundary environmental impact;
- it requires the state in which the activity is planned (party of origin) to examine its environmental impacts on other states (affected parties);
- the party of origin must notify the affected party of the activity likely to have a significant adverse transboundary environmental impact;
- the affected party must acknowledge the notification and indicate whether it wishes to participate in the assessment procedure;
- the party of origin must prepare an environmental impact assessment documentation and submit it for comments to the authorities and the public of the affected party/parties;
- the parties concerned should consult each other, for example, on alternative and mitigation measures;
- the party of origin must take a decision on the planned activities while taking into account the environmental impact documentation, the comments received and the outcome of the consultations;
- the final decision should be provided to the affected party with the reasons and considerations on which it was based.

There are currently 45 Parties to the Espoo Convention.[9] The EU is also a Party, which means that EU and EURATOM law must be consistent with the provisions of the Espoo Convention.

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[8] The Convention on Environmental Impact Assessment in a Transboundary Context, adopted in Espoo (Finland) on 25 February 1991.

[9] The current list of contracting parties can be found here: United Countries Treaty Collection, Convention on Environmental Impact Assessment in a Transboundary

The convention obligations apply to proposed activities in its Appendix I. Article 1(5) defines a 'proposed activity' as follows: 'Proposed activity: means any activity or any major change to an activity subject to a decision of a competent authority in accordance with an applicable national procedure'. The specific activities listed in Appendix I provide further clarification of the concept of proposed activities and include oil refineries, airports, thermal and hydropower plants and wind farms, roads, railways, large diameter pipelines for the transport of oil, gas or chemicals.[10] Appendix I, 2(b) includes 'nuclear power stations and other nuclear reactors, including the dismantling or decommissioning of such power stations or reactors 1/ (except research installations for the production and conversion of fissionable and fertile materials, whose maximum power does not exceed 1 kilowatt continuous thermal load)'. Footnote 1 clarifies this: 'For the purposes of this Convention, nuclear power stations and other nuclear reactors cease to be such an installation when all nuclear fuel and other radioactively contaminated elements have been removed permanently from the installation site'.

Although the Espoo Convention lacks a specific definition for decommissioning or dismantling, these activities clearly fall within its scope. This raises the question of when these obligations should take effect and, consequently, which specific actions in the decommissioning or dismantling process require a preceding EIA and transboundary consultation. Should these obligations begin at the point of shutdown, marking the transition to decommissioning? Or did the Contracting Parties intend, consistent with nuclear safety practices, for the environmental impact assessment to occur at the actual dismantling stage—where a specific license is required—and thus regard decommissioning as synonymous?

The answer to this question is not only of theoretical importance, but could also have far-reaching practical consequences. If the entire process of decommissioning, including the transition period, is to be subject to EIA and transboundary consultation, the subject matter of EIA and transboundary consultation will be of a very different nature than if EIA and transboundary consultation is limited to the environmental impacts of

Context, https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-4&chapter=27&clang=_en [access: 5 November 2024].

[10] Opinion advocate-general 29 November 2018, C-411/17, points 75–76; ECJ 17 March 2011, *Brussels Hoofdstedelijk Gewest and Others*, C-275/09.

the actual physical dismantling operations. The nature of the environmental issues and public input prior to final closure, as a first step in the decommissioning process, will by definition be of a more general nature than when the subject matter is physical dismantling.

The legal confusing is due to the fact that both decommissioning and dismantling are considered to be a proposed activity under the Espoo Convention, in combination with a broad interpretation of Appendix I by the Advocate General of the European Court of Justice in the Doel 1 and 2 case, according to which, in the case of nuclear power stations, the operation of a nuclear power station in itself is a proposed activity without the need for specific action.[11]

Indeed, as we will see, in the EU, Member States can look to the EIA Directive for guidance on interpreting the Espoo Convention and at what stage in a decommissioning process an EIA is required. For a project to fall within the scope of the EIA Directive, it must consist of physical works or other interventions in the natural environment. Although there is no reference to such physical works or interventions in the natural environment in the Espoo Convention, the definition of 'proposed activity' ('any activity or any substantial change to an activity that is subject to a decision by a competent authority in accordance with an applicable national procedure') suggests a similar result, since in most jurisdictions it is the physical works and interventions in the natural environment that are subject to a decision by a competent authority. For example,

[11] Opinion advocate-general 29 November 2018, C-411/17, points 77–78:
77. There are thus some types of activity which are characterised by specific actions, such as deforestation of large areas (Appendix I, point 17 to the Espoo Convention) or construction of motorways, express roads and lines for long-distance railway traffic and of certain airports (point 7). Nevertheless, the vast majority of the types of activity covers certain kinds of installations or facilities in themselves, such as crude oil refineries (point 1), major installations for the initial smelting of cast-iron and steel and for the production of non-ferrous metals (point 4) or integrated chemical installations (point 6).
78. Nuclear power stations (Appendix I, point 2 to the Espoo Convention) come under this second category. The Espoo Convention Implementation Committee rightly inferred from this that not only the construction and first operation of a nuclear reactor is an activity, but also the continued operation beyond the originally authorised lifetime of a nuclear reactor, as a significant adverse transboundary impact is likely to be caused by such operation. […] Accordingly, the renewal of consent for a nuclear power station also constitutes an activity.

a decision to shut down a nuclear installation with a view to decommissioning is taken by the operator of the nuclear installation, not by the authorities. With this in mind, the preferred interpretation is that it is only when there are physical works aimed at dismantling a nuclear power plant that there is a proposed activity under the Espoo Convention. However, additional guidance should be provided by the Espoo Convention bodies.

(b) ***Aarhus Convention***

The Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, adopted in Aarhus on 25 June 1998 (hereinafter: 'Aarhus Convention'), is also relevant to public participation in this case. The Aarhus Convention refers to the public's right to participate in environmental decision-making. Public authorities are obliged to allow the public and environmental NGOs to participate meaningfully in decision-making on projects affecting the environment and on plans and programmes relating to the environment (Article 6). There are now 47 Parties to the Convention.[12] The EU is also a Party and, similar to the Espoo Convention, this is reflected further in the paper with regard to interpretation under the EIA Directive.

Article 6(1) of the Aarhus Convention refers to Annex I for the list of the proposed activities to which the provisions of the convention apply: 'Nuclear power stations and other nuclear reactors including the dismantling or decommissioning of such power stations or reactors 1/ (except research installations for the production and conversion of fissionable and fertile materials whose maximum power does not exceed 1 kW continuous thermal load)'; with a footnote 1/ 'Nuclear power stations and other nuclear reactors cease to be such an installation when all nuclear fuel and other radioactively contaminated elements have been removed permanently from the installation site'.[13] The Aarhus Convention doesn't include a definition of decommissioning/dismantling.

[12] Current list of Parties to the Aarhus Convention can be found here: United Countries Treaty Collection, Convention, 13. Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-13&chapter=27&clang=_en [access: 5 November 2024].

[13] The Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, adopted in Aarhus on 25 June 1998.

The Annex to the Aarhus Convention is similar to that of the Espoo Convention. However, there is a difference in that the Aarhus Convention doesn't require a proposed activity to have a significant adverse environmental impact in order for it to apply and to trigger the need for effective public participation (Article 6). The annex of the Aarhus Convention is in line with that of the Espoo Convention.[14]

As is the case with the Espoo Convention, it is unclear what the rationale of the Contracting Parties as for using both the terms decommissioning and dismantling. Article 1 of the Aarhus Convention states the objective of the Convention as follows: 'In order to contribute to the protection of the right of every person of present and future generations to live in an environment adequate to his or her health and well-being, each Party shall guarantee the rights of access to information, public participation in decision-making, and access to justice in environmental matters in accordance with the provisions of this Convention'. The analogy we made for the Espoo Convention should, in our view, apply here as well: the objective of the decommissioning phase is the protection of the public and the environment. The moment when a decision is made in this process that can be relevant to the protection of the public and the environment is when the dismantling is to be licensed, and this is at the moment before a decision is made on the proposed activity.

(c) ***EIA Directive***

(i) *General legal framework*

For the EU, the main legal instrument governing Member States' obligations regarding environmental impact assessment, is the EIA Directive.[15]

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[14] Opinion advocate-general 29 November 2018, C-411/17, points 91–92:
91. Article 6(1)(a) of the Aarhus Convention provides that Article 6 is to be applied to decisions on whether to permit proposed activities listed in Annex I. The term 'activity' corresponds to the term 'project' used in the EIA Directive.
92. The fifth indent of point 1 of Annex I to the Aarhus Convention mentions 'nuclear power stations' and no threshold is defined with respect to commercial use. Unlike in the Espoo Convention, there is no requirement for an assessment whether such a project causes a significant adverse environmental impact in a specific case.

[15] Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment 2011/92/EU, *OJ* L 26, 28.1.2012, as amended by Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/

The EIA Directive applies to the environmental impact assessment of public and private projects likely to have significant effects on the environment (Article 1(1)). A 'project' is defined as:

- the execution of construction works or of other installations or schemes;
- other interventions in the natural surroundings and landscape including those involving the extraction of mineral resources (Article 1(2)).

Article 2(1) of the EIA Directive requires Member States are to take the necessary measures to ensure that, before consent is given, projects likely to have significant effects on the environment, having regard, *inter alia*, to their nature, size or location, are made subject to a requirement for development consent and that their effects on the environment are assessed. Such projects are defined in Article 4 of the EIA Directive.

Pursuant to Article 4(1), and subject to Article 2(4), the projects listed in Annex I shall be subject to an assessment in accordance with Articles 5 to 10.

Annex I, Section 2(b) states the following: 'Nuclear power stations and other nuclear reactors including the dismantling or decommissioning of such power stations or reactors (1) (except research installations for the production and conversion of fissionable and fertile materials, whose maximum power does not exceed 1 kilowatt continuous thermal load)'. The footnote further clarifies that: 'Nuclear power stations and other nuclear reactors cease to be such an installation when all nuclear fuel and other radioactively contaminated elements have been removed permanently from the installation site'.

The terms 'dismantling' and 'decommissioning' are not defined in the EIA Directive itself. The original EIA Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment[16] didn't include dismantling or decommissioning in Annex I. The inclusion of dismantling and decommissioning was adopted by the Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public

EU on the assessment of the effects of certain public and private projects on the environment.

[16] *OJ* L 175, 5.07.1985, pp. 40–48.

and private projects on the environment[17] without a specific reference to the *ratio legis* behind the inclusion of the terminology.

According to the case-law of the Court of Justice, if a category of projects is open to different interpretations, must be interpreted in the light of the general scheme and objective of the legislation of which it forms part.[18] The main aim of the EIA Directive is to require projects with significant environmental effects to undergo an environmental impact assessment before development consent (a permit) is granted.[19] When interpreting the terms 'dismantling' and 'decommissioning', therefore, it is not possible to ignore the fact that the projects must have a significant environmental impact.

The lack of a definition in the EIA Directive was the main issue in a case brought before a Belgian court.[20] The case was initiated following the closure of the Doel 3 nuclear power plant on 24 September 2024. This was done on the basis of the Nuclear Phase-out Act of 31 January 2003.

The plaintiffs in this civil case argued that all acts following the shutdown were subject to an EIA on the basis of the EIA Directive.

The plaintiffs wanted the Belgian State to

> demand a project EIA of the operator of the nuclear power plant Doel 3 (taking into account public consultation following a public inquiry) by an expert recognised for that purpose before initiating, carrying out or continuing any act, measure or activity that falls within the concept of decommissioning or dismantling (within the meaning of section 2b of Annex I to the project EIA Directive 2011/92/EU) and then to act accordingly itself…[21]

Specifically for the Belgian situation, the shutdown of electricity production and related safety aspects, including the removal of nuclear fuel and industrial waste and the flushing and emptying of the pipes, can be carried out under the current operating licence for the Doel 3 unit.[22]

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17 *OJ* L 73, 14.3.1997, pp. 5–15.

18 ECJ 24 October 1996, *Kraaijeveld*, C-72/95; ECJ 16 September 2004, *Commission/Spain*, C-227/01.

19 ECJ 19 September 2000, *Linster*, C-287/98; ECJ 16 September 2004, *Commission/Spain…*

20 Rb Brussels 16 November 2022, unpublished.

21 Ibid.

22 Elements of authorization: *Stopzetting van de activiteiten en ontmanteling van de Belgische kerncentrales*, https://fanc.fgov.be/nl/dossiers/kerncentrales-belgie/stopzetting-van-de-activiteiten-en-ontmanteling-van-de-belgische [access: 5 November 2024].

The Belgian Nuclear Regulatory Authority describes this as follows (translation from Dutch):

> Between the shutdown of the installation and the approval of the dismantling license, there is a transitional period, the so-called 'phase after cessation of activities'. This phase is still covered by the operating license and ends at the start of the dismantling activities, which then fall under the dismantling license.
>
> In this second phase, Electrabel is still waiting for the dismantling license, but a number of preparatory works for the dismantling may already be carried out. These preparatory works and the associated safety aspects are described in advance in the cessation notification. These include the removal of nuclear fuel and operational waste and the flushing and emptying of pipes. Such works may be carried out under the operating license, because they are activities that are also carried out when a reactor is still operational. However, for all real dismantling activities, Electrabel must wait for the dismantling license. Some (administrative) buildings that are not related to nuclear activities can be dismantled without applying for a license from the FANC.[23]

This approach of the Belgian regulator is similar to those in other European countries. An overview of the approaches following the closure of an NPP has been carried out under ENSREG.[24] As regards the existence of a 'transitional period' after the operational phase and before the actual dismantling work begins, it concluded that:

> The most reported situation is that during the transition period the operating license remains in force. Operations performed during this period aiming to prepare decommissioning should not result in a significant modification to the facility or its authorized operating conditions, i.e., such modifications can only be minor or nonsignificant. France, Germany, Belgium, Italy, The Netherlands and Romania apply this principle strictly and report that any decommissioning activity that is not expressly covered by the operating license will require decommissioning license. Other countries applying this principle are Lithuania, Slovakia or Sweden.[25]

[23] Ibid.

[24] *Comparison of national policies for decommissioning*, October 2023, https://www.ensreg.eu/document/comparison-national-policies-decommissioning-october-2023 [access: 5 November 2024].

[25] Ibid.

These findings make the Belgian case relevant to other European countries as well, since the Belgian court has interpreted the applicable European principles.

In order for there to be an obligation to subject the decommissioning and associated works to the requirement of prior authorisation with an environmental impact assessment, there must therefore first be a 'project' within the meaning of the EIA Directive that has significant environmental effects. According to the established case law of the Court of Justice, the term 'project' refers to works or interventions that change the material condition of the site.[26] It is clear and undisputed that the actual dismantling of a nuclear power station qualifies as 'works or interventions that change the material condition of the site'.

The Belgian Court also took note of the IAEA's General Safety Standards (see above) that a transition period between the permanent cessation of operations and the approval of the final decommissioning plan is in line with the general approach to nuclear safety.[27]

The use of the terms dismantling and decommissioning was found by the Court to be in line with the European Regulation:

> The claimants do not sufficiently explain why the Belgian definitions of dismantling and decommissioning would not be in line with European law and in particular with the words dismantling or decommissioning referred to in the EIA Directive. In the light of the definition adopted by the European Commission in the aforementioned opinion of 11 October 2010, there appears to be no, prima facie, problem since dismantling or decommissioning is considered to be the procedures, measures and activities that follow the definitive closure of a facility, and no problem appears to arise in the context of the EURATOM definition either, which speaks of measures aimed at ensuring the long-term protection of the population and the environment. Both definitions leave open, prima facie, in accordance with the purpose and scope of the EIA Directive, the possibility of certain, in this case even apparently reversible, actions aimed at a transition, namely the period between the cessation of electricity production and the definitive closure (shutdown) of the plant or reactor.
>
> European legislation does not provide—at least at first sight—that after the cessation of electricity production a phase of dismantling or

[26] Judgment of 29 July 2019, *Inter-Environment Wallonie ASBL*, C-411/17.

[27] IAEA, *Decommissioning of Facilities…*, 7.8 and 8.10.

> decommissioning as referred to in Annex I to the EIA Directive immediately begins.[28]

For Belgium, based on this case law, the position is clear that the transition period after decommissioning, which is considered part of the final phase in the life of an NPP (cf. IAEA), is not in itself a project requiring an EIA. The Belgian approach to the EIA Directive is that decommissioning and dismantling, as used in Annex I, are synonyms referring to the actual dismantling phase as described by the IAEA and EURATOM.

However, as the work of ENSREG shows, there are different approaches possible to the post-closure period. In the EU itself there are different approaches too, depending on whether the post-operational transition period is covered by the operating licence, the decommissioning licence or even a separate licence.[29] This can lead to an uncertainty within the EU and broader for the Contracting Parties under the ESPOO and Aarhus Convention. On the basis of the *ratio legis* of the legal framework it should be clear that there is only a proposed activity or project when a possible impact on the environment is to be considered, not already covered by the operating license. This will most likely be the case when the works for the effective dismantling of the nuclear power plant.

(ii) *EIA and nuclear waste management*

The impact of nuclear waste is a critical component that must be considered in an EIA for nuclear decommissioning. Nuclear waste management is one of the most significant environmental and health risks associated with decommissioning due to the potential for long-lasting contamination.

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[28] Rb Brussels 16 November 2022, unpublished.

[29] *Comparison of national policies…*, p. 13:
The transitional period is key to determine the assumption of responsibilities among the license holder for operation of the NPP, and the one in charge of decommissioning the facility. The question whether the transitional period should be part of an operational or decommissioning license, or even constitute a separate license, can become very relevant, not only for posing important differences in terms of safety at licensing, but also for financial estimates and distribution of costs. On the other hand, in countries where the license holder during the operation of the NPP is also the legal entity entrusted to decommission the facility, the transitional period may be also a critical time during which the license holder faces the challenge of adapting to the changing nature of activities from operation to decommissioning.

According to the case-law of the Court of Justice, all identifiable impacts of a given project consisting of different components should be identified at the earliest possible stage. In this respect, the management of radioactive waste resulting from decommissioning activities is inevitably linked to the decommissioning itself. This means that, as early as the approval of a decommissioning project, the government should have an insight into the potential significant effects of the further management of the radioactive waste, insofar as they are already identifiable. We thereby think of the following effects:

- Waste generation and classification. An EIA must assess the types and volumes of nuclear waste generated during decommissioning. This includes categorizing waste by its radioactivity level (low, intermediate, or high-level waste) and identifying specific hazardous materials, like spent fuel, contaminated equipment, and radioactive soil.
- Transportation and storage risks. The EIA evaluates risks associated with transporting nuclear waste from the decommissioning site to storage or disposal facilities. This includes assessing the potential for accidents, spills, or contamination along transport routes and any impacts on air, water, and soil quality. For waste that will be stored on-site or nearby, the EIA must address the suitability of storage facilities, containment measures, and long-term security. Proper storage is especially vital for high-level waste, which requires shielding and cooling to prevent radiation release.
- Contamination control and pollution prevention. The EIA must include measures for preventing and controlling contamination, particularly for soil and groundwater, as radioactive waste can pose risks to local ecosystems and human health if not properly contained.
- Long-term monitoring and management. Given the long half-lives of radioactive materials, EIAs for decommissioning projects typically include plans for ongoing environmental monitoring. This involves setting up monitoring systems for air, soil, and groundwater around storage or disposal sites and having contingency plans in place to address potential leaks or contamination incidents.

The complexity and long-term considerations of nuclear waste management often require a separate decision-making process, independent

of the decommissioning process itself. As the final disposal methods and facilities may be subject to regulatory developments, technological advances and site-specific considerations, disposal planning is treated as a separate stage with a separate EIA. In our view, this is not incompatible with the EIA Directive and ECJ jurisprudence, as the long-term management of nuclear waste and its disposal do not fall within the definition of decommissioning and are therefore not part of the same project. This approach also ensures that each component—decommissioning and waste management—receives a tailored and thorough environmental impact assessment. It allows flexibility in decision making and ensures that the disposal facilities are designed to the latest standards of safety, environmental impact and public health protection when they're ready to be implemented.

2.3 Habitat Directive

(a) ***General legal framework***

The Habitats Directive[30] has significant implications for nuclear decommissioning, particularly where decommissioning activities may affect protected habitats or species designated under Natura 2000. Nuclear decommissioning can involve significant earthworks and changes to land and water resources. Decommissioning may result in the release of pollutants or soil contamination, which may threaten sensitive habitats. Certain species (e.g. bats, amphibians, birds) may inhabit nuclear installations or surrounding areas.

Article 6 of the Habitats Directive imposes on Member States a number of specific obligations and procedures designed to maintain, or where appropriate restore, natural habitats and species of wild fauna and flora of Community interest at a favourable conservation status in order to achieve the more general objective of the Directive, which is to ensure a high level of environmental protection for the sites protected under the Directive. Article 6(3) of the Habitats Directive provides for an assessment procedure designed to ensure, by means of a prior assessment, that a plan or project not directly connected with or necessary for the management of the site concerned but likely to have a significant effect thereon is authorised only if it will not adversely affect the integrity of that site.

[30] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, *OJ* L 206, 22.7.1992, pp. 7–50.

Article 6(3) distinguishes two stages in the required assessment procedure. The first, the subject of the first sentence of the provision, requires Member States to carry out an appropriate assessment of the implications for a protected site of a plan or project where there is a likelihood that the plan or project will have a significant effect on the site. The second, which is the subject of the second sentence and which follows from the appropriate assessment, allows such a plan or project to be authorised only if it will not adversely affect the integrity of the site concerned, subject to the provisions of Article 6(4) of the Directive. Appropriate assessment of the implications of a plan or project also means that, before the plan or project is approved, all aspects of the plan or project which, either individually or in combination with other plans or projects, may affect the conservation objectives of the site must be identified in the light of the best scientific knowledge available. The competent national authorities must not authorise an activity unless they are satisfied that it will not adversely affect the integrity of the site. This is the case where there is no reasonable scientific doubt as to the absence of such effects. In addition, in respect of sites classified as Special Protection Areas, the obligations under Article 6(3) of the Habitats Directive replace, pursuant to Article 7 of that Directive, any obligations under the first sentence of Article 4(4) of the Birds Directive[31] from the date of classification under the Birds Directive if that date is later than the date of transposition of the Habitats Directive.

As the Habitats Directive does not define the term 'project', for the purposes of Article 6(3), according to the ECJ, account must be taken of the definition of 'project' in Article 1(2)(a) of the EIA Directive. The Court has previously held that if an activity is covered by the EIA Directive, it must, *a fortiori*, be covered by the Habitats Directive.[32] It follows that if an activity is regarded as a 'project' within the meaning of the EIA Directive, it may constitute a 'project' within the meaning of the Habitats Directive.[33]

It follows from the case-law of the Court that the requirement to carry out an appropriate assessment of the implications of a plan or project under Article 6(3) of the Habitats Directive is conditional on the existence

[31] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds, *OJ* L 20, 26.1.2010, pp. 7–25.

[32] ECJ 7 November 2018, *Coöperatie Mobilisation for the Environment and Others*, C-293/17 and C-294/17, paragraph 65.

[33] Ibid., paragraph 66.

of a likelihood or risk that the plan or project will have significant effects on the site concerned. Taking account in particular of the precautionary principle, such a risk is deemed to exist where, in the light of the best scientific knowledge available, it cannot be ruled out that the plan or project may compromise the site's conservation objectives. The assessment of that risk must take account, in particular, of the characteristics and specific environmental conditions of the site affected by such a plan or project.[34]

(b) ***When the assessment should take place***

The second sentence of Article 6(3) of the Habitats Directive specifies that following an appropriate assessment, the competent national authorities are to 'agree' to the project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public.

It follows that the assessment must be conducted before agreement is given.

Furthermore, while the Habitats Directive does not define the conditions governing how the authorities 'agree' to a given project under Article 6(3) of that directive, the definition of 'development consent' in Article 1(2)(c) of the EIA Directive is relevant in defining that term. Accordingly, by analogy with the Court's findings on the EIA Directive, if national law provides for a number of steps in the consent procedure, the assessment under Article 6(3) of the Habitats Directive, should, in principle, be carried out as soon as the effects which the project in question is likely to have on a protected site are sufficiently identifiable.[35]

(c) ***What to do in case of significant adverse impact?***

In cases where nuclear decommissioning projects are expected to have a significant adverse impact on habitats or species protected by the Habitat Directive, compensatory measures can be required.

Before considering compensation, the decommissioning project must first explore options to avoid and mitigate potential impacts. This often involves adapting the decommissioning plan to reduce effects on habitats

[34] *See*, to that effect, ECJ 17 April 2018, *Commission v Poland (Białowieża Forest)*, C-441/17, paragraphs 111 and 112 and the case-law cited.

[35] ECJ 29 July 2019, *Inter-Environnement Wallonnie ASBL*, C-411/17, point 143.

and species, such as scheduling work outside sensitive periods (e.g., breeding seasons), implementing pollution controls, or modifying techniques to limit habitat disruption. However, if the appropriate assessment concludes that adverse impacts are likely and no alternative solutions exist, the project can only proceed if it meets the strict requirements for compensatory measures under Article 6(4).

If no feasible alternative exists, and the project must proceed for 'imperative reasons of overriding public interest,'—which decommissioning project undoubtedly are— compensatory measures are necessary to offset the impact. These measures aim to provide ecological compensation by creating or restoring habitats, enhancing existing habitats, or even designating new protected areas. Examples include:

- habitat restoration: restoring degraded areas either on-site or nearby to support similar species and ecosystem functions;
- habitat creation: creating new habitats elsewhere that provide the same ecological functions as the impacted site;
- species protection initiatives: implementing programs to protect affected species, such as building artificial nesting sites, establishing new breeding areas, or funding research and conservation efforts for impacted species;
- designating new protected areas: sometimes, an entirely new area with similar ecological value may be designated as protected under Natura 2000.

Where, under the EIA framework, the authorities have a significant margin of discretion in implementing the conclusions of the EIA in a particular decommissioning or dismantling case, an appropriate assessment is therefore critical to the physical organisation of the decommissioning/dismantling activities.

(d) *Interplay between EIA/AA and technical and regulatory safety requirements*

The decommissioning of nuclear facilities involves a complex interplay between stringent technical and regulatory requirements under EURATOM and IAEA standards, and the environmental considerations detailed in and EIA and an appropriate assessment.

EURATOM and IAEA set foundational standards for nuclear safety, covering aspects like radiation protection, waste management and accident prevention. These regulations provide technical benchmarks that

all decommissioning activities must meet to minimize radiological risks to workers, the public, and the environment. While nuclear safety requirements set strict technical parameters for protecting people and the environment from radiation hazards, the EIA and appropriate assessment broaden the scope to assess a wider range of environmental impacts associated with decommissioning activities, including non-radiological effects, such as ecological impacts (potential impacts on local habitats, biodiversity and water resources beyond radiological risks) and pollution control (measures to mitigate dust, noise and chemical emissions that might arise during decommissioning but aren't directly related to nuclear safety).

In summary, while nuclear decommissioning is bound by technical safety standards, an EIA and appropriate assessment complement these by addressing the wider environmental impacts.

3 CONCLUSIONS

Our paper has provided an overview of the main legal instruments that are at play when looking at the final phase of a nuclear power plant. It has shown that the interaction between the nuclear safety terminology and the terminology used in environmental treaties and legislation isn't as clear cut as it should be.

When a nuclear power plant is shut down, the first issue that arises is the definition of decommissioning and dismantling. In our understanding, the objective of the EIA legislation is to come into play when, after shutdown, works are carried out to effectively dismantle the nuclear power plant. From a nuclear safety point of view, decommissioning has to be seen as the phase that starts after shutdown. Dismantling is to be seen as a part of the decommissioning phase that is not covered by the operating licence and for which a specific licence/decision ('development consent') is required.

The use of the terms 'decommissioning' and 'dismantling' in the ESPOO Convention, the Aarhus Convention, and hence the EIA Directive, creates confusion as to what constitutes a project or proposed activity requiring an EIA with possible transboundary consultation.

In our paper, we pointed out that when interpreting the concepts of 'dismantling' and 'decommissioning', it is therefore essential to stress

that the projects must have significant environmental effects for there to be an EIA obligation. This conclusion is based on the fact that all legal texts aim to protect the public and the environment from the possible risks posed by a project/nuclear installation. In order to provide clarity for future decommissioning and dismantling projects, we recommend a common approach by all relevant international and European regulatory bodies to provide sufficient legal certainty on the stage at which the obligation to start the EIA process kicks in in the context of a decommissioning or dismantling project.

Compliance with EIA requirements and the Habitats Directive is crucial for nuclear decommissioning projects due to the comprehensive environmental, health and safety challenges associated with the decommissioning and dismantling of nuclear facilities. The EIA process ensures a thorough examination of both radiological and non-radiological impacts, enabling a holistic approach to managing potential risks to ecosystems, local communities and public health. It guides the implementation of appropriate mitigation measures and promotes transparency through stakeholder engagement, which is particularly important for nuclear projects with far-reaching environmental impacts.

The Habitats Directive further protects biodiversity by requiring specific assessments and mitigation measures where decommissioning activities may affect protected habitats or species. This ensures that nuclear decommissioning is consistent with the EU's biodiversity conservation objectives and that the integrity of Natura 2000 sites and other ecologically sensitive areas is maintained. Where, under the EIA framework, the authorities have a significant margin of discretion in implementing the conclusions of the EIA in a particular decommissioning or dismantling case, an appropriate assessment of the physical organisation of the decommissioning/dismantling activities is critical.

Together, the requirements of the EIA and the Habitats Directive help to balance the technical requirements of nuclear safety with the environmental responsibility and legal accountability that underpin sustainable decommissioning.

Chapter 12

NUCLEAR NEW BUILD RENAISSANCE, DECOMMISSIONING AND RADIOLOGICAL PROTECTION IN THE UK: LEGAL AND REGULATORY FRAMEWORK

Lorraine Chiwenga*
Doctoral Candidate
University of Stirling
lorraine.chiwenga@ed.ac.uk

*Presenting author

Abstract

The 'nuclear renaissance' in the United Kingdom (UK) has sparked both the development of new nuclear projects and the decommissioning of existing power stations. This simultaneous occurrence introduces significant legal and regulatory challenges to radiological protection and decommissioning. This paper critically analyses the existing legal and regulatory frameworks governing radiological protection and waste management during decommissioning in the UK. The study evaluates the effectiveness of international, regional, and national policies while considering national social and legal concerns. Finally, the paper concludes that the UK's framework for radiological protection during decommissioning is reasonably effective, as demonstrated by improvements in regulatory structures, independent oversight and international collaboration.

Introduction

The resurgence in nuclear energy, often termed the 'nuclear renaissance', is driven by factors such as energy security, climate change mitigation and technological advancements such as small modular reactors (SMRs). This paper focuses on the UK, which is not only developing new nuclear projects but is also decommissioning a significant number of existing reactors. Effective waste management and the associated legal and regulatory provisions during decommissioning is crucial for safeguarding human health and the environment. The UK's 'nuclear renaissance' comprises proposed initiatives to construct several nuclear power stations with the aim of bolstering energy security, achieving net-zero carbon emissions, and replacing aging nuclear power stations.[1]

Hinckley Point C is under construction in Somerset and is expected to be operational by 2026–2027, with a capacity of 3.2 Gw. Sizewell C, with a capacity of 3.2 GW, has been approved and is in early development, aiming for completion in the early 2030s. Bradwell B has been proposed and is in the planning and assessment phases subject to approval and is expected to provide 2.2 GW of electricity. Prospective projects include Wylfa Newydd (Anglesey, Wales) and Moorside. Although the original plans for a large-scale nuclear project were temporarily halted, there is now a re-evaluation of the project, which includes the possibility of constructing new nuclear power stations equipped with advanced nuclear technology. Moorside (Cumbria, England) has the capacity to host both large reactors and SMRs, although the present focus of the project is to seek investment proposals. The government's ambition for the 'nuclear renaissance' is to reach 24 GW of nuclear capacity by 2025, contributing to a quarter of the country's electricity needs. If successful, these developments could provide the UK with a robust and low-carbon energy mix. For this reason, the legal and regulatory provisions for nuclear power station decommissioning is of paramount importance.

Indeed, the Chernobyl disaster in the former Soviet Union brought attention to the possible risks of nuclear power to the environment and

[1] Energy Act 2023.

human health.[2] Consequently, these risks are likely to persist for an extended period of time and are expected to continue into the future, posing a challenging legacy for future generations, especially with regards to radioactive waste, which is believed to retain its hazardous nature for several millennia.[3]

This paper will explore the international legal framework for the waste management aspect of decommissioning, looking at the International Atomic Energy Agency, the Organisation for Economic Co-operation and Development (OECD) / Nuclear Energy Agency (NEA) specifically and their role in the safety of nuclear power stations decommissioning. The UK legal and regulatory infrastructure is then explored in detail. The chapter will conclude that the UK has pursued an innovative model for waste management capabilities, delivered through a robust legal and regulatory framework which can serve as a model for countries in pursuit of nuclear energy.

International Regulatory Framework

This section provides a critical overview of key international regulations and conventions that the UK is party to. The UK operates within a complex regulatory environment governed by international organizations such as the International Atomic Energy Agency (IAEA) and the Organisation for Economic Co-operation and Development (OECD)'s Nuclear Energy Agency (NEA). The IAEA plays a vital part in setting international standards, although its guidelines are considered 'soft law' with limited enforceability.[4] The Joint Convention on the Safety of Spent Fuel Management and Radioactive Waste Management (JC) attempts to establish a coherent approach but lacks strong enforcement mechanisms. Crucially, it is worth noting that while the IAEA legislation has the authority to create standards and guidelines, these requirements do not

[2] A. J. Gonzàlez, *Legal Imputation of Radiation Harm to Radiation Exposure Situations*. In: International Atomic Energy Agency (ed.), *Nuclear Law: The Global Debate*, The Hague: T.M.C. Asser Press 2022.

[3] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (1997) preamble and art 1.

[4] M. Montjoie, *Treaty Implementation applied to Conventions on Nuclear Safety*, "Nuclear Law Bulletin" 2015, Vol. 2, No. 96, pp. 9–34.

hold any legal weight in member states, including the UK. Viewing them as 'soft law' is challenging because they lack procedural tools to provide adequate governmental consent and authority.[5] The IAEA's guidelines, particularly those related to radiological protection and waste management, inform UK regulations despite their non-binding nature. This section reviews the relevant articles within IAEA statutes and discusses how the UK integrates these guidelines into its domestic legal framework.

The UK's adherence to the JC is central to its legal obligations. Despite being non-binding, the IAEA's safety standards influence the UK's regulatory framework, demonstrating their importance in shaping national policy. In addition, the International Commission on Radiological Protection (ICRP) plays an important role in shaping the principles and guidelines that influence radiological protection during decommissioning of nuclear power stations in the UK.

The Joint Convention

Adopted in 1997, the Joint Convention marks a significant step toward international cooperation in nuclear safety. Article 24 of the JC focuses on operational radiation protection during decommissioning.[6] It emphasises the need to incorporate safety measures into the process in order to safeguard human health and the environment. The Article stipulates that decommissioning activities must be conducted within a controlled framework that encompasses safety evaluations and preventative measures to manage radioactive potential hazards. This entails the surveillance and reduction of radiation exposure and the adherence to the ALARA (as low as reasonably achievable) principle. Further, it requires that suitable provisions be established for the handling of any radioactive waste produced during the decommissioning process, with a particular emphasis on ensuring radiological safety. The UK method incorporates key features such as the involvement of the Office for Nuclear Regulations (ONR). The ONR is tasked with overseeing safety, security and radiation protection during the decommissioning process. It guarantees

[5] K. S. Nick, *The Future of Nuclear Energy and the Role of Nuclear Law*, "Nuclear Law Bulletin" 2022, Vol. 1–2, No. 108/109, pp. 7–26.

[6] Joint Convention on the Safety…, Article 24.

that operators comply with rigorous safety standards and regulatory obligations. In addition, the Environmental Agencies oversee the regulation of environmental protection measures, assuring safe management of radioactive waste and compliance with legal restrictions for any releases into the environment. The UK's obligations under this convention include regular reporting and participation in peer review meetings. However, the lack of stringent enforcement mechanisms and the voluntary nature of compliance limit its effectiveness.

Current UK Legislative Framework

In addition to the Nuclear Installation Act 1965 (NIA 65),[7] which lays the foundation for nuclear industry in the UK, the Radioactive Substances Act 1993[8] (RSA 93) is the current legislation for waste management aspects of decommissioning and is a devolved matter. The Act consolidated and replaced the 1960 Act and, subsequently, those made in the Environment Protection Act 1990.[9] The Act controls the keeping of waste through authorisation and regulatory systems and also provides for public information held by enforcing authorities according to section 39 of the RSA 93. Enforcement and prohibition notices are issued by environment agencies in the respective regions. In Scotland, however, the Scottish Environmental Protection Agency (SEPA) uses its compliance assessment scheme to assess compliance with regulations and authorisations under the RSA 93. It is important to note that in the UK, the management of waste is based on the principles of radiological protection. These principles are derived from the standards and guidelines of the International Atomic Energy Agency (IAEA) and are used to guide domestic legislation and policy which flow down to inform domestic legislation and policies. The principles are enshrined in UK law and underpin the UK government's devolved policies on managing waste.

In this respect, the legislative framework for radioactive waste is assigned to devolved governments as set out in the Scotland Act 1998,[10] the

[7] Nuclear Installations Act 1965, c. 57, s. 7.

[8] Radioactive Substances Act 1993, c. 12.

[9] Environmental Protection Act 1990, Environmental Authorities (Scotland) Amendment Regulations 2025 (SSI 2025/65), sch. 21 para. 2; *see* also reg. 44 and sch. 23.

[10] Scotland Act 1998, c. 46, s. 1.

Government of Wales Act 1998[11] and Northern Ireland Act 1998.[12] Even so, the Radioactive Substances Act 1993 is the same across the nation. Chapter 1(1) of the Environment Act 1995[13] provided for the establishment of the corporate body, known as the Environment Protection Agency (SEPA) in Scotland and as the Environment Agency in England and Wales, to provide for the transfer of functions such as waste management.

In this respect, waste management as a devolved matter aims to reform assignments of responsibilities across the country. This development has important implications for waste regulation, particularly to ensure compliance with legislation. This entails the transfer of some of the responsibilities from Westminster to the regional level and enables affected parties to review legislation. However, Scotland, as a devolved government, has no authority over nuclear power installations as a devolved competence, but it does have complete competence in environmental matters and planning. As a devolved power, the Scottish government has the power to block the installation of nuclear power stations in Scotland and is still against nuclear power. The main legal problem is that Scotland lacks authority over nuclear power installations, as a devolved state. The horizontal and vertical approaches present in the UK have the potential to cause compliance issues across legislation and regulatory instruments across various regions.

The Ionising Radiation Protection Regulations 2017

The Ionising Radiation Regulations 2017[14] (IRR 2017) have their roots in both international guidelines and earlier UK legislation. Early frameworks for radiation regulation and radioactive material management include the Radioactive Substances Act 1960[15] and the Ionising Radiation

[11] Government of Wales Act.

[12] Northern Ireland Act 1998.

[13] Environmental Act 1995, c. 43, s. 62, The provision was repealed on 16 July 2005 by the Hazardous Waste (England and Wales) Regulations 2005, SI 2005/894, although transitional arrangements continued to apply under Schedule 12.

[14] Ionising Radiation Regulations 2017, regulation 5–9, 13, 16–19, 20–24, 36.

[15] Historically, the Radioactive Substances Act 1960 did not represent statute that required a nuclear power station to be decommissioned. Historically, before later reforms, RSA was one of the main UK statutes controlling the environmental side of radioactive

Regulations 1985,[16] designed to regulate and manage radiation and to manage radioactive materials and restrict radiation exposure in the UK. The formulation of these regulations was based on extensive scientific research on radiation risk over the years, along with international and European initiatives to establish uniform safety standards.

The Ionising Radiation Regulations 1999 (IRR 1999) were the direct predecessor of the Ionising Radiation Regulations 2017. While the 1999 regulations provided a robust framework for radiation protection, advances in scientific understanding, changes in industry practices and the new Euratom Directive needed some revisions. Therefore, the impetus for the IRR 2017 was primarily the European Union's Basic Safety Standards Directive (Council Directive 2013/59/Euratom),[17] which sought to standardise radiation protection legislation among EU member states. The directive incorporated revisions in scientific knowledge and executed new regulations for exposure, waste management and emergence preparedness. The UK, as a member of the EU at the time, was required to transpose this directive into national law. The IRR 2017 was introduced to fulfil this obligation and replace the previous IRR 1999.

In that aspect, the IRR 2017 incorporated the latest requirements for the Euratom Directive, aligning UK law with updated international best practices and ensuring continued compliance with the European legal framework. The IRR 2017 offers comprehensive guidelines on dose limits, a regulated approach that customises safety measures according to the level of risk and enhanced provisions for safeguarding workers, the public and the environment. Although the UK is no longer a member of the EU, the IRR 2017 remains in force, reflecting the UK's commitment to radiation protection and ensuring that safety measures are updated.

The IRR 2017 Regulation 8 (1–4) requires radiation risk assessment. The implementation of these rules does not conflict with the provisions

substances regulation. None the less, the RSA has been repealed and replaced by the Radioactive Substances Act 1993.

[16] Ionising Radiation Regulations 1985.

[17] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom, *OJ* L 13, 17.1.2014, pp. 1–73, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013L0059&qid=1781955083290 [access: 21 June 2026].

of Regulation 3 of the Management of Health and Safety at Work Regulations 1999.[18] The IRR 2017 also requires restriction of exposure according to Regulation 9, personal protective equipment (PPE) (Regulation 10) and dose limitation (Regulation 12). In addition to these regulations, there is a requirement for contingency plans according to (Regulation 13) and also the need for a radiation protection advisor (Regulation 14).

The Role of the ICRP in Decommissioning in the UK

While the ICRP does not directly regulate nuclear decommissioning in the UK, its guidelines are foundational to the country's regulatory framework. The ONR, EA, and other regulatory bodies apply ICRP principles in the oversight of decommissioning activities, ensuring that radiological protection for workers, the public and the environment align with international best practices. As an independent, non-governmental organisation, the ICPR establishes radiological protection principles that are applied globally, focusing on areas such as exposure limits, safety standards and dose management. Its fundamental principles applied to decommissioning include justification, optimisation and dose limitation.

The UK Regulatory Framework

The UK's regulatory framework is anchored by the Nuclear Installations Act 1965,[19] the Energy Act 2004 (EA 2004) and Energy Act 2013 (EA 2013).[20] While the Energy Act 2004 established the Nuclear Decommissioning Authority (NDA) and provided a coordinated framework for managing the UK's nuclear legacy, the Energy Act 2013 built upon the decommissioning framework by strengthening financial arrangements to ensure that operators of new nuclear power stations cover the complete costs associated with the decommissioning and management of nuclear power stations.

[18] Management of Health and Safety at Work Regulations 1999, reg. 3, S1 1999/3242.
[19] Nuclear Installations Act 1965 (N6).
[20] Energy Act 2004, ss. 1–3 and Energy Act 2013, s. 149.

The Nuclear Decommissioning Authority (NDA)

The creation of the Nuclear Decommissioning Authority (NDA) under the Energy Act 2004 revealed positive shifts towards decommissioning. However, the establishment of the EA 2004 also signalled the government's commitment to phase out nuclear power stations, as highlighted in the White paper of 2006. Nonetheless, the UK Government's Energy Review represented a significant shift from the approach adopted in the 2003 Energy White Paper.[21] Rather than allowing nuclear power generation to be phased out, the Review concluded that new nuclear power stations would make a significant contribution to achieving the UK's energy security and climate change objectives, thereby paving the way for new nuclear build programme.[22]

The NDA's responsibilities include site management, strategic oversight and stakeholder engagement across 17 nuclear sites in the UK according to sections 1–7 of the EA 2004. Additionally, it is responsible for evaluation of the socioeconomic effects on nearby communities surrounding the decommissioning sites and facilitating local development.

When the NDA was initially set up, it adopted a model that involved parent body organisations (PBOs) to manage the day-to-day operations of specific nuclear sites. The PBO model was based on the principle of outsourcing management to private sector consortia with specialised expertise in nuclear operations. In this aspect, the NDA remained the owner of the sites and held strategic oversight, while PBOs were contracted to operate on the sites. PBOs were private companies or consortia awarded contracts through competitive bidding to management Site Licence Companies (SLCs), which directly handled operations at individual nuclear sites. PBOs were responsible for delivering decommissioning plans, managing budgets and meeting performance targets. Their contracts included financial incentives based on successful performance. The multi-layered structure of the NDA overseeing PBOs, which in turn managed the SLCs, created complex and sometimes inefficient management

[21] Department of Transport, Department for Environment, Food and Rural Affairs, *Energy White Paper: Our Energy Future – Creating a Low Carbon Economy*, 2003, Cm 5761.

[22] Department of Trade and Industry, *The Energy Challenge: Energy Review Report 2006*, 2006, Cm 6887.

chains and as a result there were challenges in aligning the objectives of private sector PBOs with public sector priorities, leading to conflicts of interest and governance issues.

The model came under scrutiny from government auditors, including the National Audit Office (NAO), which highlighted significant shortcomings in performance and value for money withing the model. In 2015, the UK government and the NDA terminated the PBO model at Sellafield and transitioned to a more direct management approach. Thereafter, the NDA adopted a direct management model for the site, creating Sellafield Ltd. as a wholly owned subsidiary of the NDA. The change allowed for more streamline decision-making and better alignment with public sector goals and better safety measures.

Nonetheless, waste management under the current regime remains regulated under the liability regime until ONR has given notice in writing to the operate holding the nuclear site licence when, in its opinion, 'there has ceased to be any danger from ionising radiations from anything on the site'. The Energy Act 2023 states that any radioactive waste remaining at the site and any further site monitoring should continue to be regulated by the relevant environmental agencies, who would continue to regulate the site until the RSR environmental permit was able to surrender.

Regulatory Regimes
Office for Nuclear Regulations

How regulations are implemented and enforced, and how compliance is ensured and promoted, are critical determinants of whether a regulatory system is working as intended. In this respect, in addition to regulating nuclear safety, through site licensing, the independent public cooperation Office for Nuclear Regulations (ONR), established by Part 3 of the Energy Act 2013[23] (EA 13)'s purpose, is outlined in Sections 67 and 69 of the Act. It also regulates conventional health and safety law on nuclear-licensed sites. Some of these purposes are covered by the purposes of the Health and Safety Executive, as set out in section 1 of the Health and Safety at Work Act 1974 (HSWA 74).[24] Generally, the Act

[23] Energy Act 2013 (N 20).

[24] Health and Safety at Work Act 1974, ss. 2–3.

places obligations on operators to safeguard employees and the public against risks resulting from industrial operations, including those related to nuclear decommissioning. Furthermore, section 68(1A) of the Energy Act 2013 states that the ONR is responsible for enforcing statutory provisions relating to waste management. To facility this, Part 1 of Schedule 8 gives the ONR the power to appoint inspectors to ensure that activities are carried out according to specified regulations. Paragraph 5 allows for remedial action to be sought in accordance with the improvement and prohibition notices. Notably, the ONR increasingly adopts a goal-setting regulatory approach, whereby operators are required to demonstrate that risks are reduced 'so far as reasonably practical' rather than complying with prescriptive rules.[25] The approach reflects the recognition that decommissioning projects are highly specific, involving risks, and extend several decades. Black and Baldwin's theory of responsive regulations suggests that regulators should focus on outcomes and organisational capabilities rather than detailed rule compliance.[26] This approach is evident in the ONR's emphasis on duty holder responsibility and the demonstration that risks have been reduced to a level that is as law as reasonably practicable. Similarly, Decker argues that goal-setting regulations is appropriate for complex, high risk industries.[27] In this context, ONR therefore relies heavily on safety cases, requiring operators to justify the adequacy of their safety arrangements and demonstrate continuous risk reduction. This strategy if further supported by international studies conducted by OECD Nuclear Energy, which highlight the need for successful decommissioning regulations to be sufficiently adaptable in order to address evolving organisational, technical, and environmental issues throughout the decommissioning lifecycle.[28]

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[25] Office for Nuclear Regulation, *Safety Assessment Principles for Nuclear Facilities*, 2014 edn, Revision 1, January 2020. For more on goal setting regulatory approach *see* for example, S. Willis et al., *Understanding the Regulator–Regulatee Relationship for Developing Safety Culture*, "Risk Analysis" 2024, Vol. 44, Issue 4, pp. 972–990.

[26] R. Baldwin and J. Black, *Really Responsive Regulation*, "Modern Law Review" 2008, Vol. 7, Issue 1, p. 59.

[27] Ch. Decker, *Goals-based and Rules-Based Approaches to Regulation*, BEIS Research Paper No 8, London: Department for Business, Energy and Industrial Strategy 2018.

[28] Nuclear Energy Agency, *The Regulatory Challenges of Decommissioning Nuclear Reactors*, Paris: OECD Publishing 2003.

The ONR applies the ALARA principle throughout the decommissioning of nuclear power stations in the UK. The ALARA principle is a foundation of radiation protection and involves minimising radiation exposure to workers, the public and the environmental to levels as low as reasonably achievable, taking into account social, technical and economic factors. In this case, the ONR's duty is to provide detailed guidance and sets expectations for operators to follow the ALARA principle during the decommissioning cycle. The ONR's regulations require that nuclear licenses demonstrate how they will implement ALARA in their decommissioning strategies, ensuring that radiological risks are minimised. Before decommissioning can start, operators are required to submit detailed decommissioning plans to the ONR stating how exposure will be reduced according to the ALARA principle. The ONR requires operators to use appropriate technologies, safety protocols and protective equipment to reduce radiation doses to workers. The ONR also ensures that operators optimise protection by considering alternative methods, tools and strategies that could further reduce exposure while still being practical and costeffective. For example, the use of remote-controlled equipment as an option. The ONR plays a vital role in ensuring that the ALARA principle is embedded in the lifecycle of nuclear power station decommissioning in the UK. Through comprehensive regulatory oversight, planning, monitoring and continuous review, the ONR ensures that radiation exposures are minimised to protect workers, the public and the environment, while balancing practical and economic factors. This approach aligns with international best practices and reinforces the UK's commitment to safe and responsible waste management aspects of nuclear decommissioning.

Legal sanctions for non-compliance for licence conditions or the avoidance of a licence have been based on a combination of criminal penalties and administrative sanctions, such as the revocation of a licence. However, the concept of civil penalties is not well developed in the UK, as argued by Macrory.[29] In many areas, the ONR, as the regulator, has powers under EA 13 to provide various forms of enforcement, such as warnings, letters, notices and information, and improvement and prohibition notices. From a viewpoint of waste management, this type of legal

[29] R. Macrory, *Regulating a Risky Environment* (2002). In: idem, *Regulation, Enforcement and Governance in Environmental Law*, London: Bloomsbury Publishing 2014.

structure is effective. Social-legal structure studies of pollution control authorities have shown the extent to which the emphasis on smooth environmental administration rather than law enforcement as such has encouraged a non-confrontational relationship between regulators and those they regulate, such as the operators. Furthermore, in making these points, it should be recognised that close links between regulators and operators can be mutually beneficial and serve safety interests by encouraging effective regulation in the highly specialised and technical area of waste management. However, it must also be acknowledged that overly close relationships and competing interests with the regulatory system can pose significant risks and lead to regulatory failures, as was the case with the Fukushima Daiichi accident.

In this regard, while the ONR has substantial enforcement powers within the statutory framework governing nuclear safety, it rarely resorts to the most severe sanctions, such as licence revocation under the Nuclear Installation Act of 1965[30] or requesting injunction. Instead, the ONR often uses a graded enforcement strategy, issuing warnings, regulatory letters, information notices, improvement notices, and prohibition notices. Improvement notices are issued pursuant to section 21 of the Health and Safety at Work Act 1974,[31] while prohibition notices are authorised by section 22 of the same Act.[32] For example, the ONR served an improvement notices on Magnox Ltd at the Wylfa site[33] for deficiencies in the management of asbestos-containing materials and, on 1 March 2024, served a further improvement notice on Nuclear Restoration Services at the Dounreay site concerning shortcoming in the storage of alkali metals.[34] These cased illustrate the ONR's preference for securing compliance through corrective enforcement measures rather than through more severe licensing sanctions. As a result, revocation is extremely rare not just due to of regulatory caution, but because nuclear sites often require

[30] Nuclear Installations Act 1965, s. 5.

[31] Health and Safety at Work Act 1974, s. 21.

[32] Ibid., s. 22.

[33] Office for Nuclear Regulation, *Improvement Notice Served on Magnox Ltd at Wylfa Site,* 21 April 2017, https://www.onr.org.uk/news/all-news/2017/04/improvement-notice-served-on-magnox-ltd-at-wylfa-site/ [access: 22 June 2026].

[34] Office for Nuclear Regulation, *Improvements Required for Storing Materials at Dounreay Nuclear Site*, 1 March 2024, https://www.onr.org.uk/news/all-news/2024/03/improvements-required-for-storing-materials-at-dounreay-nuclear-site [access: 21 June 2026].

continuous regulatory oversight even during decommissioning. For this reason, the ONR generally achieves compliance through licence conditions and HSWA enforcement warnings rather than revocation.

The Dounreay improvement notice demonstrates that, despite the existence of a thorough regulatory structure, compliance lapses are nevertheless possible. As a result, the regime's efficacy is determined not just by the substantive legal obligations imposed on operators, but also by the ONR's ability to monitor compliance and act as needed.

Health and Safety at Work Act 1974

The Health and Safety at Work (HSWA 74) was designed to protect workers at nuclear sites during the management of waste. The control of potential worker exposure resulting from waste management at nuclear power stations is the focus for the legislation. To this effect, the provisions under the HSWA 74 is that an employer is required to ensure as far as is reasonably practical that he does not cause harm either to his employees or to other people either on or off the site by providing a clear allocation of responsibilities to the bodies involved in the different steps of radioactive waste management.

Crucially, the HSWA 74 provides a more comprehensive regulatory framework for the enforcement of health and safety obligation at prescribed nuclear power installations, even though the Nuclear Installations Act 1965[35] establishes the licensing and inspection regime for those installations.

Although the ONR normally seeks compliance through inspections, regulatory engagement, and improvement letters, it retains the authority to increase action when major violations occur. This mirrors the graded approach to regulation advocated by the Regulatory Enforcement and Sanctions Act of 2008[36] and the ONR's Enforcement Policy Statement.

[35] Health and Safety at Work Act 1974, ss. 2–3; Nuclear Installations Act 1965, ss. 1–3; Office for Nuclear Regulation, *The Purpose and Scope of Nuclear Regulation*, ONR 2024, https://www.onr.org.uk [access: 23 June 2026].

[36] Regulatory Enforcement and Sanctions Act 2008, c. 13. The Regulatory Enforcement and Sanctions Act 2008 form a wider framework promoting proportionate, transparent and risk-based enforcement, under which prosecution is generally reserved for more serious or persistent breaches.

One example is the prosecution of EDF Energy Nuclear Generation Ltd and Doosan Babcock Ltd for an incident at Hinkley Point B in which a worker fell through a skylight.[37] EDF was charged with violating Section 3(1) of the Health and Safety at Work Act 1974, and Doosan Babcock with violating Regulation 4(1) of the Work at Height Regulations 2005. Both companies were fined and ordered to pay costs. In sentencing, Judge Ticehurst observed that although appropriate safety systems existed, they had not been properly implemented. The case demonstrates that the ONR is prepared to move beyond corrective enforcement measures and pursue criminal sanctions where failures create substantial risks to health and safety. Consequently, the UK nuclear regulatory regime combines cooperative compliance mechanisms with the credible threat of prosecution, thereby strengthening its overall effectiveness.

In addition to the Health and Safety at Work Act 1974, the Radiation (Emergency Preparedness and Public Information) Regulations 2019 (REPPIR 2019) play an important role in protecting the public and the environment from radiation emergencies. The Regulations require operators to undertake hazard evaluation and assessment, and to prepare both on-site and off-site emergency plans. Local authorities are also under a statutory duty to prepare emergency arrangements in the event of a radiation emergency, and both operators and authorities must ensure that relevant safety information is made available to potentially affected members of the public.[38]

Major accident hazards with significant environmental consequences are regulated separately under the Control of Major Accident Hazards Regulations 2015 (COMAH 2015), which establish a preventive regime for the control of major industrial accidents involving dangerous substances.[39]

In relation to transparency and environmental governance, the Freedom of Information Act 2000 and the Environmental Information

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[37] Health and Safety at Work Act 1974, s. 3(1); The Work at Height Regulations 2005, SI 2005/735, 4(1); Office for Nuclear Regulation, *Companies Fined for Health and Safety Breaches*, 1 February 2019, https://www.onr.org.uk/news/all-news/2019/02/companies-fined-for-health-and-safety-breaches/ [access: 22 June 2026]. It should be noted that the Hinkley Point B prosecution did not generate a reported law report citation (it was a Crown Court sentencing following a guilty plea).

[38] Radiation (Emergency Preparedness and Public Information) Regulations 2019, SI 2019/703, regs 5–8.

[39] Control of Major Accident Hazards Regulations 2015, SI 2015/483.

Regulations 2004 contribute to a broader 'right to know' culture in public administration.[40] The Environmental Information Regulations 2004 give effect in domestic law to the United Kingdom's obligations under the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters 1998.[41] While the Aarhus framework represents a significant development in environmental governance by strengthening procedural rights in environmental decision-making, its effectiveness is largely dependent on domestic implementation and enforcement mechanisms rather than supranational enforcement powers.[42]

Challenges

Radiological waste management remains a contentious issue, with potential risks including environmental contamination and nuclear proliferation. The UK still faces significant challenges in finding long-term solutions for high-level radioactive waste. Nonetheless, the legal and regulatory provisions for decommissioning and radiological protection in the UK are comprehensive but face challenges related to regulatory complexities, funding uncertainties, waste management and evolving nuclear safety standards.[43] The 'nuclear renaissance' is expected to increase the volume of radioactive waste, including high-level waste, which must be safely managed and disposed of. The UK currently does not have a fully functional Geological Disposal Facility (GDF) to store high-level nuclear waste for extended periods of time.[44]

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[40] Freedom of Information Act 2000; Environmental Information Regulations 2004, SI 2004/3391.

[41] Environmental Information Regulations 2004, SI 2004/3391; Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (adopted 25 June 1998, entered into force 30 October 2001) 2161 UNTS 447 (Aarhus Convention). *See* also Information Commissioner's Office, *Guide to the Environmental Information Regulations*, ICO 2023.

[42] Aarhus Convention; Environmental Information Regulations 2004.

[43] Health and Safety at Work Act 1974; Office for Nuclear Regulation, *Strategy for the Regulation of Nuclear Safety and Security*, https://www.onr.org.uk [access: 23 June 2026]; Nuclear Decommissioning Authority, *Strategy for Radioactive Waste Management*.

[44] Department for Energy Security and Net Zero, *Implementing Geological Disposal: Working with Communities* (UK Government policy paper, updated 2022), https://www.gov.

Major nuclear accidents, including the Chernobyl disaster in the former Soviet Union and the Fukushima Daiichi accident in Japan illustrate the lasting risks associated with nuclear technology and the importance of robust regulatory oversight through the nuclear lifecycle.[45] The regulatory provisions for decommissioning in the UK are intricate, involving multiple regulators, such as the ONR, the Environmental Agency and SEPA.[46] The presence of overlapping jurisdiction can result in difficulties in coordinating efforts, delays in implementation regulations and a rise in administrative expenses on operators.

The process of decommissioning can span several years, during which there is a possibility of standards and regulatory changes. This situation generates uncertainty for operators who need to adjust to changing demands while ensuring regulatory compliance. The extended duration of decommissioning also raises questions about the resilience of financial provisions and the potential regulatory changes that could impose additional costs and obligations.

Conclusion

The United Kingdom's approach to radiological protection and waste management during decommissioning is widely regarded as highly developed, supported by a comprehensive legal framework and independent regulatory oversight. However, challenges remain, particularly in relation to the non-binding nature of certain international guidelines and the fragmentation of responsibilities across devolved administrations, which may affect regulatory coherence and consistency.

While the so-called 'nuclear renaissance' in the United Kingdom is driven by objectives such as energy security and climate change mitigation, it also introduces significant legal and regulatory challenges for decommissioning. These include the long-term management of increased

uk/government/publications/implementing-geological-disposal-working-with-communities [access: 22 June 2026].

[45] International Atomic Energy Agency, *The Chernobyl Accident: Updating of INSAG-1* (IAEA Safety Series 75-INSAG-7, 1992); International Atomic Energy Agency, *The Fukushima Daiichi Accident* (IAEA 2015).

[46] Office for Nuclear Regulation; Environment Agency; Scottish Environment Protection Agency.

waste volumes, the adequacy of funding arrangements, the development and maintenance of specialist regulatory and technical expertise, and the need to sustain public confidence in nuclear governance.

It is therefore essential that decommissioning strategies for new nuclear power stations are aligned with evolving international standards and incorporate adaptive regulatory approaches. Interim storage facilities must be designed with sufficient capacity and resilience to accommodate potentially increased waste arisings over extended timeframes, particularly given the prolonged development horizon for a Geological Disposal Facility (GDF). A key regulatory challenge lies in maintaining an appropriate balance between facilitating nuclear development and ensuring rigorous safety, environmental protection, and decommissioning obligations within a complex and politically sensitive policy environment.

The United Kingdom's experience with legacy nuclear sites provides valuable regulatory and operational lessons for future programmes, but also underscores the scale of the challenges associated with long-term radioactive waste management. Overall, the UK's legal and regulatory framework for decommissioning and radiological protection is highly developed and may serve as a reference point for other jurisdictions pursuing nuclear expansion alongside long-term waste management strategies.

Chapter 13

WHEN ARMIES MARCH – RADIOLOGICAL PROTECTION DURING A TIME OF WAR

Mark Callis Sanders*
Consultant – Project Management & Nuclear Law
Sanders Engineering
Las Vegas, USA
mark@sandersengineering.us
ORCID: 0000-0003-2427-9758

Dr. Charlotta E. Sanders
P.E., Associate Research Professor
Department of Mechanical Engineering
University of Nevada, Las Vegas
Las Vegas, USA
charlotta.sanders@unlv.edu
ORCID: 0000-0002-7511-6994

* Corresponding author

Abstract

Just before dawn on the morning of February 24, 2022, Russian ground troops rushed across Ukraine's borders. This was the first time in world history when a large nuclear state (both with operating civilian nuclear reactors and nuclear weapons) invaded another country with a significant civilian nuclear power program.

Despite many fears, no major radiological threats to public health and safety have occurred. However, questions remain should a significant radiological release occur:

(1) Do the current peacetime radiological protection systems and regulatory frameworks assure adequate safety to human health and the environment during armed conflict?

(2) Do these peacetime frameworks have the required adaptability where sovereign authority over a facility and surrounding areas may not be possible whilst under the control of an invading army?

In November 2023, the Nuclear Energy Agency's Committee on Radiological Protection and Public Health (CRPPH) and the Norwegian Radiation and Nuclear Safety Authority (DSA), with support from the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU), held a workshop in Oslo, Norway. This paper provides an overview of relevant discussions from the workshop, as well as areas for improvement in radiation protection frameworks and the governing body of international nuclear conventions.

1 Introduction

Russia Invades Ukraine![1] screamed the newspaper headlines. Just before dawn on the morning of February 24, 2022, the peace of Europe was shattered when the Russian invasion began with dozens of missiles strikes on cities all over Ukraine. Soon, Russian ground troops rushed across Ukraine's borders. The world held its breath as within a few weeks' time expansive areas of Ukraine, including the seizure and occupation of the Chernobyl Exclusion zone, as well as a nuclear plant site, were under Russian control. Constantly, the International Atomic Energy Agency (IAEA) chief Rafael Grossi continues to warn that safety and security at Ukraine's Zaporizhzhia Nuclear Power Plant (ZNPP) remain fragile as significant staffing cuts at the plant site by Russian authorities occupying the facility take their toll. While to date, no major radiological threats to public health and safety have occurred, questions and

[1] H. Ellyatt, *Russian forces invade Ukraine*, published Thu, Feb 24 2022 4:05 AM EST, updated Thu, Feb 24 2022 11:38 AM EST, CNBC Website, https://www.cnbc.com/2022/02/24/russian-forces-invade-ukraine.html [access: 17 October 2024].

concerns are at the forefront of policy makers minds and the public regarding the realities of current radiation protection standards and legal framework's ability to continue to provide adequate protections in this regard.

In November 2023, the Nuclear Energy Agency's Committee on Radiological Protection and Public Health (CRPPH) and the Norwegian Radiation and Nuclear Safety Authority (DSA), with support from the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU), held a workshop in Oslo, Norway. The workshop aimed to address prospective issues of radiological protection in the context of armed conflict – *Radiological protection during armed conflict: Improving regulatory resilience and operational applications*. This paper provides a limited overview of some relevant discussions from the workshop and whether the current radiological protection frameworks are still relevant during a time of armed conflict at or near a civilian nuclear power plant.

2 Decades of Radiation Protection Development Focus – 1900 through Today

When we think of radiation protection guidance, what is glaringly apparent is there are 'two distinct eras separated by World War II'.[2] Before World War II, the major areas of concern were directed at simple solutions to a specific problem (i.e., X-ray protection). From the moment an atomic bomb was dropped on the Japanese city of Hiroshima on August 6, 1945, the world entered a nuclear age with a new term that spread fear among the populace – radiation sickness.[3] As the public learned more about the scale of the massive destruction caused by one bomb (70 per cent of all buildings destroyed and an estimated 140,000 deaths[4]), it

[2] R. L. Kathren, *Evolution of Radiation Protection Guidance in the United States*. In: S. Dewji, N. E. Hertel (eds), *Advanced Radiation Protection Dosimetry* (1st ed.), Boca Raton: CRC Press 2019, pp. 79–122, https://doi.org/10.1201/9780429055362-3.

[3] F. Solomon, R. Q. Marston (eds), *The Medical Implications of Nuclear War* (1st ed.), Washington D.C.: National Academy Press 1986.

[4] The International Campaign to Abolish Nuclear Weapons, *Hiroshima and Nagasaki bombings*, https://www.icanw.org/hiroshima_and_nagasaki_bombings#:~:text=The%20uranium%20bomb%20detonated%20over,chronic%20disease%20among%20the%20survivors [access: 27 August 2024].

shocked the conscious. From 1949, when the Soviet Union detonated its first nuclear device at a remote site in Kazakhstan, the main focus of policy makers (and the public) turned to the 'immediate' destruction and illnesses caused in high-population urban centers. One lasting memory of 1950's school children in the United States (US) were the duck-and-cover drills teaching children in school what they should do when there was an atomic attack, which helped to channel the mounting 'panic over an escalating arms race'.[5]

By the 1960's, radiation protection had evolved to include the civilian aspects of the use of the atom. This involved the identifying and measuring the various sources of radiation exposure to the public by categorizing the potential sources of radiation exposure. These exposure scenarios ranged from releases (both minimal and major) from civilian nuclear power plants, medical uses, to the abnormally high natural radiation levels in certain regions,[6] as well as from nuclear war. This potential commercial radiation dose exposure concern is shown in the Nuclear Liability Conventions[7] of the era which were adopted to ensure people were compensated for certain types of economic loss and the cost of measures to reinstate a significantly impaired environment etc. from the consequences of nuclear accidents from a commercial nuclear power plant, both within the Contracting Party and other contracting parties to the convention of a cross-boundary nature.

During the 1970's, on the military side, a new theory emerged that there was more likely to be a greater effect on the military rather than the civilian population, as it was believed a shift in strategy was taking place towards the strategic use of nuclear weapons constrained to the

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[5] History.com Website, *How 'Duck-and-Cover' Drills Channeled America's Cold War Anxiety*, https://www.history.com/news/duck-cover-drills-cold-war-arms-race [access: 27 August 2024].

[6] A. Barahona, *Radiation Risk in Cold War Mexico: Local and Global Networks*, "Naturwissenschaften, Technik Und Medizin" 2022, Vol. 30(2), pp. 245–270, https://doi.org/10.1007/s00048-022-00331-0.

[7] Paris Convention on Third Party Liability in the Field of Nuclear Energy, https://www.oecd-nea.org/jcms/pl_20196/paris-convention-on-third-party-liability-in-the-field-of-nuclear-energy-paris-convention-or-pc [accessed 27 August 2024]; and, Vienna Convention on Civil Liability for Nuclear Damage, https://www.iaea.org/topics/nuclear-liability-conventions/vienna-convention-on-civil-liability-for-nuclear-damage [accessed 27 August 2024].

battle field, more than being aimed at urban centers. At the end of the 1970's, 1979 to be precise, the most serious accident at a US commercial power plant occurred at The Three Mile Island Unit 2 reactor, near Middletown, in Pennsylvania. Although there was only 'small radioactive releases [which] had no detectable health effects on plant workers or the public… sweeping changes involving emergency response planning, reactor operator training, human factors engineering, and radiation protection'[8] were brought about. Once again, there was a renewed focus on radiation protection measures surrounding the potential releases from commercial power plants rather than caused by nuclear war.

As the world approached the end of the Cold War in the 1980's, two major events brought simultaneous emphasize on radiation protection in both military and civilian applications. The first was the North Atlantic Treaty Organization (NATO) exercise 'Able-Archer' simulating a nuclear attack that brought the US and Soviet Union 'to the brink of nuclear war by miscalculation'[9] and ending the détente of the 1970's. It also kicked off a renewed arms race in what has been termed the 'Second Cold War'. Second, on the civilian side, the accident at the Chernobyl Nuclear Power Plant (ChNPP) in Ukraine was a milestone event taking place on April 26, 1986. As a result of the explosion and fire in the Number Four RBMK reactor, and the resultant release of radioactive elements including plutonium, iodine, strontium and cesium into the atmosphere, it is estimated that approximately 200,000 persons had to be relocated, with some 150,000 square kilometers in Belarus, Russia and Ukraine being contaminated.[10] Furthermore, Scandinavian countries in particular were affected by the radioactive releases from Chernobyl. As a result of the Chernobyl accident two major international conventions were adopted:

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[8] Nuclear Regulatory Commission, *Backgrounder on the Three Mile Island Accident*, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html [accessed 27 August 2024].

[9] S. Radchenko, *The Soviet Union and the Cold War Arms Race*. In: Th. Mahnken, J. Maiolo, and D. Stevenson (eds), *Arms Races in International Politics: From the Nineteenth to the Twenty-First Century*, Oxford: Oxford University Press 2016; online edn, Oxford Academic, 1 Jan. 2016, https://doi.org/10.1093/acprof:oso/9780198735267.003.0008 [access: 27 August 2024].

[10] International Atomic Energy Agency, *Frequently Asked Chernobyl Questions*, https://www.iaea.org/newscenter/focus/chernobyl/faqs [access: 27 August 2024].

Convention on Early Notification of a Nuclear Accident[11] and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.[12]

During the 1990's, and for a period of 20 years (with the de-escalation of possible nuclear war with the fall of the Soviet Union), the international community continued to strengthen radiation protection measures and limit dose exposures in the civilian arena with renewed focus on the As Low As Reasonably Achievable (ALARA) doctrine. By the mid-2000's, there were talks of a nuclear renaissance, or a possible revival, of the nuclear power industry. A global slowdown in the construction of new nuclear projects had brought about renewed calls for an expanded energy mix driven by rising fossil fuel prices and concerns about meeting greenhouse gas emission limits. This renaissance collapsed in 2011, on 11 March, with the accident at the Fukushima Daiichi Nuclear Power Station (FDNPS).

3 Fukushima Accident – A Leap Forward in Radiation Protection and Response

On 11 March 2011, an earthquake of magnitude 9.0 occurred along the Japan Trench. The earthquake and resultant tsunami triggered a severe nuclear event, with these events leading to the release of radioactive material from FDNPS into the environment. While it is not the intent of this paper to comprehensively discuss this accident in detail, the lessons-learned from this accident, and the actions taken to protect life and property, not only strengthened nuclear safety culture around the world, but our radiation protection frameworks, too. Importantly, they also provide a potential template for preparing and managing radiation protection activities during armed conflict.

It should be noted that radiation protection actions were immediately employed for emergency workers. The radiation protection measures /

[11] Convention on Early Notification of a Nuclear Accident, https://www.iaea.org/topics/nuclear-safety-conventions/convention-early-notification-nuclear-accident [access: 27 August 2024].

[12] Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, https://www.iaea.org/topics/nuclear-safety-conventions/convention-assistance-case-nuclear-accident-or-radiological-emergency [access: 27 August 2024].

allowable dose rates were: (1) An upper radiation exposure dose limit of 100 mSv for workers engaged in emergency works at FDNPS (immediately applied); (2) This was increased to 250 mSv on March 15, 2011; and, (3) On November 1, 2011 this limit and returned to its pre-existing value of 100 mSv for workers commencing work after November 1 and on December 16, 2011 for most other workers, with April 30, 2012 for all remaining workers.[13] In other words, radiation protection measures were adopted and changed due to shifting circumstances over the time span of one year. Flexibility is key for managing changing circumstances and for maintaining adequate levels of safety during the various phases towards recovery.

In commenting on the safety and health risks of these measures, the UNSCEAR 2020/2021 Report Volume I report states, 'A small proportion of workers (174 workers, about 0.8%) received effective doses within the first year of 100 mSv or more, with an average of about 140 mSv. […] The Committee therefore consider[ed] that it is unlikely that an increased incidence of cancer due to irradiation would be discernible, because the normal variability in baseline rates of cancer incidence is much larger than the inferred radiation-associated cancer rates.'[14] This statement does become important later in the paper's discussion when discussing proposed updates to Sweden's radiation protection legislation, as well as nuclear liability issues.

Also, it is valuable to note that evacuation and shelter in place measures were undertaken in a step wise basis as shown in Figure 1, which could indicate some sort of template during time of war. Although, given fast changing conditions with moving battle fronts, evacuations on any scale may not be advisable and shelter in place is most likely the best solution. The worst-case scenario for the public is to become stuck between shifting front lines without the possibility to either complete the evacuation or return to their homes. As will be discussed later, the public will need to be better educated on dose exposure rates/limits to reduce panic and assist the public in making more informed decisions during an extremely stressful situation.

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[13] *UNSCEAR 2020/2021 Report*, Volume I: *Sources, Effects And Risks of Ionizing Radiation*, New York: United Nations 2022, https://www.unscear.org/unscear/publications/2020_2021_1.html [access: 28 August 2024].

[14] Ibid.

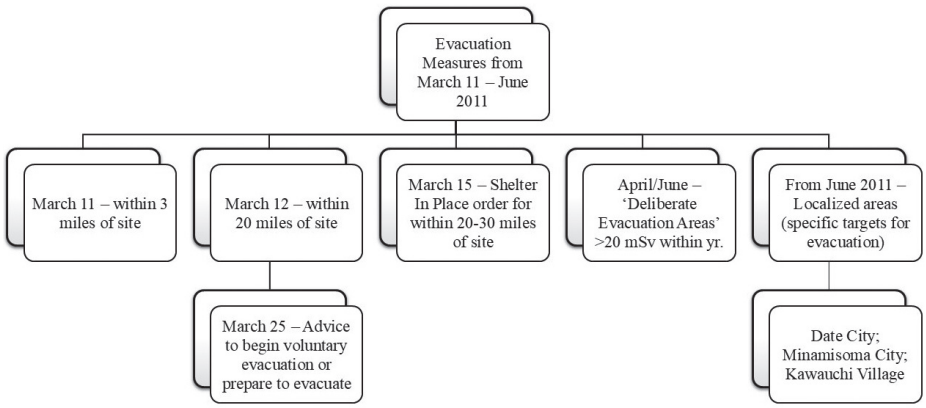

Figure 1. Evacuation and 'Shelter in Place' Orders from March 11 through June 2011

Source: own elaboration on the basis of PowerPoint Presentation from the Workshop: *Regulatory and Operational Radiological Protection Issues and Challenges in Ukraine* by Nataliia Rybalka – Director of the Department for Safety of Radiation Technologies and Radioactive Waste Management, Deputy Chief State Inspector for Nuclear and Radiation Safety of Ukraine. Presentations may be found at: https://www.oecd-nea.org/jcms/pl_82793/radiological-protection-during-armed-conflict-improving-regulatory-resilience-and-operational-applications [access: 2 September 2024].

3.1 Fukushima Accident Lessons-Learned and their Application during Time of War

There are a number of lessons-learned that arose from the Fukushima accident, which are appropriate with updates within the context of the paper. Do note that while all these actions and lessons-learned occurred during a peacetime accident, these lessons are useful in preparing for potential actions that could be taken during a nuclear emergency caused by a military incursion at a civilian power plant with a radiological release to the environment. The lessons-learned are taken from the IAEA 2015 Report of the Fukushima accident.[15]

Lesson-learned #1 – Radiation Protection Principles & Criteria Understandable to Non-Specialist

[15] International Atomic Energy Agency, *The Fukushima Daiichi Accident*, Vienna: IAEA 2015, https://www-pub.iaea.org/mtcd/publications/pdf/pub1710-reportbythedg-web.pdf [access: 28 August 2024].

There is a critical need to develop better useable information and how to more simply explain the principles and criteria for radiation protection. These need to be comprehensible to non-specialists. How the protection criteria and measures are to be applied must be clearer for both political decision makers and the public. Importantly, an improved communication and education strategy is needed to convey the justification for such measures and actions to all stakeholders, including the public.

Response: This is especially vital in a nuclear emergency during time of war where communication may be limited, and where decisions might have to be taken at the local level or even within the smaller 'neighborhood' setting without consultations with central or regional government agencies. Also see lesson-learned #5.

Lesson-learned #2 – Comprehensive & Coordinated Approach to Decision Making at All Government Levels

Arrangements need to be in place to ensure that protective actions and other response actions in a nuclear emergency do more good than harm. A comprehensive approach to decision making needs to be in place to ensure that this balance is achieved.

Response: This is a central attribute in a nuclear emergency especially during time of war where communication may be limited. Ministries and Departments must be able to flexibly delegate decision making competencies to regional and local governments. These authorities in decision making must be quickly transferred and activated, and grounded in pre-set administrative procedures. As an example, the Snow Chaos on the road E22 in southern Sweden January 2024 is an example of failures in delegation and quick decision-making.[16]

Lesson-learned #3 – Capability Probabilistic and Deterministic Safety Analyses

Comprehensive probabilistic and deterministic safety analyses need to be performed to confirm the capability of a plant to withstand applicable beyond design basis accidents and to provide a high degree of confidence in the robustness of the plant design.

[16] A.-F. Hivert, *The chaos of the snow-covered E22 route, a symbol of 'real Sweden'*, "Le Monde", published on February 14, 2024, at 12:51 PM (Paris), https://www.lemonde.fr/en/international/article/2024/02/14/the-chaos-of-the-snow-covered-e22-route-a-symbol-of-real-sweden_6523901_4.html [access: 28 August 2024].

Response: The authors would add to these particular assessments a caveat to include assessments of potential scenarios as a result of military engagements in the vicinity of a commercial power plant. The authors also refer the reader to lesson-learned #4.

Lesson-learned #4 – Assessment of Natural Hazards Needs to Be Sufficiently Conservative

The assessment of natural hazards that might occur within the site needs to be sufficiently conservative. As was seen in the Fukushima accident, using historical data to establish the design basis of nuclear power plants needs to be weighed whether sufficient consideration regarding the wide range of potential scenarios and how to best characterize the risks of extreme natural hazards is properly considered.

Response: The authors would add, and do recommend, to this lesson-learned from Fukushima a caveat to include assessments of potential scenarios as a result of military engagements, simultaneously with credible natural hazard events in the vicinity of the commercial power plant. Additionally, simulations should be undertaken for emergency preparedness and response where a nuclear emergency occurs simultaneously with a natural hazard event.

Lesson-learned #5 – Public Helpers & Factual Information (During Time of Nuclear Emergency)

Both 'Emergency Workers' and 'Public Volunteers' need to be defined, designated, and assigned clearly specified duties. They should each be given adequate training relative to the designated status to be properly protected during a nuclear emergency. Additionally, factual information on radiation effects needs to be communicated in an understandable and timely manner to individuals in affected areas in order to enhance their understanding of protection strategies, to alleviate their concerns and support their own protection initiatives.

Response: This may need to include plans where trained and 'authoritative' individuals in the local community are required to provide timely information to the regulator (should normal monitoring systems go offline) or the public within their sphere of influence when communication with regulatory bodies may not be possible. Also, a more concise determination of a what constitutes 'public helpers' should be defined in a similar categorization of Emergency Workers, their training requirements

and also use of PPE, with PPE supplies stored in various locations within the local community and county.

4 Radiation Protection – It All Changes with Major War in Europe (2022)

On February 24, 2022, Russia's invasion of Ukraine began with dozens of missiles strikes on cities all over Ukraine. Over the next weeks, Russian ground troops moved in quickly and within a few weeks were in control of large areas of Ukraine. In what was a surprisingly shocking move, the Russian army seized and occupied the Chernobyl exclusion zone. Adding insult to injury, a Russian assault on the Zaporizhzhia Nuclear Power Plant (ZNPP), which began on 3 March 2022, captured the power plant by the next day. Still this year (2024), the United Nations declared, 'that the first-ever war to be fought amid the facilities of a major nuclear power programme is bringing the prospect of nuclear accident "dangerously close"'.[17]

As a starting point, to begin international discussion on these serious events and impact to radiation protection programs and legislative frameworks, between November 22-24, 2024 a workshop titled *Radiological protection during armed conflict: Improving regulatory resilience and operational applications* was held in Oslo, Norway. The workshop had three aims, which are shown in Figure 2.

Without going into full detail of each presentation in the workshop, the goal here is to provide some basic relevant information and consider a war's impact on the functioning of international nuclear conventions. Three key regulatory issues and challenges[18] were mentioned in context of the war in Ukraine:

1. National laws and regulations have been developed without taking into account shelling conditions or occupation of nuclear installations.

[17] United Nations, 9604th Meeting (PM), *Prospect of Nuclear Accident 'Dangerously Close' at Zaporizhzhia Power Plant in Ukraine, International Atomic Energy Agency Chief Warns Security Council*, 15 April 2024, https://press.un.org/en/2024/sc15662.doc.htm [access: 2 September 2024].

[18] *See* N. Rybalka, *Regulatory and Operational Radiological Protection Issues…*

2. There is no experience anywhere in the world of the safe operation of a nuclear installation in the context of large-scale war.
3. There is no experience of nuclear regulation in the context of large-scale war and for recovery and the re-start of the regulatory body control/work in a postwar period.

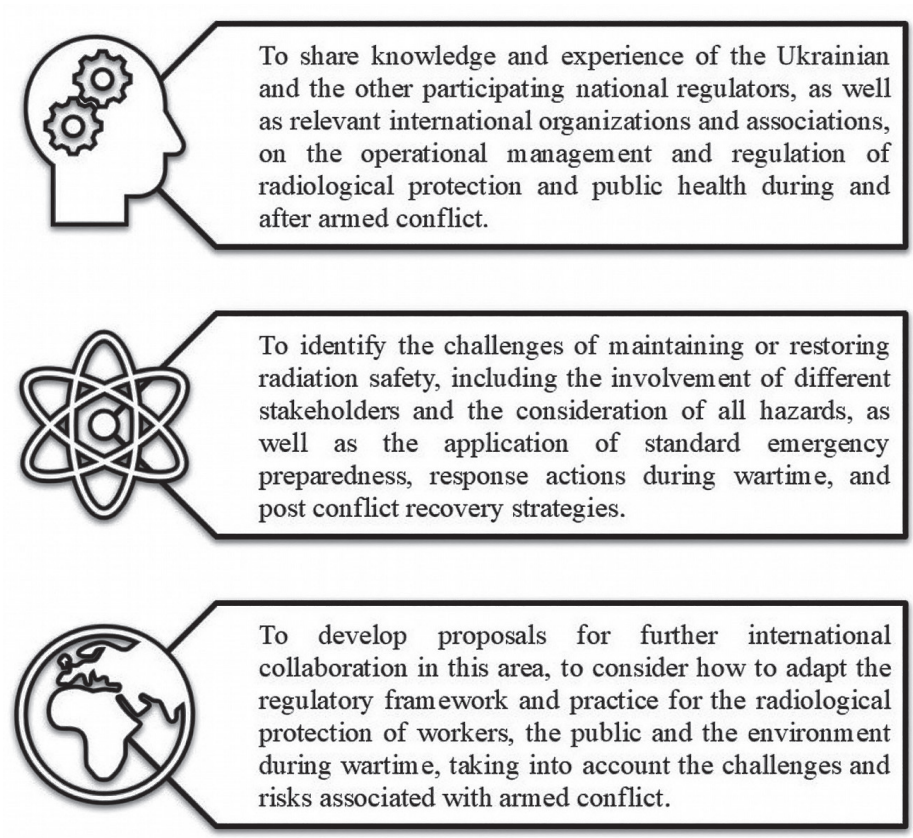

Figure 2. The Three Aims – NEA's Radiation Protection During War Workshop (2023)

Source: own elaboration on the basis of N. Rybalka, *Regulatory and Operational Radiological Protection Issues…*

5 Radiation Protection Example during War – Sweden: A Case Study

During the workshop, a presentation by Sweden[19] was given which is used as a case study for this paper. Sweden is currently conducting a review of its radiation protection legislation and framework to consider how appropriate they would still be during a heightened state of alert and war. The two guiding doctrines for their review are:

1. Develop a framework for radiation protection in connection with emergency exposure situations during a heightened state of alert and war as part of a complete protection strategy.
2. Propose the necessary changes to the Swedish legislation in order to implement the framework.

One main concern for Sweden in its review is: 'what constitutes a worker involved in an Emergency Response'? Sweden is reviewing this question in context with the European Union Basic Safety Standard for an emergency worker, 'which means any person having a defined role in an emergency and who might be exposed to radiation while taking action in response to the emergency'.[20] Workers, though, not designated as emergency workers are treated as members of the public with regards to radiation protection in emergency exposure situations. However, some of these workers, though ancillary, would still need to participate in vital societal functions. Therefore, Sweden seeks to propose the following solution:

– *The redesignation of non-emergency workers as 'workers in an emergency exposure situation' and their being treated as emergency workers.*

[19] J. Johansson et al., *Development of a Swedish framework for radiation protection during a heightened state of alert and war*, Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority), November 2023, https://www.oecd-nea.org/jcms/pl_82793/radiological-protection-during-armed-conflict-improving-regulatory-resilience-and-operational-applications [access: 2 September 2024].

[20] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom, Article 4, Definitions, (31), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02013L0059-20140117 [access: 16 October 2024].

The argument Sweden wishes to put forward in its 'worker' redesignation justification is that such a change in the Swedish legislation would ensure adequate regulation of radiation protection for these emergency ancillary workers during a time of heighten alert, as well as for peacetime emergencies. This would also ensure that responsibilities and individual rights are adequately regulated for these emergency ancillary workers. This, at least, is the technical protection justification. Sweden also proposes drastic changes from current guidance for 'Occupational Exposure in Emergency Exposure Situations' and 'Reference levels for the Public in Emergency Exposure Situations'. These are shown in Figures 3 and 4.

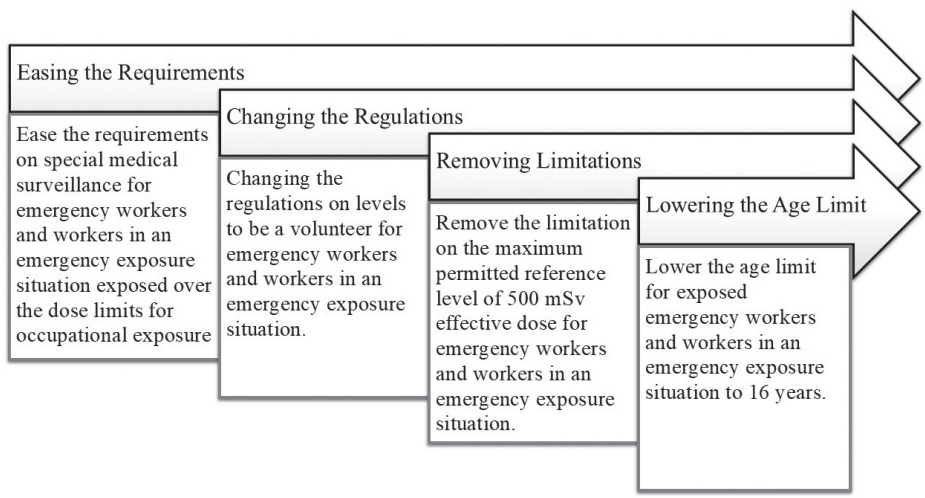

Figure 3. Sweden's Proposed Changes for Occupational Exposure in Emergency Exposure Situations

Source: own elaboration on the basis of N. Rybalka, *Regulatory and Operational Radiological Protection Issues…*

We foresee two challenges with implementing these approaches.

Challenge 1: Removing the permitted reference level of 500 mSv.

A strong technical justification would have to be presented and explained as in this instance one is moving into the moderate dose exposure range and out of the questionable risk to health category.[21] Further, and

[21] *See*: Swedish Rescue Services Agency, *Swedish emergency preparedness for nuclear energy accidents* (Pamphlet – Public Release), Räddnignsverket 2001, https://rib.msb.se/Filer/

importantly, Article 51, 2. (b) states: 'in exceptional situations, in order to save life, prevent severe radiation-induced health effects, or prevent the development of catastrophic conditions, a reference level for an effective dose from external radiation of emergency workers may be set above 100 mSv, **but not exceeding 500 mSv**'.[22] As this in European Union (E.U.) directive, and the foundational goal of the E.U. is to bring about harmonization in legislation, it is not clear how this change in permitted dose exposure would be applied, especially should other E.U. member states send emergency workers to assist in a nuclear emergency in Sweden. Would two tiers apply – one allowable limit for Swedish Emergency Workers and another for other E.U. Emergency Workers?

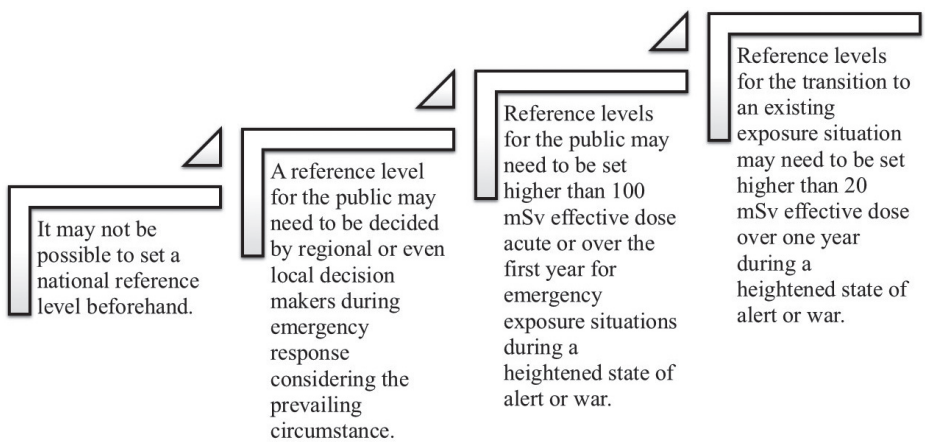

Figure 4. Regarding Reference Levels for the Public in Emergency Situations (Sweden)

Source: own elaboration on the basis of N. Rybalka, *Regulatory and Operational Radiological Protection Issues…*

Also, it would be advisable, where possible, to have a two-tiered definition of Emergency Worker with differing allowable dose exposures relevant to certain training requirements and availability of PPE, which

pdf%5C20844.pdf [access: 4 September 2024]. Also *see*: M.C. Sanders and C.E. Sanders, *Three Blind Mice – Low-Dose Radiation, Epidemiology and the Law*, Proceedings of the International Nuclear Law Association Inter Jura 2022, Washington D.C., USA, 24–27 October 2022, https://www.researchgate.net/publication/364142820_Three_Blind_Mice_-Low-dose_Radiation_Epidemiology_and_the_Law [access: 4 September 2024].

[22] Council Directive 2013/59/Euratom of 5 December 2013…

would be in line with the general concepts found in Council Directive 2013/59/Euratom of 5 December 2013. The following is suggested:

(1) Emergency Worker – Radiological (e.g., power plant staff, trained emergency workers (fire, police, doctors/nurses)), and

(2) Emergency Worker – Public Helper (e.g., Red Cross Volunteer, ancillary hospital staff, etc.).

Should one proceed along this route, it is recommended that proposals are developed how different exposure levels could be applied over a set time frame, the training requirements as well as Personal Protection Equipment use, etc., which would be applied for each 'worker' category – 'Emergency Worker' or 'Public Helper' ('Emergency Worker').

In conjunction with this particular challenge, consideration should be directed to Sweden's nuclear liability law, Law (2010:950), Law on Responsibilities and Compensation in the Event of Radiological Accidents.[23] In 11 § it states: 'This law does not apply to injuries as the result of a radiological accident that is directly caused by acts of war or similar acts during armed conflict, civil war or rebellion'. A better connection to the State's managing abilities (i.e., who the decision makers are and their authorities listed), State's actions ensuring the public is compensated, etc., should be provided now in the event of war. The public would need to be able to have adequate information available on claims processes and limitations applied. In short, where one turns for assistance needs to be given in advance. Other changes in the law might include a potential carve out for special compensation allowance for Emergency Workers (e.g., ≥ 250 mSv) and Public Helper Worker (e.g., ≤ 250 mSv but ≥ 100 mSv) in situations where dose exposure from a civilian power plant exceed certain regulatory limits.[24] In Table 1, the exposure criteria during a Radiation Emergency in the US are provided as a point of reference.

[23] Lag (2010:950) om ansvar och ersättning vid radiologiska olyckor, "Denna lag gäller inte skador orsakade av en radiologisk olycka som är en direkt följd av en krigshandling eller en liknande handling under väpnad konflikt, inbördeskrig eller uppror", https://www.riksgalden.se/globalassets/block---gemensamma/karnavfall/lag-2010-950-om-ansvar-och-ersattning-vid-radiologiska-olyckor.pdf [access: 4 September 2024].

[24] Article 53 3. Provides for a 100 mSv limit. "Member States shall ensure that emergency workers who are liable to undertake actions whereby an effective dose of 100 mSv may be exceeded are clearly and comprehensively informed in advance of the associated health risks and the available protection measures and undertake these actions voluntarily".

Table 1. Emergency Radiation Exposure Criteria in the US

Emergency Radiation Exposure Criteria – 10 CFR 835.1302		
Dose Limit	Activity	Conditions
50 mSv	ALL	ALL
100 mSv	Protect Major Property	Lower dose not practical
250 mSv	Lifesaving or protection of large populations	Lower dose not practical
> 250 mSv	Lifesaving of protection of large populations	Only on a voluntary basis to personnel fully aware of the risks involved

Challenge 2: Increased Reference Levels for Public to ≥ 100 mSv

Any change to reference levels for the public would require a massive coordinated education campaign and stakeholder engagement. It would also have to be better explained/justified why the disparity in the current peacetime allowable release of 1 mSv per annum from an operating nuclear power plant to ≥ 100 mSv for public exposure in a nuclear emergency during war time situation is acceptable. A major stumbling block is that there is a chasm of understanding by the public between a regulatory limit of 1 mSv per annum dose exposure from a civilian nuclear power plant during normal operation and what is a safe limit of dose exposure. The public and other stakeholders have mistakenly applied the line between what is safe and what is not safe to the 1 mSv per year regulatory limit. Further, the stakeholders should be educated that the ALARA principle is not being turned on its head from its current application, but rather will still be applied but from another vantage point.

Also, the lowering of the age limit for emergency workers in a nuclear emergency will be problematic as this goes against the current E.U. directive.[25] This should also be considered in view of the legal age in Sweden, when one is considered an adult, which is 18 years of age. In 2024, Sweden changed its laws so a person can change their legal gender at age 16, but they need approval from their parents, a doctor, and the National Board of Health and Welfare. Consider too, the legal drinking age in Sweden is set at 18 years old. Despite this, purchasing alcohol from

[25] Article 8, Age limit for exposed workers, "Member States shall ensure that subject to Article 11(2), persons under 18 years of age may not be assigned to any work which would result in their being exposed workers".

Systembolaget, the government-run liquor store, requires individuals to be at least 20 years old. Further, in Sweden, people are generally treated as adults for criminal purposes once they reach the age of 15. However, there are special rules. So, whilst there are different standards applied for different situations, which could be used to justify the lowering of the age limit for emergency workers, perhaps, similar to the gender change law, parents' approval for a 16-year-old to participate as a worker in a nuclear emergency might be needed – though it could be difficult to properly manage. It is suggested, should this change occur, that the government consider mandating radiation protection training and use of PPE in the school curriculum from the age of 16 with follow-up training each succeeding year during high-school.

6 Russia's Invasion of Ukraine: Impacts to International Nuclear Conventions – Changes Needed!?

There are several key conventions that form part of the international nuclear legal framework and provide for stability with regards to safety, liability, and security. Russia's unlawful occupation of the ZNPP has raised questions among experts and the international community how suitable the conventions are in their current form and how potentially these are affected during armed conflict.

*6.1 Nuclear Liability [**green light**]*

- Vienna Convention on Civil Liability for Nuclear Damage, https://www.iaea.org/topics/nuclear-liability-conventions/vienna-convention-on-civil-liability-for-nuclear-damage
- Convention on Supplementary Compensation for Nuclear Damage, https://www.iaea.org/topics/nuclear-liability-conventions/convention-supplementary-compensation-nuclear-damage[26]

A very good recent article in the Nuclear Law Bulletin No. 111 by Nathalie L. J. T. Horbach and Omer F. Brown, II[27] performs an outstanding

[26] [access: 2 September 2024].

[27] Please *see*: N. L. J. T. Horbach and O. F. Brown, II, *Nuclear liability in respect of Ukraine's nuclear installations under Russian military control*, "Nuclear Law Bulletin" 2024, No. 111, Vol. 2023/2, pp. 7–22, https://www.oecd-nea.org/jcms/pl_95469/nuclear-law-bulletin-

job of discussing various challenges in the texts to the liability conventions and some recommendations. Generally, though, the nuclear liability conventions provide good assurance of compensation and assistance to victims from accidents caused by military hostilities. One that needs to be considered is should a nuclear accident occur at a Ukraine nuclear power plant, most likely Ukraine would be liable and would have to provide compensation to victims in Ukraine and other countries, including Russia. How would these payments occur given Ukraine's financial situation? Most likely, western nations would have to pony up to assist Ukraine to meet its obligations.

Simply, one could find oneself in a situation where one Party would be liable to pay and would not have the means to do so, especially if nuclear insurers cancelled coverage before the event (e.g., Ukraine), and another Party who could be found liable but refuses to compensate victims or delays compensation by legal maneuvering (e.g., Russia). Some minor edits and updates to definitions in the texts are recommended. Discussions may be advisable around a threshold or reference dose when compensation during a time of war is warranted. Example: dose exposure is ≥ 20 mSv.

*6.2 Nuclear Safety [**yellow light**]*

- Convention on Nuclear Safety, https://www.iaea.org/topics/nuclear-safety-conventions/convention-nuclear-safety[28]

The Ukraine experience has shown difficulties in being fully compliant with Article 9 'Responsibility of the License Holder', Article 10 'Priority to Safety' and Article 16 'Emergency Preparedness'. It should be pointed out that the preamble states: 'Reaffirming that responsibility for nuclear safety rests with the State having jurisdiction over a nuclear installation'. Therefore, as jurisdiction and actual control are two separate issues and definitions, some tweaks to the Convention on Nuclear Safety will be needed to take into account these issues.

*6.3 Radioactive Waste and Spent Fuel Management [**yellow light**]*

- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention),

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no-111-volume-2023/2?utm_source=mnb&utm_medium=email&utm_campaign=Just Published [access: 2 September 2024].

[28] [access: 2 September 2024].

https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste[29]

The Joint Convention is primarily a civilian sector convention. It also applies to spent fuel and radioactive waste from military or defense programs if such materials are transferred permanently to and managed within exclusively civilian programs, or when declared as spent fuel or radioactive waste for the purpose of the Convention by the Contracting Party concerned.

The war in Ukraine has shown quite a large impact on Ukraine's ability to maintain obligations under the Joint Convention, which are listed below. However, the easiest solution here may be to designate in the Joint Convention that civilian spent fuel and radioactive waste facilities / disposal sites are areas of special protection which should be excluded from active military operations. Additionally, should an aggressor nation occupy such a site, then the obligations of the Joint Convention are encumbered on that nation to protect and preserve undisturbed any such facilities and wastes stored there.

- Due to unauthorized configuration change of the facility design (unauthorized modification) committed by Russia, operational license of the Dry Spent Fuel Storage Facility on ZNPP site was limited. **Affected – Articles 8, 21**
- On March 9, 2022 the external grid power supply was fully lost; diesel generators have limited amount of diesel fuel – the situation could lead to a loss of heat removal from the ChNPP SF-1 pools. **Affected – Article 4(i)**
- Logistical chains for staff rotation, equipment supply, spears, materials, medicals etc. were disrupted at ChNPP. **Affected – Articles 22(i), 26, 16(iii) (iv)**
- Radiation control system in the ChNPP Exclusion Zone (EZ), which serve radwaste management facilities and monitor the contaminated territory of the EZ incurred significant damage during the Russian occupation and need to be restored. **Affected – Articles 17(iii), 24(iii)**
- Radiological and Radioactive Waste characterization laboratories in the EZ and within the town of Chernobyl have been damaged. **Affected – Article 16(v)**

[29] [access: 2 September 2024].

- ! From April to August 2022, the regulator suspended a number of the licenses of facilities and activities in the EZ due to inability of the licensees to fully comply with regulations on nuclear and radiation safety, physical protection, and license conditions. **Affected – Article 19, point 2(ii)**
- ! An adequate emergency response is impossible due to the limitation of access of emergency staff (at the currently occupied ZNPP site and at the ChNPP site during its occupation and recovery period). **Affected – Articles 1, 25**
- ! The military actions significantly increased the threat and risk for sealed radiation sources to be damaged. Also 'orphan' or lost sources, which due to military invasion, have become out of the control of Ukraine and can be significantly damaged. **Affected – Article 28(1)**

*6.4 Notification of Nuclear Accident [**red light**]*

- Convention on Early Notification of a Nuclear Accident, https://www.iaea.org/topics/nuclear-safety-conventions/convention-early-notification-nuclear-accident

This convention requires States to report the accident's time, location, nature, and other data essential for assessing the situation. Notification is to be made to affected States directly or through the International Atomic Energy Agency (IAEA), and to the IAEA itself. Reporting is mandatory for any nuclear accident involving facilities and activities listed in Article 1.

From the Ukrainian perspective, the data transfer from ARMS (ASKRO) was blocked, as part of the information exchange between the Nuclear Power Plant crisis centers and the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU). Also, the transmission of this data in real time to the Decision Support Systems (JRODOS) and the IAEA International Radiation Monitoring System (IRMIS[30]) has been interrupted. Additionally, 11 stationary reporting posts are out of working condition and cannot

[30] *See* Presentation *Nuclear Safety and Security in Ukraine Risks, Threats, Lessons Learned* by Oleh Korikov, Acting Chairman – Chief State Inspector on Nuclear and Radiation Safety, https://www.oecd-nea.org/jcms/pl_82793/radiological-protection-during-armed-conflict-improving-regulatory-resilience-and-operational-applications [access: 2 September 2024].

be repaired. Because of the absence of direct communication between the regulator and the ZNPP operator, timely receipt of a notification from ZNPP in the event of an accident and verification of the reliability of information of conditions are impossible.

Compliance with the requirements of Articles 2 and 5 of the Convention becomes problematic not only for Ukraine, as a party to the Convention, but also for the IAEA to perform its functions. Further Article 4 of the Convention is hampered, since the tools for verifying the authenticity of information that can be broadcast from the site of the occupied ZNPP. Thus, changes to the convention should be made to ensure that interference by an aggressor nation on reporting requirements and equipment of the responsible operator / national authority are not severed.

*6.5 Physical Protection – Nuclear Material [**red light**]*

- Convention on the Physical Protection of Nuclear Material (CPPNM), https://www.iaea.org/publications/documents/conventions/convention-physical-protection-nuclear-material-and-its-amendment[31]

In the CPPNM, legal obligations are established for Parties regarding the physical protection of nuclear material used for peaceful purposes. This is for (1) during international transport, (2) the criminalization of certain offences involving nuclear material; and (3) international cooperation, (example: theft, robbery or any other unlawful taking of nuclear material or credible threat thereof). The 2005 amendment[32] expanded the scope of the original treaty to cover physical protection of nuclear facilities and nuclear material used for peaceful purposes in domestic use, storage and transport. However, observe how the language waffles/excludes considerations for the activities of armed forces during an armed conflict.

Article 2, 4(b) – 'The activities of armed forces during an armed conflict, as those terms are understood under international humanitarian law, which are governed by that law, are not governed by this

[31] [access: 2 September 2024].

[32] Amendment to the Convention on the Physical Protection of Nuclear Material (2005) https://www.iaea.org/sites/default/files/publications/documents/infcircs/1979/infcirc274r1m1c.pdf [access: 2 September 2024].

Convention, and the activities undertaken by the military forces of a State in the exercise of their official duties, inasmuch as they are governed by other rules of international law, are not governed by this Convention.'

Certainly, changes are warranted in this context given the experiences in Ukraine. The physical protection of nuclear material must be respected by 'military forces of a State in the exercise of their official duties' given the amount of destruction and damage caused by Russian military forces to various laboratories, hospitals, health clinics and other nuclear sites across Ukraine. Further, criminal liabilities should be prescribed for military commanders and/or soldiers in the field for breach and failing to adhere to these obligations.

Impacts on Ukraine's ability to meet obligations of the convention are:

- FUNDAMENTAL PRINCIPLE A: Responsibility of the State
- FUNDAMENTAL PRINCIPLE C: Legislative and regulatory framework
- FUNDAMENTAL PRINCIPLE D: Competent authority
- FUNDAMENTAL PRINCIPLE E: Responsibility of the license holders

*6.6 Assistance During Nuclear Emergency [**red light**]*

- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, https://www.iaea.org/topics/nuclear-safety-conventions/convention-assistance-case-nuclear-accident-or-radiological-emergency

The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, adopted in 1986 following the Chernobyl nuclear plant accident sets out an international framework for co-operation among State parties and with the IAEA to facilitate prompt assistance and support in the event of nuclear accidents or radiological emergencies. What has been shown in the case of Ukraine, should a nuclear accident occur, that it could be difficult for the affected Party and other Contracting Parties to adequately respond to requests for assistance.

Major changes and updates to the convention should be undertaken to include:

- Safety corridors to allow Contracting Parties to bring material and personnel unhindered into the affected area when requested under the convention.

- Requirement for the establishment by the military authorities of safe-passage and evacuation routes for the civilian population, when needed.
- When a nuclear emergency has been declared and determined to be a reality by the IAEA, an agreement to cease military operations within a > X-mile radius from the impacted nuclear facility or site.

7 Conclusion & Final Thoughts

What is shown, the peacetime Radiation Protection standards and guidance that have been employed for the past 60-80 years provide adequate protection for the public and nuclear workers. As can be seen from the Sweden example, using current guidelines provide a reasonable basis for setting expanded directives with an increasingly allowable dose exposure during a nuclear emergency during a time of war. As was mentioned, there are going to be challenges to re-explain radiation exposure safety principles in conjunction with established regulatory limits, as current guidelines are a mixture of scientific findings and societal judgments in the development of acceptable radiation dose limits, with societal judgments weighing heavily on these pronouncements.

Further, lessons-learned from the Fukushima accident could serve as a template for preparation and coordinated responses to a radiological emergency during a time of war. That being said, the international nuclear conventions and national laws/regulations do need to be revised taking into consideration the experiences from the Russian invasion of Ukraine and how an active military incursion near a commercial nuclear power plant could impact the functioning of nuclear legislation and regulatory agencies. Furthermore, the international community will have to begin discussions how the international nuclear framework/conventions and national law can be strengthened to better protect civilian nuclear power plants, waste disposal and storage facilities, laboratories and hospitals / health clinics (where radioactive sources are used), as well as the public and environment. Of course, gaining international consensus on any changes will be a high hurdle to overcome.

Finally, as nations, such as Sweden, work to amend their radiation protection legislation to consider higher reference dose exposure, a realization must be made that this will necessitate a huge public relations /

education campaign with wider stakeholder involvement. Given financial challenges during war, discussions on what exposure levels that would allow for compensation under national law and the liability conventions (e.g., ≥ 20 mSv), might also need to be on the table for open debate.

Authors' notes: The thoughts and opinions in this paper reflect those of the authors. They are not to be considered the opinions of any other person/organization, including the International Nuclear Law Association.

PART VI

NUCLEAR LAW AND THE NEW SPACE ERA

Chapter 14

NUCLEAR LAW IN THE NEW SPACE ERA. COMMERCIAL USE OF OUTER SPACE AND THE FUTURE OF THE LAW OF NUCLEAR ENERGY

Jakub Handrlica
Full Professor in Administrative Law, Faculty of Law
Charles University in Prague, Czech Republic
Member of the International Nuclear Law Association (AIDN/INLA)
Member of the International Institute of Space Law (IISL)
jakub.handrlica@prf.cuni.cz
ORCID: https://orcid.org/0000-0003-2274-0221

Abstract

The entire world has entered the New Space Era. Advanced space technologies have significantly reduced launch costs, and the number of actors launching satellites into orbit has increased continuously. Advanced space technologies have opened the door to nanosatellites and microsatellites, enabling missions that large satellites cannot accomplish – such as providing constellations for low-data-rate communications, in-orbit inspection of larger satellites, etc. All these technological advances have opened Outer Space for commercial use by private entities. In the New Space Era, the State has lost its previously established monopoly over the exploration and use of Outer Space. Having said this, the New Space Era also represents considerable challenges for the prospective deployment of nuclear technologies in Outer Space. For the time being,

a myriad of advanced nuclear technologies are being researched and developed by established energy companies, innovators, and nuclear start-ups. Current projects include ultra-lightweight nuclear propulsion probes for deep space exploration and advanced portable microreactors for space applications, such as space mining and delivering power to human settlements in Outer Space. Taking into account the involvement of commercial entities in these projects, one may predict that the private sector will have considerable interest in the use of nuclear energy in space activities in the future. This article argues that nuclear law needs to reflect prospective challenges arising from the future commercialisation of nuclear use in Outer Space. The current legal framework has reflected an *étatist* approach to space activities, primarily focused on government-led space projects. This approach, however, is insufficient to address the challenges posed by the prospective commercialisation and privatisation of nuclear activities in Outer Space. Future laws must address risks arising from the gradual emergence of private nuclear space corporations, innovators, and start-ups. At the same time, the New Space Era poses a challenge to the international discourse on nuclear law, which has neglected this topic to date.

1 Introduction[1]

The entire world has entered the *New Space Era*.[2] Launch costs have reduced significantly, and the number of actors launching satellites into orbit will continue to increase. Lower costs of space travel are opening the door to the establishment of extraterrestrial footholds. Experts have identified 17,000 asteroids which can be exploited for resource extraction, with one estimate putting the size of the space industry at $2.7tn per year by 2050. At the same time, the nanosatellite and microsatellite segments of the space industry have been growing. Smaller, satellites require cheaper launch vehicles and can sometimes be launched in multiples. Further,

[1] This is a written version of my presentation, delivered at the 25th Nuclear Inter Jura Congress, which was organised by the International Nuclear Law Association (AIDN/INLA) in Warsaw, Poland, from November 3rd to 7th, 2024.

[2] *See* A. Golkar, A. Salado, *Definition of New Space – Expert Survey Results and Key Technology Trends*, "IEEE Journal on Miniaturization for Air and Space Systems" 2021, Vol. 2, No 1, at pp. 2 et seqq.

smaller and lighter satellites bring the opportunity to enable missions large satellites cannot accomplish, such as providing constellations for low data rate communications, in-orbit inspection of larger satellites, testing or qualifying new hardware before using it on a more expensive spacecraft, manufacturing of pharmaceuticals under space conditions (space pharmacy), etc.[3]

All these technological advances have opened the space for commercial use by private entities.[4] Thus, in the New Space Era, the State has lost its previously established monopoly on the exploration and use of Outer Space. In this respect, the New Space Era has been characterised by both intensive technological development and the gradual commercialisation and privatisation of space activities.

Having said this, the New Space Era also represents considerable challenges for the prospective deployment of nuclear technologies in Outer Space.[5] For the time being, a myriad of advanced nuclear technologies is being researched and developed by established energy companies, innovators, and nuclear start-ups. This leads to the gradual emergence of a commercial space nuclear market. Despite being in its infancy, one may already know Jericho Locke and Bhavya Lal have outlined[6] four distinctive components of this prospective market, which are as follows:

1. **Suppliers:** Potential suppliers range from recent startups to established suppliers, and most have an existing terrestrial power business. These companies are leveraging developments and trends in terrestrial technology, including small or microreactors, lower power levels, advanced fuels, high outlet temperatures, and offsite fabrication and assembly.[7]

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[3] A. Gilbert, *Nuclear for space propulsion and surface power*. In: A. Foss, N. Stauff (eds), *New Directions in Nuclear Energy. Innovation and Opportunities in Fission and Fusion for Global Decarbonization*, Sawston: Woodhead Publishing 2026, pp. 339–374.

[4] *See* G. Denis et al., *From new space to big space: How commercial space dream is becoming a reality*, "Acta Astronautica" 2020, Vol. 166, at pp. 431 et seqq.

[5] This article aims to address exclusively prospective peaceful uses of nuclear energy in Outer Space.

[6] *See* J. Locke, B. Lal, *Emergence of a Commercial Space Nuclear Enterprise*, "Nuclear Technology" 2020, Vol. 206, Issue 8: Selected papers from the 2019 Nuclear and Emerging Technologies for Space Topical Meeting (NETS 2019), at pp. 1109 et seqq. Also *see* G. Leterre, *Protecting the Last Frontier. Space Mining and Environmental Sustainability*, Aalphen an den Rijn: Wolters Law International 2024.

[7] Ibid.

2. **Fuel Developers:** Space fission systems require higher enrichment levels than their terrestrial counterparts to increase energy density but enriching above 20% has proliferation and business challenges. Highly Enriched Uranium (HEU) has high safety and proliferation risks similar to Pu-238. The only privately owned facilities licensed to handle and manufacture HEU fuel are owned by BWXT, which supplies and services the Navy's nuclear reactors. For the time being, licensing facilities to handle HEU is potentially cost-prohibitive without government support.[8]
3. **Launchers:** In recent years, United Launch Alliance has launched nuclear payloads. The fact is, however, that these launches have so far had a research and development nature. Newer private companies—namely SpaceX and Blue Origin—are developing larger rockets and could, in principle, launch nuclear payloads as commercial providers.[9]
4. **Users:** For the time being, private entities have shown considerable interest in using nuclear power in Outer Space. This interest covers the entire range of nuclear systems, including nuclear electric or thermal propulsion and surface reactors to support human and in situ resource utilisation operations (including space mining) on the surface of the Moon or Mars.[10]

Private space companies have a commercial interest in nuclear power, both to use its outputs (e.g., propulsion and power) and to provide those outputs by operating the systems. For the time being, however, a real boom of commercial nuclear projects for space use is expected in the decade to come.[11] It is crystal clear that commercial use of nuclear power in Outer Space will require a transparent and predictable legal framework that guarantees a high level of safety and transparency. Such a framework plays an important role both for the environment and the concerned public and for the private entities themselves, as many of them

[8] Ibid.

[9] Ibid.

[10] *See* H. Vertadier, A. Gilbert, *The importance of nuclear energy governance in establishing sustainable lunar settlements*. In: *Proceedings of the 74th International Astronautical Congress*, IAC 2023, paper 77123. Also *see* S. Borowski, *The use of nuclear propulsion, power and "in-situ" resources for routine lunar space transportation and commercial base development*, "Science and Technology Series" 2004, Vol. 108, at pp. 225 et seqq.

[11] *See* J. Locke, B. Lal, *Emergence of a Commercial Space Nuclear Enterprise…*, at p. 5.

have identified the lack of clear rules as a significant obstacle to the further development of the nuclear project for space use.[12]

The fact is, however, that the discourse in nuclear law hasn't paid any considerable attention to the legal framework applicable to future commercial use of nuclear energy in Outer Space so far.[13] The following examples may demonstrate this more clearly: In 2022, Sweet & Maxwell published the 3rd edition of *The Law of Nuclear Energy*, authored by Helen Cook. While the author addresses[14] advanced nuclear technologies and their legal implications in extensive detail in her book, the issues of prospective nuclear use in Outer Space remain beyond the author's attention. Neither the *Principles and Practice of International Nuclear Law*, published[15] by the OECD/NEA in the same year, paid any attention to legal issues prospectively arising from nuclear use in Outer Space. The *Burges Salmon Guide to Nuclear Law*,[16] published very recently by the leading British law firm, also remains silent regarding the legal framework applicable to uses of nuclear energy in Outer Space. This fact reflects, to some extent, that priority is being given to advanced nuclear technologies which are most likely to be deployed in the forthcoming decade, such as small modular reactors. At the same time, most of the major international agreements adopted in the field of peaceful use of nuclear energy do limit their geographical scope of application to terrestrial technologies. Also, the presentations held at the *25th Nuclear Inter Jura Congress* have demonstrated the same degree of disinterest in the deployment of advanced nuclear technologies in Outer Space. While the overall theme of the Congress was *Nuclear New Build Renaissance: In Search for New Approaches to Legal and Regulatory Challenges*, almost exclusive attention

[12] *See* ibid., at p. 4.

[13] For a salient exception, *see* A. Villicaña, *Nuclear Space Law: Past, Present, and Future Issues for Commercial Launch*, Washington DC: Association of Commercial Space Professionals 2024, https://acsp.space/wp-content/uploads/2024/10/Nuclear-Space-Law-PPF.pdf [access: 1 July 2026]. Also *see* J. Long, *Space nuclear power resources*. In: P. J. Blount, M. Hofmann (eds), *Elgar Encyclopedia of Space Law*, Cheltenham: Edward Elgar 2025, at pp. 281 et seqq.

[14] *See* H. Cook, *The Law of Nuclear Energy*, 3rd edition, London: Sweet & Maxwell – Thomson Reuters 2022, at pp. 423 et seqq.

[15] *See* OECD/NAE (eds), *Principles and Practice of International Nuclear Law*, Paris: OECD/NEA 2022.

[16] *See* I. Salter, I. Truman (eds), *Burges Salmon Guide to Nuclear Law*, 3rd edition, sine loco: Burges Salmon 2024.

was paid to the prospects of advanced nuclear technologies on Earth (small modular reactors) or at the High Seas (transportable nuclear power plants).

Neither discourse on space law has shown a different picture. Traditionally, the scholarship of space law has paid attention to legal implications arising from government-let nuclear use in Outer Space.[17] Also, those authors who addressed the future of space law have, in principle, paid only attention to the government-led use of nuclear energy in Outer Space.[18] The fact is, however, that very recently, the focus has been shifted towards legal issues arising from the commercial use of Outer Space.[19] Despite this, only a few authors[20] have addressed the phenomenon of space privatisation with respect to the prospective deployment of advanced nuclear technologies in Outer Space.

This article argues that nuclear law needs to reflect prospective challenges arising from the future commercialisation of nuclear use in Outer Space. The current legal framework has been reflecting an *étatist* approach to any activities in Outer Space. This approach is, in principle, focused on the obligations of the State *vis-à-vis* other States in the field of space exploration. It reflects the monopoly of the State on any space

[17] *See* J. MacAvoy, *Nuclear Space and the Earth Environment: The Benefits, Dangers, and Legality of Nuclear Power and Propulsion in Outer Space*, "William & Mary Environmental Law and Policy Review" 2004–2005, Vol. 29, Issue 1, at pp. 191 et seqq.; N. Malysheva, O. Chebotaryov, *International law and peaceful use of nuclear power sources in outer space*. In: *Proceedings of the 47th Colloquium on the Law of Outer Space*, Reston, VA: American Institute of Aeronautics and Astronautics 2005, at pp. 481 et seqq.; I. Bouvet, *Use of nuclear power sources in Outer Space. Key technology legal challenges*, "Journal of Space Law" 2004, Vol. 30, Issue 2, at pp. 203 et seqq. Also *see* V. Kopal, *The Use of Nuclear Power Sources in Outer Space: A Net Set of United Nations Principles*, "Journal of Space Law" 1991, Vol. 19, Issue 2, at pp. 103 et seqq.

[18] *See* S. Mirmina, D. Den Herder, *Nuclear Power Sources and Future Space Exploration*, "Chicago Journal of International Law" 2005, Vol. 6, No 11, at pp. 149 et seqq.

[19] *See* L. Smith, I. Baumann, S. Wintermuth (eds), *Routledge Handbook of Commercial Space Law*, London: Routledge 2024. Also *see* M. De Zwart, S. Henderson (eds), *Commercial and Military Uses of Outer Space*, Vienna: Springer International 2021.

[20] *See* G. Venturini, *The Legal Regime of the Use of Nuclear Power Sources in Space Missions*. In: J. L. Black-Branch, D. Fleck (eds), *Nuclear Non-Proliferation in International Law*, Volume V: *Legal Challenges for Nuclear Security and Deterrence*, Vienna: Springer International 2020, at pp. 73 et seqq. *See* also Y. Zhao, *Soft Laws Relating to Space Activities*. In: S. Bhat, D. Ukey, A. Variath (eds), *International Space Law in the New Space Era: Principles and Challenges*, Oxford: Oxford University Press 2024, at pp. 183 et seqq.

activities, including those where peaceful use of nuclear energy is being deployed. This approach, however, is not sufficient to address challenges arising from the prospective commercialisation and privatisation of activities in Outer Space. Future laws must address risks arising from the gradual emergence of private nuclear space corporations, innovators, and start-ups.

At the same time, the New Space Era represents a challenge to the international discourse on nuclear law, which has neglected this topic so far.

2 *Étatist* approach to nuclear activities in Outer Space

The *étatist* approach to nuclear activities in Outer Space has been enshrined in the *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*.[21] This statement deserves further clarification: the fact is that the Preamble provides that: 'in some missions in outer space nuclear power sources are particularly suited or even essential owing to their compactness, long life and other attributes.'[22]

Thus, the Preamble itself does not exclude commercial use of nuclear energy in Outer Space by private entities.[23] At the same time, the *Principles* provide that:

> States shall bear international responsibility for national activities involving the use of nuclear power sources in outer space, whether such activities are carried on by governmental agencies or by non-governmental entities […]. When activities in outer space involving the use of nuclear power sources are carried on by an international organisation, responsibility for compliance with the aforesaid Treaty and the recommendations contained in these Principles shall be borne both by the international organisation and by the States participating in it.[24]

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[21] Resolution adopted by the General Assembly of the United Nations. 48/67 *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* (85th plenary meeting, 14 December 1992).

[22] Ibid.

[23] *See* H. Quizhi, *Towards a New Legal Regime for the Use of Nuclear Power Sources in Outer Space*, "Journal of Space Law" 1986, Vol. 14, Issue 2, at pp. 95 et seqq.

[24] Principle 8.

This wording has been influenced by the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies[25], which establishes the international responsibility of States for space activities in general.[26] Having cited this provision, it is crystal clear that the *Principles* permit the commercial use of nuclear energy in Outer Space not only by government-led projects but also by private entities (*non-governmental entities*).[27]

When referring to the *étatist* character of the regulation, one refers to the fact that the *Principles* govern exclusively the mutual relations between the States. In this respect, the *Principles* use the term *launching State*, or *State launching*, to refer to the State that 'exercises jurisdiction and control over a space object with nuclear power sources on board at a given point in time that is relevant to the principle concerned.'[28]

Thus, the *Principles* provide for a general rule, under which 'in order to minimise the quantity of radioactive material in space and the risks involved, the use of nuclear power sources in outer space shall be restricted to those space missions which non-nuclear energy sources cannot operate in a reasonable way.'[29] This general principle is subsequently elaborated in further obligations of the *launching States*:

1. States launching space objects with nuclear power sources on board shall endeavour to protect individuals, populations and the biosphere against radiological hazards.[30]
2. Further, a launching State shall ensure that a thorough and comprehensive safety assessment is conducted at the time of launch. This assessment shall cover all relevant phases of the mission and all systems involved, including the means of launch, the space platform, the nuclear power source and its equipment,

[25] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (adopted 19 December 1966, in force 27 January 1967), 610 UNTS 205.

[26] Article VI.

[27] V. Iavicoli, *Nuclear Power Sources in Outer Space for Peaceful Purposes: An Evolving Legal Framework*. In: C. Cinelli (ed.), *Regulation of Outer Space International Space Law and the State*, London: Routledge 2024, at pp. 153 et seqq.

[28] Principle 2.

[29] Principle 3.

[30] Ibid.

and the means of control and communication between ground and space.[31]

3. Any State launching a space object with nuclear power sources on board shall, in a timely fashion, inform States concerned in the event this space object is malfunctioning with a risk of re-entry of radioactive materials to the Earth.[32] In this respect, the *Principles* also provide for obligations of States to mutual assistance in the case of an expected re-entry into the Earth's atmosphere of a space object containing a nuclear power source on board and its components.[33]
4. Lastly, the *Principles* also provide that each State which launches or procures the launching of a space object and each State from whose territory or facility a space object is launched shall be internationally liable for damage caused by such space objects or their parts. This fully applies to the case of such a space object carrying a nuclear power source on board.[34]

Consequently, while a comprehensive set of rules has been established regarding mutual relations between States, a similar set of rules governing relations between the launching State and private entities aiming at nuclear use in Outer Space has been absent. This situation clearly reflects the overall situation in the past decades, where States possessed a monopoly on nuclear use in Outer Space.[35] However, with the gradual commercialisation and privatisation of Outer Space, one must expect the deployment of advanced nuclear technologies there also by private entities. In the future, such entities may be represented either by commercial nuclear corporations or by nuclear innovators and start-ups. A transparent and foreseeable legal framework applicable to these private entities will be urgently needed to ensure a very high degree of nuclear safety in Outer Space.

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[31] Principle 4.

[32] Principle 5.

[33] Principle 7.

[34] Principle 9.

[35] *See* IAEA (ed.), *The Role of Nuclear Power and Nuclear Propulsion in the Peaceful Exploration of Space*, Vienna: IAEA 2005, at pp. 2–7.

3 Modern approach to nuclear activities in Outer Space

Any prospective deployment of commercial ultra-lightweight nuclear propulsion probes for deep space exploration and advanced portable microreactors for space applications in the future will require an appropriate legal framework. Such a legal framework must address mutual relations between the *launching State* on the one hand and *the private entity* (*non-governmental entities* in the wording of the *Principles*) aiming to use nuclear power in Outer Space on the other commercially. The fact is that the *launching State* will still bear international responsibility for any launched space object bearing advanced nuclear technologies. This will most probably become the trigger for establishing new rules that will specify provisions for the safe operation of their technologies in Outer Space.

Having said this, one may ask to what extent the currently accepted principles of nuclear law[36] will apply to the future use of advanced nuclear technologies in Outer Space. The following paragraphs aim to address the applicability of the 1) permission principle, 2) sustainable development principle, and 3) compensation principle with respect to the future commercial deployment of advanced nuclear technologies in Outer Space.

Ad 1) While the Convention on Nuclear Safety[37] has provided the rules for authorisation, this Convention will not be applicable to any advanced nuclear technologies deployed in Outer Space – neither to those serving as means of propulsion nor to those which will serve as a source of power for space mining, or for human settlements. The Convention was designed exclusively to reflect the peculiarities of Earth-based nuclear installations. Consequently, its framework is not suitable for covering the specific nature of nuclear use in outer space. The use of nuclear power in outer space has unique safety considerations compared with terrestrial applications. Mission launch and outer-space operational requirements impose size, mass, and other space-environment limitations that are not present at many terrestrial nuclear facilities. For some applications,

[36] C. Stoiber et al., *Handbook on Nuclear Law*, Vienna: IAEA 2003, at pp. 5–20.

[37] Convention on Nuclear Safety (adopted 20 September 1994, in force 24 October 1996), 1963 UNTS 294.

space nuclear technologies must operate *autonomously* at great distances from Earth in harsh environments. Potential accident conditions resulting from launch failures and inadvertent re-entry could expose these technologies to extreme physical conditions. These and other unique safety considerations for the use of space nuclear technologies are significantly different from those for terrestrial nuclear systems.[38] This is the reason why the Convention limits its technological scope to 'land-based civil nuclear power plants under its jurisdiction, including such storage, handling and treatment facilities for radioactive materials as are on the same site and are directly related to the operation of the nuclear power plant.'[39]

In this respect, the *Safety Framework for Nuclear Power Source Applications in Outer Space*, which has been adopted jointly by the United Nations Committee on the Peaceful Uses of Outer Space Scientific and the IAEA, argues[40] that the permission principle must be applicable also *vis-à-vis* advanced nuclear technologies in Outer Space. In this respect, the *Safety Framework* provides that:

> the government that oversees and authorises the launch operations for space NPS (= nuclear power sources) missions should establish a mission launch authorisation process focused on nuclear safety aspects. The process should include an evaluation of all four relevant information and considerations from other participating organisations. The mission launch authorisation process should supplement the authorisation processes covering non-nuclear and terrestrial aspects of launch safety. An independent safety evaluation (i.e. a review, independent of the management organisation conducting the mission, of the adequacy and validity of the safety case) should be an integral part of the authorisation process. The independent safety evaluation should consider the entire space NPS application—including the space NPS, spacecraft, launch system, mission design and flight rules—in assessing the risk to people and the environment from relevant launch, operation and end-of-service phases of the space mission.[41]

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[38] *See* UN/IAEA (eds), *Safety Framework for Nuclear Power Source Applications in Outer Space*, Vienna: IAEA 2009, at p. 1.

[39] Convention on Nuclear Safety, Article 2.i.

[40] *See* UN/IAEA (eds), *Safety Framework for Nuclear Power Source Applications…*

[41] Ibid.

In this respect, the *Safety Framework for Nuclear Power Source Applications in Outer Space* also argues that, unlike many terrestrial nuclear applications, space applications are used infrequently, and their requirements can vary significantly depending on the specific mission.[42] While this statement can be considered correct for the time being, the future will most probably involve more frequent use of advanced nuclear technologies in space. Consequently, future laws will be able to distinguish among various types of advanced technologies and set specific rules to address safety considerations for each.

Having said this, one must remember that not only authorisation but also continuous control of nuclear technologies operated in Outer Space will need to be secured. In this respect, one has to seriously consider the future use of satellites for observation purposes by national regulatory authorities.

Ad 2) Any prospective use of advanced nuclear technologies in Outer Space will imply the need to address the problem of nuclear waste. Small modular reactors deployed to power mining colonies or human settlements on space objects will produce nuclear waste that must be safely stored and subsequently disposed of. The fact is that neither the *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* nor the *Safety Framework for Nuclear Power Source Applications in Outer Space* had explicitly addressed the issue of nuclear waste arising from the use of nuclear technologies in Outer Space. Neither the provisions of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management[43] seem to be applicable to this type of waste, as the Joint Convention was adopted explicitly to complement the Convention on Nuclear Safety.

However, one may argue that the issues of nuclear waste mitigation and the obligation to use nuclear sources sustainably actually arise from the concept of the launching State's international responsibility, as enshrined in the *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*.[44]

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[42] Ibid., at p. 1.

[43] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (adopted 5 September 1997, in force 18 June 2001), 2153 UNTS 303.

[44] Principle 8.

In this respect, one may argue that the sustainable development principle must apply to nuclear waste produced in Outer Space, in the same way it currently applies to nuclear waste produced on Earth. While the *launching State* will bear ultimate responsibility for waste produced under its jurisdiction, the authorisation holder will be primarily responsible. Consequently, the future law of nuclear energy must provide for obligations of the authorisation holders to bear responsibility for their waste in accordance with the *polluter pays principle*. Financial and other arrangements for the safe disposal of waste produced in Outer Space will be the obligation of the authorisation holder.

Having said this, one may add that the technical solution for the safe disposal of this waste remains open for the time being.[45] Future technological developments may enable the disposal of nuclear waste in geological formations on space objects, which could represent a viable solution.

Ad 3) The fact is that any commercial use of nuclear energy in Outer Space will represent a source of risk. Consequently, compensation arrangements must be provided by law. In this respect, a significant difference has arisen between space law and nuclear law. Space law has traditionally followed the concept of the launching State's international liability. This has been enshrined in the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies[46] and in the Convention on International Liability for Damage Caused by Space Objects.[47] Subsequently, this regime has also been reflected in the *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*, which provide that:

> Each State which launches or procures the launching of a space object and each State from whose territory or facility a space object is launched shall be internationally liable for damage caused by such space objects or their parts. This fully applies to the case of such a space object carrying a nuclear power source on board. Whenever two or more States jointly launch

[45] *See* H. Kim, C. Park, O. Kwoon, *Conceptual design of the space disposal system for the highly radioactive component of the nuclear waste*, "Energy" 2016, Vol. 115, at pp. 155 et seqq.

[46] Article VII.

[47] Convention on International Liability for Damage Caused by Space Objects (adopted 29 November 1971, in force 1 September 1972), 961 UNTS I-13810.

> such a space object, they shall be jointly and severally liable for any damage caused, in accordance with Article V of the above-mentioned Convention (= Convention on International Liability for Damage Caused by Space Objects).[48]

Under the scheme of international liability, the *launching State* bears liability for damages caused by launched space objects *vis-à-vis* other States. The liability scheme, as applicable in nuclear law, is somewhat different. Both the Paris Convention on Third Party Liability in the Field of Nuclear Energy[49] and the Vienna Convention on Civil Liability for Nuclear Damage[50] provide for the exclusive liability of the authorisation holder. The fact is, however, that this regime has been so far limited to terrestrial nuclear installations.

A future deployment of advanced nuclear technologies in Outer Space by commercial entities will imply a significant challenge for the *launching States.* Without any further legal measures, the *launching States* will be held liable for any damages caused by advanced nuclear technologies launched from their territory or launched by an entity under their jurisdiction. Such a situation will undeniably trigger lawmakers' interest in channelling liability directly to authorisation holders and obliging them to provide appropriate insurance. This can be realised either by means of domestic legislation or in the form of a brand-new instrument of international law.

To summarise briefly what has been said, gradual commercialisation and privatisation of space activities also imply myriad challenges for nuclear law. While the attention of the community of nuclear law is being paid today in particular to legal issues arising from nuclear new build on Earth, the New Space Era opens a totally new perspective for the deployment of advanced space technologies at the final frontier of our Universe. A future commercial use of advanced nuclear technologies in Outer Space is highly probable. The law on nuclear energy must address this future scenario and provide a robust, comprehensive legal framework.

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[48] Principle 9.

[49] Convention on Third Party Liability in the Field of Nuclear Energy (adopted 29 July 1960, in force 1 April 1968), 329 UNTS 13706.

[50] Vienna Convention on Civil Liability for Nuclear Damage (adopted 21 May 1963, in force 12 November 1977), 1063 UNTS 266.

4 A way forward

Ten years ago, the *21st Nuclear Inter Jura* convened in the Palacio San Martín in Buenos Aires, Argentina. A comparison between the congress programme held in Buenos Aires and the one held ten years later in Warsaw demonstrates the dynamic development of the nuclear industry. While ten years ago, virtually no attention was paid to legal implications arising from advanced nuclear technologies, the *25th Nuclear Inter Jura* was almost entirely focused on challenges arising from small and micro-reactors to various fields of nuclear law. In this respect, one may ask what the focus of *Nuclear Inter Jura 2034* will be. The answer will depend on advances in nuclear technology and national energy strategies, as well as on the likelihood of a major nuclear incident occurring. Reflecting on the current discussions, one may expect that the use of advanced nuclear technologies in Outer Space will represent one of the challenges discussed at the *Nuclear Inter Jura 2034.*

The challenges arising from the perspective of nuclear law are two-fold. Firstly, the discussion on nuclear law must abstain from the purely terrestrial focus and must begin to realise that the final frontier of relations governed by the law of nuclear energy lies in Outer Space. Secondly, one must take into consideration that the use of nuclear power in Outer Space will pose distinct risks and implications that will require appropriate legal tools to address. Thus, one may expect that the future law of nuclear energy, as used commercially in Outer Space, will not merely duplicate the existing legal framework but, to some extent, also constitute a brand-new set of rules.

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SMALL MODULAR REACTORS (SMRs): LEGAL AND REGULATORY CHALLENGES

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PART V
DECOMMISSIONING AND RADIOLOGICAL PROTECTION

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Lorraine Chiwenga

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PART VI
NUCLEAR LAW AND THE NEW SPACE ERA

Chapter 14
Nuclear Law in the New Space Era. Commercial Use of Outer Space and the Future of the Law of Nuclear Energy
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Wydawnictwo Naukowe
Uniwersytetu Pomorskiego w Słupsku

UNIWERSYTET POMORSKI W SŁUPSKU
DUBIUM SCIENTIAE INITIUM

www.wydawnictwo.upsl.edu.pl
wydaw@upsl.edu.pl
tel. 59 840 53 78

9 788374 674331