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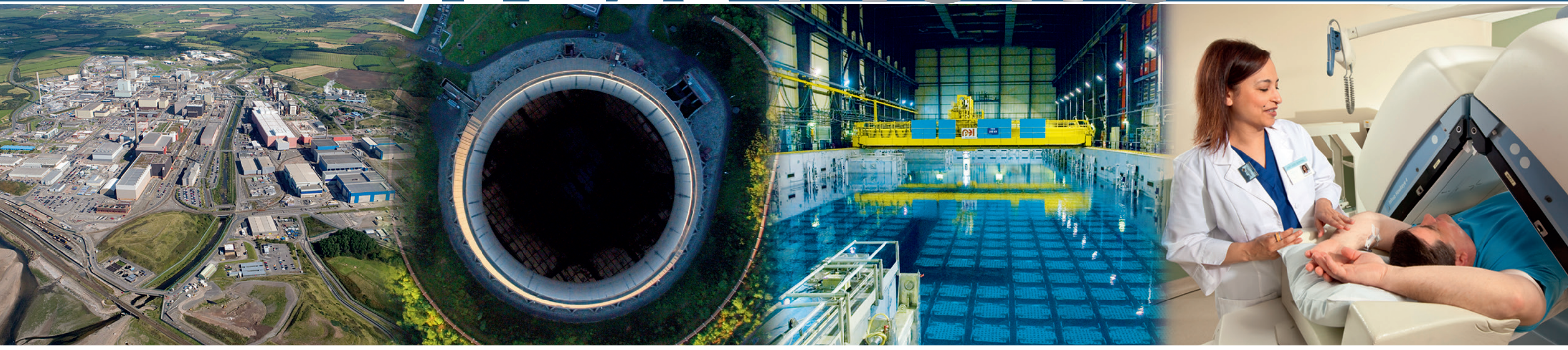

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NEA
NUCLEAR ENERGY AGENCY

NEA News

Volume No. 35.1 2017

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OECD Boulogne building.

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Innovation in nuclear power for a sustainable energy future

Most countries agree on the importance of developing a sustainable energy policy in response to security of supply, environmental protection and affordability concerns.

For nuclear energy to effectively contribute to sustainability, it will need to simultaneously meet the challenges arising in relation to flexibility, safety and cost through a constant push for technological evolution:

- In relation to security of supply, nuclear technology already provides robust baseload electricity and is further deployable on a large-scale to meet the expected increasing needs in generation capacity associated with strong decarbonisation scenarios. But a low-carbon energy mix with a large share of variable renewable energy will require nuclear generation to evolve towards more flexibility, which implies a need for optimisation and innovation in nuclear technology, including load-following, small and medium reactors and co-generation.
- As a clean air, low-carbon technology, nuclear technology can meet environmental protection objectives with continuous improvements triggered through innovation in safety and radioactive waste management.
- The decreasing cost of renewable technologies and the growing production of shale gas will also require innovation on the part of nuclear technology to optimise costs throughout its entire life cycle so that it can remain competitive.

To help its member countries respond to such challenges, the Nuclear Energy Agency launched a broad initiative called "Nuclear Innovation 2050" (NI2050) with the aim of bringing countries around the table to consider new co-operative approaches that would accelerate the pace of research and the deployment of innovative nuclear technologies that contribute to a sustainable energy mix. This goal is also addressed through the organisation of international events such as the NEA Workshop on Advanced Reactor Systems and Future Energy Market Needs (see article on p. 24).

Multilateral approaches will create the confidence needed for the worldwide deployment of innovative technologies via a joint identification of priorities, the establishment of solid common foundations based on the scientific validation of technologies and the definition of shared qualification methods to feed into robust licensing processes.

Because safety has to be "built-in" to the early stages of any technological evolution, some level of interaction with safety related bodies is necessary from these early stages. International collaboration among safety bodies that share an interest in the ongoing evolution of technologies is probably one of the most effective ways for them to get early insight into the safety aspects of a "new" technology, without compromising regulatory independence. The NEA could offer such a framework, allowing safety insights into new technologies by providing a broad platform for discussion, in particular within the NEA Committee on the Safety of Nuclear Installations (CSNI) and the NEA Committee on Nuclear Regulatory Activities (CNRA).

The NI2050 has now selected a set of topical areas to develop "10-year programmes of action" on accident-tolerant fuels, severe accident knowledge and management, passive safety systems, the management of ageing structures, advanced fuels and materials, advanced components, fuel cycle chemistry/recycling, heat production and cogeneration, modelling and simulation, digitalisation and measurements, infrastructures and demonstrations.

Creating the necessary drivers for innovation in nuclear technology is the most important condition for nuclear energy to play a role in the sustainable energy mix of the future. The multilateral approaches to technological evolutions and innovation developed within the context of NI2050 can help in accelerating this innovation process and creating the confidence necessary for the licensing and deployment of new technologies in a worldwide market. Not all countries are facing innovation with the same level of proactivity. Those countries lacking innovation capacities may soon reach a point of no-return when they will have to largely rely on technologies emanating from the limited number of countries in which nuclear technology is still evolving to fit the future, as yet uncertain, global energy framework.

Daniel Iracane,
Deputy Director-General and Chief Nuclear Officer

Legacy management: An old challenge with a new focus

by M. Gillogly

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Aerial view of the Sellafield site (2014).

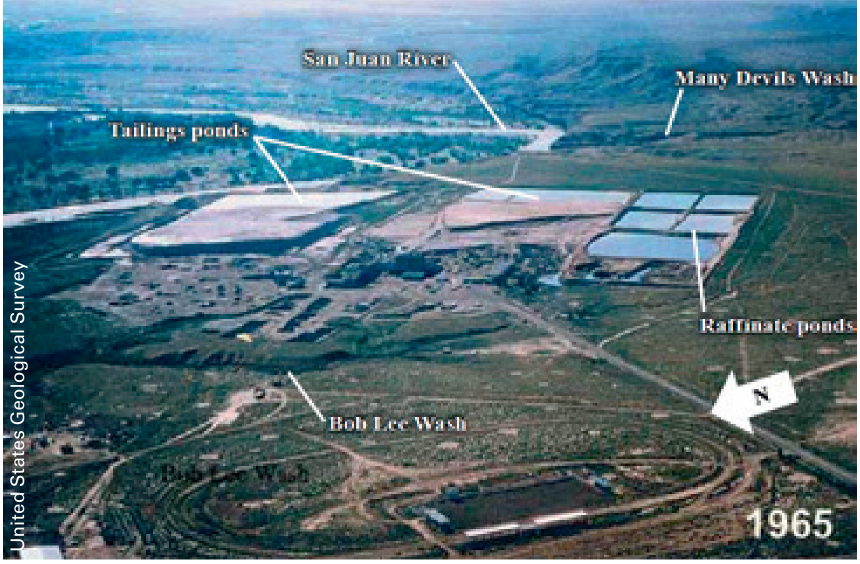
The roots of "legacy": Where is it all from?

Following the cessation of hostilities after the end of the Second World War, many physicists turned to studying wartime nuclear technologies with a new purpose: using nuclear energy as an alternative energy source to gas and oil. With so many nations hoping to improve their generation capacity, the development of nuclear reactors thus grew quickly in the 20th century, resulting in over 400 nuclear power plants worldwide today.

In the early years, nuclear power plants, research reactors and nuclear fuel cycle facilities were creating radioactive waste without much thought to long-term waste management and the need for disposal paths. This was also the case for medical, research, industrial and defence-related sources of radioactive waste. The first nuclear power plants entered their decommissioning phases as early as 1964, and many more were to follow in the next decades (WNA, n.d.). The need to completely defuel these plants, so as to remove radioactivity in the context of full decontamination, often sped up waste production in an era devoid of guidance on storage and the safe disposal of radioactive waste.

Absent, inadequate and/or ineffective controls resulted in abandoned, poorly remediated and badly degraded facilities. Additionally, few controls covered areas affected by spills and other events, or those contaminated with long-lived, radioactive and, quite commonly, toxic residues. The result was large volumes of waste that were difficult to manage, with on-site dumping or trenching practices allowed in many places that lacked dedicated storage or treatment facilities.[1] In some countries, operators could dispose of waste off-site and, for many, sea dumping of packaged radioactive material was a normal practice.[2]

It is commonly accepted today that the key, long-term objective of radioactive waste management and waste disposal is to protect the environment and humans – or more specifically to isolate or dilute waste to a point of being harmless to the biosphere. As such, it is easy to understand why early dumping and irregular or inadequate storage created a liability for future generations and why it challenges modern approaches to decommissioning and waste management. While the large majority of radioactive waste has been produced and managed in mature industrial frameworks in an optimised manner, the past activities described above – combined with other factors such as a lack



The Shiprock disposal site is the location of a former uranium- and vanadium-ore processing facility, located within the Navajo Nation in the northwest of New Mexico.

Source: US Department of Energy (2011).

of resources, trained staff and national policies or regulatory frameworks for the management of radioactive waste – have resulted in some isolated cases of extreme conditions lingering today.

Introduction of the term "legacy"

Awareness of past practices in the nuclear sector and their impact in terms of "residual radioactive material" finally became a topic of greater interest in 1998 when the International Atomic Energy Agency (IAEA) began to examine the radiological impacts of nuclear weapons tests after 30 years of French testing in the Atolls of Mururoa and Fangataufa. The intent was to determine if "radiological hazards exist now or will exist in the future, and to make recommendations on the form, scale and duration of any monitoring, remedial action or follow-up action that might be required" (IAEA, 1998). The resulting report recommended, for the first time, that migration behaviours be monitored over a few decades for long-lived and relatively mobile radionuclides (including those in the biosphere). Such monitoring would help to reassure the public of radiological safety in the Atolls and surrounding area.

The term "legacy" then appeared for the first time in reference to residual radioactive material when a substantial overview of these issues was recorded during an IAEA Conference in 2000, placing particular focus on radioactive waste in former Soviet Union countries (IAEA, 2002). A 2002 report published from the conference proceedings assessed contaminated sites and sources of potential environmental contamination through thorough reviews and case studies. Coupled with a projection for waste production, the report concluded that future international efforts were necessary in order to ensure environmental restoration and resolve policy issues, including those relating to the criteria for rehabilitation and remediation of areas affected by radioactive residues.

In the case of the restoration of residual contamination resulting from unplanned events such as nuclear and radiological accidents and poorly controlled past practices, it had become clear that guidance from the International Commission on Radiological Protection (ICRP) and the IAEA would be controversial. The controversy resulted from the difficulty of distinguishing between practices and intervention situations (from which the current ICRP system of exposure situations evolved), and the problems associated with decisions on restoration, which are often strongly influenced by other factors such as public opinion, and both legal and political constraints.

Countries were finally provided the necessary impetus to examine their national situations more closely following the 2002 report. However, regulatory supervision would be challenging since a large number of issues – from the protection of the environment and human health to radiation and nuclear safety and security; remediation work; management of solid and effluent radioactive waste, and coherent management of other hazards, such as chemically toxic materials and physical hazards – would need to be examined alongside social, economic and other constraints.

In 2003, an *International Seminar on Strategy Selection for the Decommissioning of Nuclear Facilities* (NEA, 2003), organised by the Nuclear Energy Agency, brought further focus to this issue. The conference encouraged broad sharing of lessons learnt at the national level, not only in decommissioning but also in radioactive waste management, including waste disposal routes and standards of clearance. In the same year, the Office of Legacy Management was created within the United States Department of Energy (US DOE) and was assigned national responsibility for nuclear legacy clean up (DOE, 2016). This served to more formally introduce "legacy management" (LM) into the vocabularies of other national bodies and international organisations.

In 2004, an NEA report entitled *The Regulatory Control of Radioactive Waste Management* provided information from NEA member countries on this topic, covering each of the above types of nuclear sources and facilities (NEA, 2004). One of the key challenges identified in this report was that of finding a path from legacy recognition to implementation, and within this context defining urgent mitigation measures and developing a longer-term recovery strategy through to release from regulatory control.

Differing regulations means differing definitions for "legacy"

Today, radioactive waste is managed through specially designed packaging and storage facilities. National policies, laws and regulations have evolved to comply with modern, internationally agreed guidelines and standards on how to protect the public and environment through the safe isolation of radioactivity that could cause harm.[3] Although national guidance on how to address the different aspects of nuclear legacies may have existed previously, these addressed only individual issues, such as the management of radioactively contaminated land (ASN, IRSN and MEDDE, 2011) or potentially polluted sites (Gonzalez et al., 2013).

Members the Expert Group on Legacy Management visit the Sellafield site, UK, May 2017.

Such dispersed guidance could obviously introduce delays in the timely and effective resolution of problems that arose. Because legacy management approaches grew up in national contexts, largely independent of bilateral or multi-lateral exchanges on definitions, approaches, practices and strategies, they could therefore not respond to specific legacy discoveries, nor could they address the longer-term management of radiation and other hazards connected to legacy waste.

In 2010, recognising that both the liabilities associated with legacy waste and the overall lack of consistent regulatory guidance presented true legislative challenges, a slightly more critical review of the legacy management state of play began. The NEA report *Partnering for Long-term Management of Radioactive Waste: Evolution and Current Practice in Thirteen Countries* summarised developments related to legacy management in national contexts, as well as what approaches had been implemented for partnering across these 13 countries[4] (NEA, 2010).

Each of the national radioactive waste management programmes considered in this NEA report were at different stages, but actual experience in implementation relating to legacies was, for the most part, reflected only at the preliminary siting and design steps. A number of issues were found to have contributed to precluding national regulations from including legacy waste more broadly. For example, in addition to the radionuclide characteristics of legacies not perfectly fitting with existing regulations, numerous changes had also taken place over time in terms of which organisations were responsible for waste. Moreover, while funding arrangements were provided for nuclear power plants and other facilities to safely and effectively handle and store modern waste stocks, these arrangements had not typically covered waste dumped or stored via historically unconventional methods.

More importantly, it was discovered when determining which related activities and sites to involve in the process of legacy management that *definitions* of legacy waste varied tremendously from one country to another. Finding consistency in vocabulary to develop international recommendations was thus not feasible. In fact, the misunderstanding and miscommunication of technical terms and protection standards remains a problem even today. In June 2015, however, during the 4th NEA Science and Values Workshop held in Moscow, and again during a Norwegian workshop on regulatory supervision of legacy sites in Oslo later that year, legacy management issues gained new traction.

Sorting out today's legacies

Notwithstanding the lack of a consistent definition from country to country, it was agreed after 2015 that the continued development of new nuclear facilities, and the decommissioning of older facilities and related waste-producing programmes, would require that legacy sites and installations be managed in an open and transparent way, particularly if countries were to build confidence in the solutions being provided. A number of countries have more recently expressed a need for practical guidance in the regulation of radiological protection for existing exposure situations, which have fallen into the large category of sites needing specific attention to get out from under regulatory control.

The NEA and IAEA must therefore embrace the different approaches to and standards for managing legacy problems and existing exposure situations in member and non-member countries. Although preparing guidance at the international level to address the application of recommendations and standards on such disparate national aspects of legacy management and radiological protection in an integrated manner will be a challenge, the foundation has been laid with a definition for an "existing radiological exposure situation."

The IAEA International Basic Safety Standards (IBSS) from 2011 notes that a situation of exposure "already exists when a decision on the need for control needs to be taken, including situations of exposure due to residual radioactive material that derives from past practices that were not subject to regulatory control or that remains after an emergency exposure situation" (IAEA, 2011b). The NEA perspective carries this understanding forward, recognising that legacy situations are further characterised by having been exposed to such material at the conclusion of a defined emergency situation, for example following a nuclear or radiological accident.

The newly formed NEA Expert Group on Legacy Management (EGLM) uses a more explicit description of legacy, based on experiences emanating from a number of co-operative activities led by the Norwegian Radiological Protection Agency (NRPA). The EGLM has identified five major groups of legacies[5] with the help of the NRPA, as well as important distinguishing features from a radiological protection and regulatory perspective. The expert group description also notes that a change in recommendations can result in a change in regulatory requirements, which means that an exposure situation arising post-regulation (a planned exposure situation) can become an existing situation. The IAEA IBSS underlines that descriptions given "of the three types of exposure situation are not always sufficient to determine unequivocally which type of exposure situation applies for particular circumstances",[6] and thus a lack of clarity still exists around this issue, as well as on how to manage it. Such questions are being closely examined within the scope of EGLM work.

Clearer, more practical guidance is in fact needed internationally on the regulatory supervision of legacy issues, based on further guidance in relation to the practical implementation of the ICRP principles and the IBSS. Distinctions between emergency, existing and planned exposure situations must be clarified, for a number of reasons. For one, it is often the case that recommendations from existing and planned exposure scenarios (in particular, the establishment of criteria such as dose limits and references or activity levels for radioactive waste management) need to be applied to the same site to manage legacy site remediation activities. However, as the EGLM has already shown in case studies, regulatory flexibility is even more important when considering how to handle legacy management from site to site.

Better communication and outreach strategies must be developed for potentially affected populations living in the vicinity of legacy sites. Radiological protection standards are also needed to develop coherent and optimised approaches for regulatory oversight and site management (particularly for anything beyond the IAEA *General Safety Requirements* Part 7 [IAEA, 2015] and *General Safety Guide* 2 [IAEA, 2011a]). Experience has shown that guidance should not be created in a vacuum, in a single country or within a single context, but should be developed and applicable across departmental boundaries.

Radiological protection is not the only relevant issue, since the source or cause of the legacy is not that important from a radiological perspective. What matters from the radiological protection point of view are the distinguishing features identified, which materially affect options for the control of future exposure. For this reason, guidance should also accommodate other environmental and human health issues, as well as economic, social and other factors in parallel with radiological protection issues. Enhancements are needed in relation to the regulation and safety culture for remediation, and experiences should continue to be shared addressing the multi-faceted aspects of nuclear safety.

NEA member countries have begun to share their experiences and approaches on legacy management and have submitted case studies to the EGLM that illustrate the common challenges and approaches of many countries. The first report of the expert group will be based on these case studies and will be released in late 2017. A wide range of sites are being examined, from legacies with an existing radiation exposure situation to sites and facilities affected by major accidents and incidents, as well as sites that will or could become legacies in the near future. The first task of the EGLM will be to address the issues listed above at real sites. A new, broader focus on decommissioning and legacy management issues within the NEA is expected to take shape in early 2018, carrying forward the mission to develop and promote a practical and optimised approach for the regulatory supervision of nuclear legacy sites and installations.

Notes

1. For example, in the United States it was allowed by law until the late 1970s.
2. Sea dumping was demonstrated to be entirely safe in studies organised and published by the NEA until a moratorium was introduced in 1993 for reasons not connected with unacceptable radiological impact. See: NEA (1996), *CRESP Final Report 1981-1995,* NEA No. 117; and IAEA (1999), *Inventory of Radioactive Waste Disposals at Sea,* IAEA-TECDOC-1105.
3. International conventions such as the Convention on Nuclear Safety (IAEA INFCIRC/449; EIF 1996) and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (IAEA INFCIRC/546; entry into force in 2001) were also established, requiring national reporting on the safety of nuclear power installations and the safety of spent fuel and radioactive waste management, respectively.
4. The 13 countries included are: Belgium, Canada, the Czech Republic, Finland, France, Hungary, Japan, Korea, Spain, Sweden, Switzerland, the United Kingdom and the United States.
5. These five overarching groups are: the sites affected by major accidents and incidents; inadequate storage and disposal sites and facilities; NORM and Uranium mining and milling facilities; nuclear technology and development centres; and former nuclear sites that were either peaceful or weapons testing sites.
6. IAEA, IBSS, Para 1.20 and 1.21.

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NEA support to Fukushima Daiichi decommissioning strategy planning

by I. Weber, K. Funaki, N. Sandberg and I. Otsuka

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TEPCO, Japan

Fukushima Daiichi nuclear power plant.

Six years after the Fukushima Daiichi nuclear power plant accident, the Japanese government and Tokyo Electric Power Holdings, Inc. (TEPCO) are shifting their focus to strategy planning for long-term challenges related to the decommissioning of the damaged reactors.

The international community has been helping to address the unprecedented challenges of managing the accident facilities. The NEA is playing a key supporting and co-ordinating role in the international community, in particular in the area of radioactive waste management and the evaluation of the conditions and location of fuel debris.

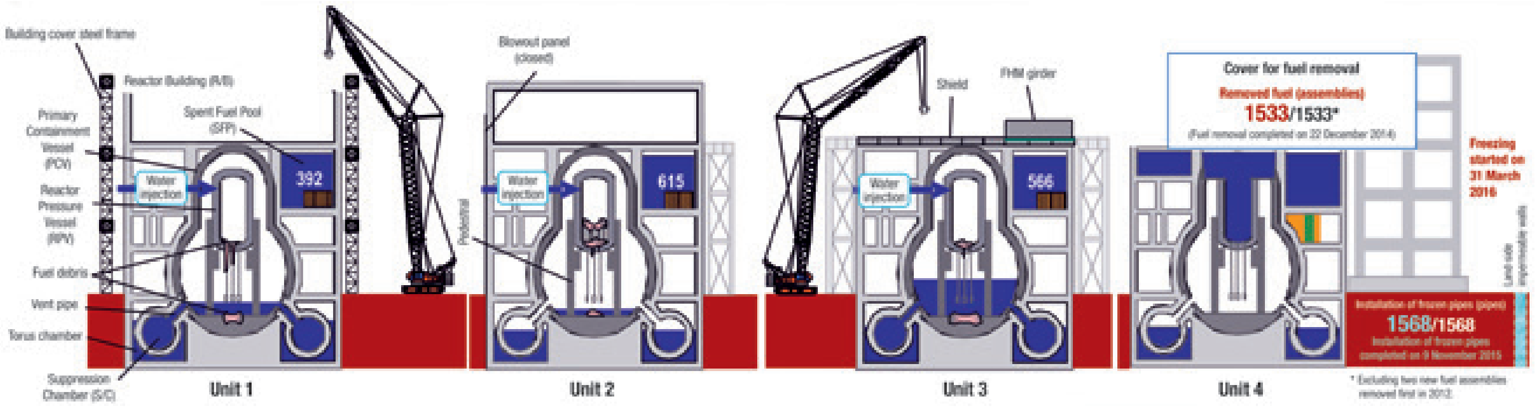
In the first half of 2017, a series of visual investigations using remotely controlled equipment and robots were performed to identify the condition of vessels inside, as well as the distribution of fuel debris in all three units. In the summer of 2017, as stated in the government roadmap, policies for fuel debris retrieval from each unit would be presented, and would result in a discussion on which unit should be the first to undergo fuel debris retrieval in 2018. In addition, the basic policy for the processing and disposal of radioactive material arising from the accident would be conceptualised in the year 2017.

This article highlights ongoing international joint activities within the NEA framework, corresponding to the challenges that have been identified in the Fukushima Daiichi decommissioning strategy planning.

Basic principles of Fukushima Daiichi decommissioning strategies

Mid- to long-term decommissioning strategies for the Fukushima Daiichi plant have been developed by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF), an entity established by the Japanese government in 2014 through the reorganisation of the former Nuclear Damage Compensation Facilitation Corporation. This new entity is dedicated to mid- to long-term strategy planning for the decommissioning of the damaged nuclear facility and has established a technical strategic plan that is reflected in the government roadmap. The establishment

Figure 1: **Progress status on Fukushima nuclear power station units 1-4**



Source: METI (2017).

of an organisation dedicated to mid- to long-term strategic planning for decommissioning has enabled the Japanese government and TEPCO to focus on addressing pressing challenges such as contaminated water management and fuel removal from the spent fuel pool.

The damaged Fukushima Daiichi plant was designated by the Nuclear Regulatory Authority of Japan (NRA) as a specified nuclear facility to be considered under specific licensing procedures, with TEPCO continuing to be responsible for delivering on-site operations and engineering works as the licensee. In addition, some research and development (R&D) organisations have become involved in associated government funded R&D projects to support decommissioning strategy planning. The NDF published a revised Strategic Plan in 2016 and will release an updated version in the summer of 2017, reflecting extensive discussions with the Japanese government, TEPCO and R&D institutions (i.e. the International Research Institute for Nuclear Decommissioning [IRID], the Japan Atomic Energy Agency [JAEA]) on updates to technical developments over the year, as well as on issues and challenges to be addressed.

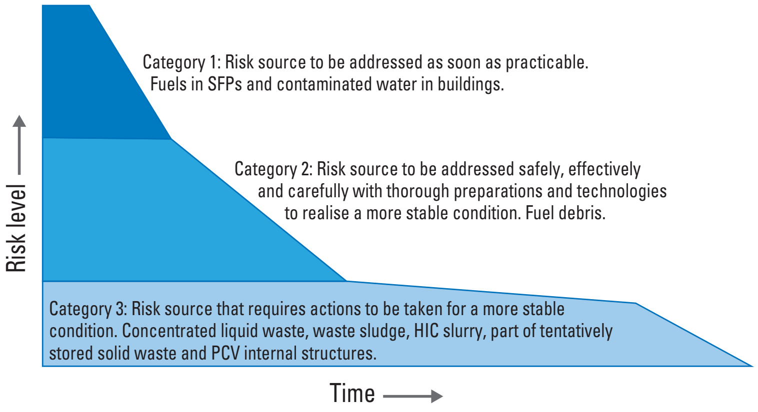
The Strategic Plan clarifies the fundamental objective for Fukushima Daiichi decommissioning as "to continuously and promptly reduce the risks associated with the radioactive materials generated by the accident," and outlines the five guiding principles for risk reduction (see Box 1 below). Strategic decommissioning planning is defined as "the design of risk reduction strategies" on a mid- to long-term basis.

Box 1: Five guiding principles

- Safe: Reduction of risks posed by radioactive materials and work safety.
- Proven: Highly reliable and flexible technologies.
- Efficient: Effective use of resources (e.g. human, physical and financial).
- Timely: Awareness of the time axis.
- Field-oriented: Thorough application of the three actuals (actual field, actual things and actual situation).

The proposed risk reduction strategy will identify various radioactive materials that are sources of risk, perform analyses and evaluations based on their characteristics and set the priorities to address issues associated with the risks identified. A comparative analysis of various radioactive risks that remain at the Fukushima Daiichi site is proposed to illustrate how the risk level quantitatively changes over time. The importance of managing project risks is also emphasised when advancing through each step of the decommissioning process.

Figure 2: **Risk reduction strategy**



Source: NDF Strategic Plan 2016.

NEA support: The WPDD and CPD

Many of the strategies and approaches that have been developed for decommissioning nuclear facilities can be applied to decommissioning preparations at the Fukushima Daiichi NPP. The **NEA Working Party on Decommissioning and Dismantling (WPDD)**, established under the NEA Radioactive Waste Management Committee (RWMC), aims to assist NEA member countries in developing safe, sustainable and societally acceptable strategies for decommissioning, and for the management of associated waste. Accumulated knowledge and expertise within the WPDD is considered a good reference for the mid- to long-term process of decommissioning the Fukushima Daiichi NPP, and Japanese organisations have benefited from their participation in information sharing throughout WPDD activities. Currently, the WPDD has tasked several expert groups with the following issues: i) decommissioning cost estimation, ii) radiological characterisation and decommissioning, iii) preparing for decommissioning during operation and after final shutdown, and iv) optimising the management of low-level radioactive materials and waste from decommissioning.

In addition, TEPCO has become a member of the **NEA Co-operative Programme on Decommissioning (CPD)**, a joint undertaking gathering a limited number of organisations mainly from NEA member countries in order to learn from other decommissioning projects and ensure that the safest, most economical and environmentally sound options for decommissioning are employed. The objective of the CPD programme is to exchange and share experience and lessons learnt from decommissioning implementation among decommissioning practitioners.

Fuel debris retrieval strategy and evaluation of reactor conditions

One major activity during the transition of a nuclear power plant from operation to decommissioning is the removal of all spent fuel and remaining fuel elements from the plant itself. The situation is very different in the case of the Fukushima Daiichi site. Large volumes of damaged fuel were generated during the accident, (i.e. nuclear fuel that contains materials in a state without containment function by fuel cladding and that is mixed with other materials). The risk factors for this material are related to criticality, decay heat, containment, high radiation, hydrogen generation and degradation of the integrity of supporting structures. However, the amount of radioactivity of fuel debris is estimated to have greatly decreased to about one several-hundredth of the amount immediately after the accident, according to the NDF. Measured plant parameters have remained stable in terms of criticality, cooling and containment. In managing the residual risks resulting from this material, three challenges need to be considered: "uncertainties" in relation to the reactor condition, "instability" of molten fuels and damage to the facility caused by the accident, as well as "insufficient management" due to severe access conditions in a high radiation environment.

To address these challenges, it is important to continuously and promptly reduce the risks associated with fuel debris, which means establishing methods for understanding, monitoring and managing internal conditions.

Another longer-term consideration is environmental contamination by potential leakage of radioactive materials resulting from the degradation of the containment function. To prevent such contamination, the fuel debris should be retrieved and collected within the first couple of decades after the accident. In all cases, initiating and implementing fuel debris retrieval is key to minimising risks.

Box 2: Key elements of the fuel debris retrieval strategy

Understanding and evaluation of the internal pressurised containment vessel (PCV), which would lead to minimising uncertainty (locations, amount and property of fuel debris, fission product distribution and damaged condition of reactor internals):

- estimation based on plant investigation (PCV and reactor pressure vessel internal survey, Muon detection, and investigation of the leak locations of the PCV);
- estimation by analysis (calculation with improved severe accident progression analysis codes);
- estimation based on knowledge and experiments (plant parameter analyses, heat balance methods, results of tests and research on severe accidents and property tests using simulated fuel debris).

Studies on the feasibility of multiple methodologies for fuel debris retrieval, which would lead to a reduction of instability through improvements in internal conditions:

- securing the structural integrity of the PCV and reactor building;
- criticality control;
- maintaining the cooling function;
- securing containment function;
- reduction of workers' exposure during decommissioning operations;
- ensuring work safety;
- establishment of an access route to the fuel debris;
- development of fuel debris retrieval equipment and devices;
- developing system equipment and working areas.

Management of fuel debris in a safe stable condition, which would lead to improvements at the management level:

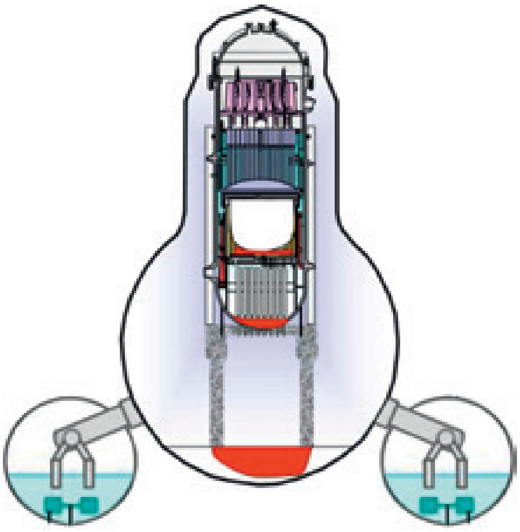
- storage canister design;
- development of a transport system;
- development of a storage system;
- establishment of safeguard measures.

Estimation and evaluation of internal reactors and fuel debris properties is an integral part of ensuring the current stable condition as uncertainty decreases. Information obtained will also offer important input into the designing and planning of safe and proven methods for fuel debris retrieval.

NEA support: The BSAF and SAREF joint research projects and the WGAMA

To better understand the accident progression and respond to the need for improved evaluation of internal reactor conditions, the international **Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station (BSAF)** was launched in 2012. Phase 2 of the project is currently underway with a total of 20 signatory organisations from 11 countries (Canada, China, Finland, France, Germany, Japan, Korea, Russia, Spain, Switzerland and the United States). It brings together international experts to advance the understanding of severe accident phenomena specific to the Fukushima Daiichi accident, while improving the methods and codes for modelling such severe accidents. The first phase of BSAF ended in 2015 with a focus on a thermal-hydraulics analysis by severe accident computer codes for the first six days of the accident. The second phase extends the time span of analyses to three weeks with a specific analysis on fission product behaviour. This second phase of the project will continue until March 2018 and will aim to have the best possible estimates of the accident scenario of each unit, as well as of the current status of molten corium concrete interaction (MCCI) and fission products.

Figure 3: Qualitative estimation of the plausible status after comparison of the best estimate case analyses for unit 1 reactor pressure vessel failure scenario



Source: NEA (2015).

Recognising the importance to both safety research and decommissioning planning, the NEA Committee on the Safety of Nuclear Installations (CSNI) established the **Senior Expert Group on Safety Research Opportunities Post-Fukushima (SAREF)** in 2013. The objective was to propose a process for identifying opportunities to advance safety knowledge and support decommissioning strategies for the Fukushima Daiichi NPP. As a result of extensive discussions chaired by the NRA, a report was compiled in 2016 with recommendations. Near-term projects were proposed to initiate the preparation for more complex undertakings such as the sampling of damaged fuel and reactor core components over the long term. It was also recommended that the second phase of the senior expert group discussions would begin in three to five years when new information had become available from discussions concerning potential long-term activities. In January 2017, a preparatory technical meeting for the SAREF near-term projects was organised to review joint research projects proposed by Japan. A research project focusing on fuel debris characterisation is currently under review by NEA member countries. A mechanism for co-ordinating multiple, post-Fukushima research activities must also be explored.

The **CSNI Working Group on Analysis and Management of Accidents (WGAMA)** has accumulated a certain amount of knowledge and expertise relevant to decommissioning strategy planning for the Fukushima Daiichi NPP. For example, the status report on MCCI, which is being prepared for release, has been a valuable input into discussions. Another task group is currently reviewing and compiling case studies and international experiences on the long-term management of damaged reactors, including with regard to a fuel melt in a nuclear power plant. Japanese organisations are participating in these discussions to share their strategies.

Radioactive waste management strategy

Fuel melt and hydrogen explosion during the Fukushima Daiichi accident resulted in the generation and dispersion of a large amount of diversified radioactive waste, including rubble, debris and felled trees, as well as secondary waste of contaminated water processing such as slurry and sludge. This radioactive waste has been stored and managed in a safe, stable condition, following categorisation processes according to surface dose rate so as to reduce associated risks. In parallel, the development of other characterisation methods is currently under investigation. Safe and optimal procedures for processing and disposal, using reliable technologies and methodologies, should be explored for the long term. The Strategic Plan advocates that the overall management of radioactive management should be undertaken with full consideration of the issues from mid- to long-term perspectives listed in Box 3 below.

Box 3: Key elements of the radioactive waste management strategy

Storage:

- reduction of waste generation (waste hierarchy, considerations for secondary waste);
- storage (storage planning, stabilisation of stored waste, solid waste generated from the retrieval of fuel debris).

Processing and disposal:

- waste characterisation (radiological analysis plan, radiological analytical capability for waste characterisation);
- study of processing and disposal management.

The Japanese government's roadmap indicates that the basic concept of processing and disposal for radioactive solid waste is to be compiled in the year 2017, and that the prospects for a processing and disposal method, as well as a technology ensuring its safety, is to be revealed by around year 2021.

NEA support: The EGFWMD

In response to a request from the Japanese government, the **NEA Expert Group on Fukushima Waste Management and Decommissioning R&D (EGFWMD)** was established in 2014 to help provide a strategic approach to the authorities in Japan for the management of large quantities of on-site waste with complex properties, to manage the complex characterisation process of waste including a sampling and analysis plan, to share experiences with the international community, and to improve knowledge of the post-accident waste management and decommissioning challenges arising from the Fukushima Daiichi site. The group was formed with specialists from Japanese organisations such as JAEA, NRA and TEPCO, alongside experts from around the world with experience in waste management after nuclear accidents at Three Mile Island and Chernobyl, as well as with the Windscale Pile 1 fire, environmental remediation and waste conditioning R&D. In December 2016, the group published a report that provides technical opinions and ideas on post-accident waste management and R&D at the Fukushima Daiichi site, as well as information on decommissioning challenges.

At the RWMC meeting in March 2017, the NDF reported on how the outcome of the expert group's discussions affected the NDF strategy and R&D project planning. A request was made at the time to launch a new initiative focused on the development of an integrated management methodology for a large amount of unknown waste. The RWMC has supported the start of this initiative.

Ways forward: Strengthened collaboration and co-ordination

Closer collaboration among relevant organisations on key technical issues, as well as periodic evaluation and reviews of decommissioning strategies reflecting the outcomes of R&D projects will be important going forward. Such co-ordination will lead to a "spiraling up of the strategy planning", moving steadily towards fuel debris retrieval and decommissioning activities. Given the unprecedented challenges, efficient and effective management of a series of R&D projects through enhanced collaboration among the organisations involved is crucial in ensuring the practical application of R&D outcomes. New JAEA research facilities, which will be an integral part of the "Fukushima Innovation Coast" initiative for boosting regional revitalisation, have been designed to further enhance international collaboration.

The NEA will continue to play a vital role as a hub for international co-operative activities, helping to share updates on progress. Ongoing relevant projects will continue to co-ordinate their activities through efficient interface management. Another international NEA initiative, NEA Nuclear Innovation 2050, is currently working to select and propose a set of international joint R&D programmes of action, one of which may include highlighting co-operative programmes on lessons learnt from the Fukushima Daiichi accident and decommissioning activities.

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Further information

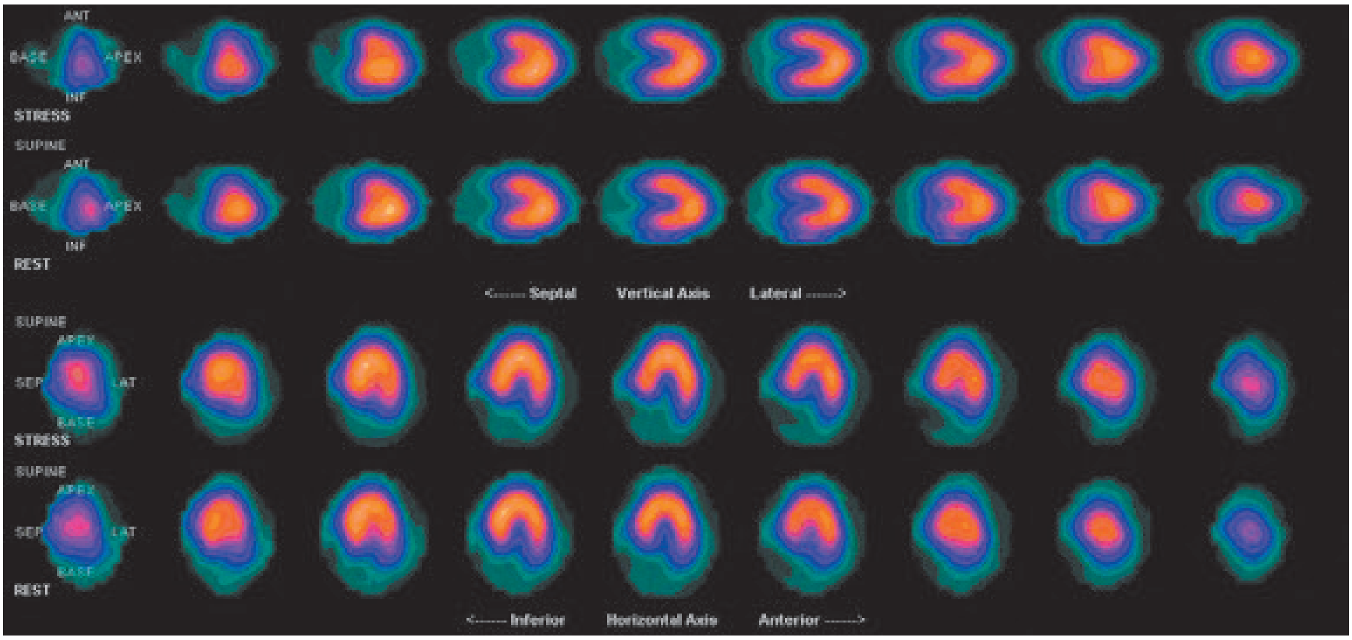
All NEA reports from the Committee on the Safety of Nuclear Installations (CSNI) and the Radioactive Waste Management Committee (RWMC) are available at www.oecd-nea.org/nsd/docs and www.oecd-nea.org/rwm/pubs/2016.

NEA publications are available at www.oecd-nea.org/pub.

The future of medical isotope supply – 2017 status update

by K. Charlton

Mr. Kevin Charlton (kevin.charlton@oecd.org) is Analyst in the NEA Division of Nuclear Development.



Wikipedia

SPECT imaging.

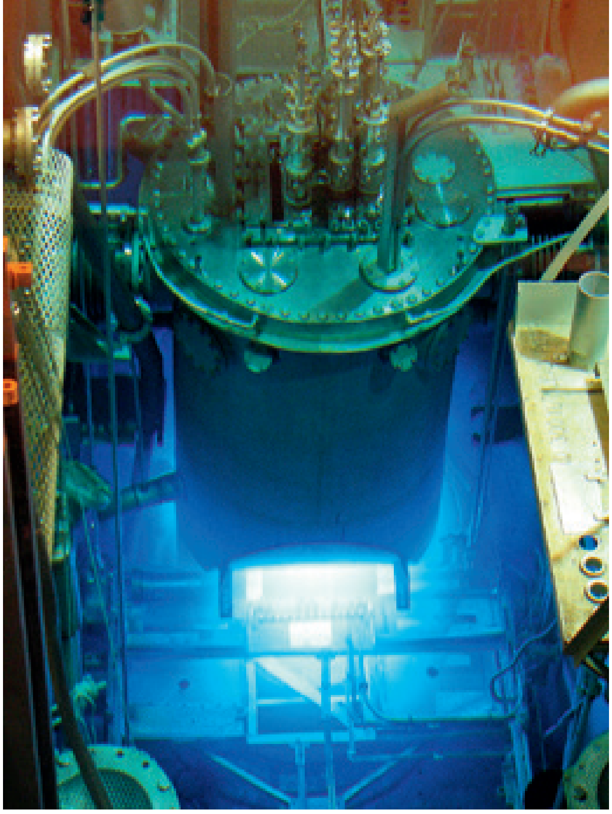
Single Photon Emission Computerised Tomography (SPECT) is an advanced 3D scanning technology used to diagnose and monitor a wide range of medical conditions, including coronary heart disease, cancers, kidney function and various brain disorders. Worldwide, between 30 and 40 million patients per year benefit from non-invasive nuclear imaging scans that can detect disease at an early stage, that can determine the extent of disease and that can track responses to therapy. Such scans thus enable personalised medicine. Molybdenum-99 (^{99}Mo) is the mother isotope of technetium-99m (^{99m}Tc), which is the most widely used isotope in nuclear medicine imaging. ^{99m}Tc is the isotope of choice for SPECT because it has pure gamma emissions ideal for image detection, a useful range of chemical characteristics that enable many targeting molecules to be used and a half-life of around six hours.

These emission energies and short half-life combine to ensure that the radiation dose to the patient from each administered injection is at a low and safe level. It also allows scans to be made at a number of time points after injection, which can provide useful additional information. Such a short half-life, however, means that ^{99m}Tc cannot be stored. It must be prepared a number of times every day, and this is carried out in specialist nuclear pharmacies. Since ^{99}Mo in the form of a ^{99}Mo/^{99m}Tc generator has a longer half-life of around 66 hours it can be used in nuclear pharmacies for between one to two weeks. The power of the ^{99}Mo declines by about 1% every hour, and so nuclear pharmacies must regularly receive new ^{99}Mo/^{99m}Tc generators and some receive them multiple times a week. The ^{99}Mo used in generators must therefore be produced on an almost continuous basis.

The production of ^{99}Mo is, in this regard, similar to the supply of electricity. The expectation is that ^{99m}Tc will always be available for hospital clinics and their patients, but it has to be produced continuously to meet that expectation. Since it cannot be stored, production capacity must exceed the normal demand level, and the supply lines have to be reactive and flexible so that changes in demand and supply conditions can be managed seamlessly. Today, most ^{99}Mo continues to be produced using nuclear reactors that have been designed and are operated for fundamental research purposes. These specialist research reactors must regularly stop – typically every three or four weeks – for refuelling and essential maintenance.

Covidien, United States

Nuclear medicine scanner using technetium-99m.



NTP, South Africa

View of the SAFARI-1 reactor located in South Africa.

The result is that ^{99}Mo delivery takes place through a supply chain network, where the participants closely collaborate on scheduling through an industry body. They co-ordinate, for example, the operating and outage schedules of their facilities to ensure that the available supply capability always exceeds the market demand. As long as production capacity is well co-ordinated and switchable, and exceeds the maximum demand level as in the case of electricity production, ^{99}Mo is always available for medical needs. However, this guaranteed availability also means that some production capacity will inevitably stand idle, in reserve, so as to mitigate against unexpected events. In the ^{99}Mo supply market, this reserve has become known as outage reserve capacity (ORC). Unlike the electricity market, however, the number of facilities in the ^{99}Mo market is very limited, and so perfect co-ordination of the available capacity is critical, as is the availability and usage of ORC.

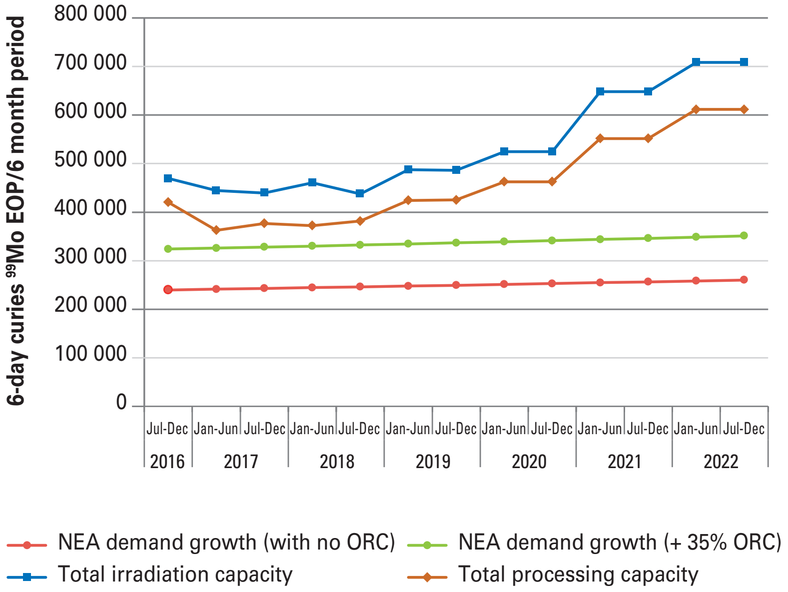
Perfect co-ordination has, unfortunately, not always been possible. In the period 2009-2010, for example, a number of substantial unexpected outages at important production facilities occurred simultaneously and the result was a period of significant shortage. It was during this period that the NEA, at the request of its member countries, established the High-level Group on the Security of Supply of Medical Isotopes (HLG-MR) and began performing extensive analyses of the medical isotope market with the co-operation of supply chain participants and governments. Various aspects of classical market failure were identified that had undermined the ability of the industry to invest in new capacity. HLG-MR members agreed on a six-point policy approach aimed at resolving the supply crisis since it was essential to encourage the market to move towards a long-term economically sustainable position. Since that time, under the guidance of the HLG-MR, and with greater industry co-operation in the planning phases, supply has remained relatively secure with only minor levels of occasional disruption in the 2012 and 2013 periods.

In April 2014, the NEA analysed likely future market demand and projected production capacity for ^{99}Mo (NEA, 2014). This research identified a period beyond 2016 of increased risk when further supply disruption could result from a number of ageing supply chain participants ending their activities. The analysis also examined the likely deployment of potential new capacity and confirmed that the introduction of new capacity would be vital to ensure security of supply. Concerns were expressed at the time about the possibility of potential new facilities experiencing project delays. The overall conclusion was that 2017 would represent the start of a period of particular risk, with a likely nadir in production capacity as a result of planned facility closures and project delays.

In 2017, the NEA is pleased to report that market participants have reacted positively to the concerns identified in 2014. The two reactors and one processing facility that were anticipated to end normal operations withdrew from routine ^{99}Mo supply by the end of 2016 as scheduled. This withdrawal was expected to substantially reduce the total production capacity at both the irradiator and the processor level of the supply chain, but that did not happen. Since 2015, market demand and capacity has been systematically assessed and revised by the NEA with regular input from supply chain participants and potential new suppliers. Two important factors can be identified from that analysis.

The first factor is that the actual market demand for ^{99}Mo in 2014 was in fact lower than the level that had been assessed. The market had substantially restructured following the 2009-2010 supply crisis, and that restructuring led to increased efficiencies in the use of material at the different layers in the supply chain. In parallel, policy actions related to the appropriate use of ^{99}Mo in medical testing were initiated in some important markets and also led to reduced demand. These effects were underestimated in 2014. The latest NEA data confirms a relatively flat market demand of around 9 000 6-day Ci ^{99}Mo/week at the end of radiochemical processing. Adjustment to the level of market demand has meant that the level of challenge today is around 10% lower than had been anticipated in the 2014 report, and that gave existing market participants an important window of opportunity.

Figure 1: Current demand (9 000 6-day Ci ^{99}Mo/week at the end of processing [EOP]) and demand +35% ORC vs. total irradiation capacity and total processing capacity – with projects delayed 12 months



The second important factor is the positive actions taken by some of the remaining supply chain members who progressively increased their production capabilities in a number of different ways. The results of such increases can be seen in the latest NEA "2017 Medical Isotope Supply Review: ^{99}Mo/^{99m}Tc Market Demand and Production Capacity Projection 2017-2022" (NEA, 2017). The baseline scenario for capacity, when only existing supply chain members are considered, has increased for the second consecutive year. These sequential increases, resulting from a more effective use of existing facilities, have lifted the baseline supply capacity for the 2017 and 2018 periods to a level safely above the revised market demand.

The 2014 report was correct in identifying a risk of project delays, because many have been reported. Such delays have been reported for both conventional and alternative production technology projects. While the technical aspects of a range of alternative production technologies have been successfully demonstrated, the market is still awaiting commercial deployment. The 2017 Market Demand and Production Capacity Projection report anticipates that further project delays can be expected, but despite potentially substantial delays, projections indicate an adequate level of supply capacity through the period until 2022. This scenario (i.e. scenario C) is considered to be the most representative of the three scenarios outlined in the report. Figure 1 shows the graph of scenario C, where capacity from some planned new facilities are included but where the introduction of those projects have been delayed by 12 months. The timely introduction of additional capacity in 2018 from conventional and alternative technologies remains important for the industry to increase the depth of defence needed to ensure the long-term security of supply of medical isotopes.

Many of the technical innovation and planning elements necessary for long-term security of supply have been demonstrated, but the market continues to face economic challenges. Progress towards the goal of removing all support provided to the supply chain by governments remains an unfulfilled ambition as full cost recovery (FCR) has not yet been fully implemented. While ORC is now recognised for the essential role that it plays throughout the supply chain, and it is reassuring that the level of ORC held by the supply chain has continued to increase, it is a concern that some supply chain members remain unrewarded for the ORC services that they provide.

The current irradiator and processor supply chain capacity for ^{99}Mo/^{99m}Tc should be sufficient. If well maintained, planned and scheduled, it should be able to manage unplanned outages with the use of ORC held in the supply chain. The supply situation will continue to require careful and well-considered planning, with a high degree of essential co-operation between supply chain participants for the foreseeable future. The market situation will continue to require regular monitoring, in particular in terms of the progress being made in bringing new capacity to market and towards establishing an economically sustainable model.

The NEA continues to play its part, supporting the activities of the HLR-MR, collecting relevant market data, monitoring progress and providing analysis and advice to stakeholders.

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A methodology for presenting national inventories of spent fuel and radioactive waste

by V. Lebedev

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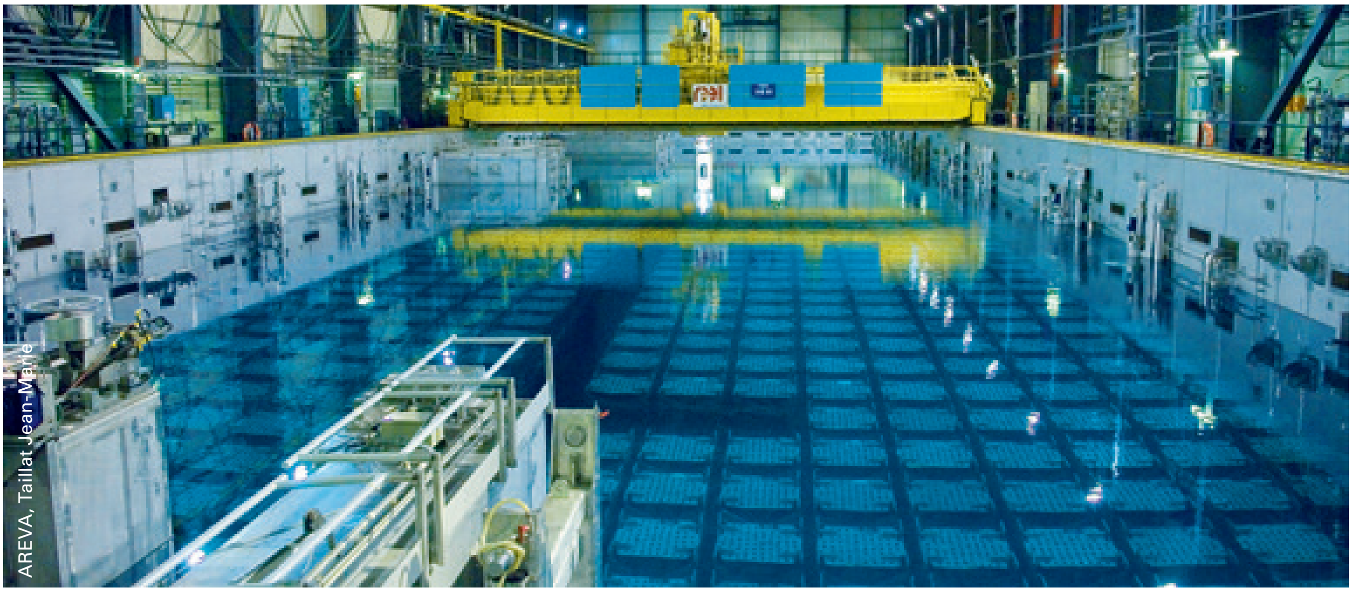
AREVA, Taillat Jean-Marie

Wet storage of spent fuel, La Hague, Cherbourg, France.

Very soon after the first nuclear programmes began operation around the world, countries started considering the grouping of radioactive materials generated in the process of nuclear energy applications. Such an aggregation was intended to address different management items such as handling, safety and long-term management. A variety of national approaches to the classification of radioactive materials and radioactive waste thus developed and subsequently led to a need to find a common terminology and understanding of national classification schemes in the context of international programmes.

Under these circumstances, the International Atomic Energy Agency (IAEA) developed the *Classification of Radioactive Waste: A Safety Guide* in 1994 (SS 111-G-1.1) and in 2009 issued the *General Safety Guide No: GSG-1* (IAEA, 2009) with a revised classification that is primarily based on considerations of long-term safety, such as a minimum appropriate disposal method. The European Commission (EC), for its part, issued Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, which required all member countries to have a national radioactive waste classification scheme. The *Final Guidelines for MS*[1] *Reports to the Waste Directive* recommended that EC members report their inventories in line with the GSG-1 international classification scheme.

A variety of national radioactive waste classification schemes have been established in most countries worldwide. Many of these schemes were created using the IAEA waste classifications as a reference (i.e. GSG-1, SS 111-G-1.1), and some countries have fully adopted the actual IAEA GSG-1 scheme in their waste classifications. However, from a technical point of view, it is often necessary to present inventory data in connection with the accepted disposal strategy. Two approaches, the first combining a comparison of inventories from a safety standpoint with the GSG-1, and the second providing a presentation in technical terms of the management strategy and disposal routes, could provide a better overall vision and improve the comparability of national inventories.

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[1] "MS = member states".

The NEA Radioactive Waste Management Committee (RWMC) has consistently underlined the importance of developing a method to transpose as best as possible national radioactive waste inventory data to a common presentation format so as to be able to compare data from different countries (e.g. through a method that would focus on the technical aspects of the disposal stages for inventory comparison). Such a scheme would combine both the spent fuel and radioactive waste inventories and the management strategies within individual countries. It would, however, have no influence on countries' existing radioactive waste classification schemes or spent fuel and radioactive waste management strategies, but would be essential for simply comparing and understanding the different spent fuel and radioactive waste management practices.

In 2014, the RWMC created the Expert Group on Inventorying and Reporting Methodology (EGIRM) to develop such a method, as the main contribution to the Status and Trends joint initiative of the IAEA, the EC and the NEA. The EGIRM has now developed the methodology in two stages, presenting the national status of spent fuel and radioactive waste management (the inventory, management strategy and disposal solution) for each country. An NEA report on the first stage of this development, considering the presentation of spent fuel and radioactive waste, was published in 2016 entitled *National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste: Methodology for Common Presentation of Data*. The methodology has since been completed and covers all types of spent fuel and classes of radioactive waste, as well as all possible management strategies with disposal routes.

The scheme was developed by the EGIRM for the presentation of national spent fuel and radioactive waste inventory in conjunction with a national management strategy. It is thus a means to represent combined spent fuel and radioactive waste inventory, as well as strategies for waste management in relation to disposal solutions, as established by the individual country. In other words, once completed by the country, the scheme presents the real picture of spent fuel and radioactive waste management during a specific period of reporting. The scheme is suitable for presenting forecasted future inventory and country strategies, if necessary. (See Table 1 for a sample presentation scheme.)

The table provides a general overview of the national situation, which can be extended depending on the needs or requirements of the implementing organisation. For example, additional rows can be inserted to present the origin of radioactive waste or its location. The amount of waste after reprocessing can be transferred into the relevant rows (e.g. 2, 3) or combined with waste from other sources when reasonable.

Table 1: Spent fuel and radioactive waste inventory presentation

Country: ______________________________

Date of inventorying: ____________________

SF/RW types (in national terms)		**No strategy**	**SF reprocessing/ service**		**Disposal in:**								
			Home	**Abroad**	**UF-1**		**UF-2**		**NSF-1**		**NSF-2**		**Optional**
(A)		**(B)**	**(C1)**	**(C2)**	**(D1)**	**(D2)**	**(E1)**	**(E2)**	**(F1)**	**(F2)**	**(G1)**	**(G2)**	**→**
1. SF + reprocessing RW													
1.1. NPP													
1.1.1. SF, (tHM)													
1.1.2 HLW (HG), (m³)													
1.1.3. RW (NHG), (m³)													
1.2. Other reactors													
1.2.1. SF, (tHM)													
1.2.2. HLW (HG), (m³)													
1.2.3. RW (NHG), (m³)													
2. Other HLW, (m³)													
3. … class, (m³)													
4. … class, (m³)													
Equivalence with IAEA GSG-1 classification	1.1.2	HLW	HLW	HLW	HLW								
	1.1.3												
	1.2.2	HLW	HLW	HLW	HLW								
	1.2.3												
	2.												
	3.												
	4.												
	5.												

The recommended units for data presentation are:

- spent fuel inventory data for NPPs and other reactors presented in tHM;
- radioactive waste inventory data (in the national classification) presented in m^3;
- disused sealed radioactive sources (DSRS) inventory data presented in pieces, when the DSRS are included separately in the inventory for radioactive waste.

To provide adequate and real comparability of data from the point of view of disposal, the EGIRM has recommended that countries present the volumes of conditioned radioactive waste ready to be disposed of in the corresponding table cell. When countries have radioactive waste in non-conditioned forms, the recalculation from an "as is" into an "as disposed of" volume is recommended when possible.

All possible spent fuel management strategies with relevant spent fuel amounts can be presented in the table, including shipments abroad for different services. All possible radioactive waste management strategies and disposal routes with relevant radioactive waste volumes can be presented in the table as well. To be fully consistent with the GSG1 international radioactive waste classification, the equivalence between national radioactive waste classes and GSG-1 classes is provided in the presenting scheme.

Figure 1: Flowchart showing the distribution of data

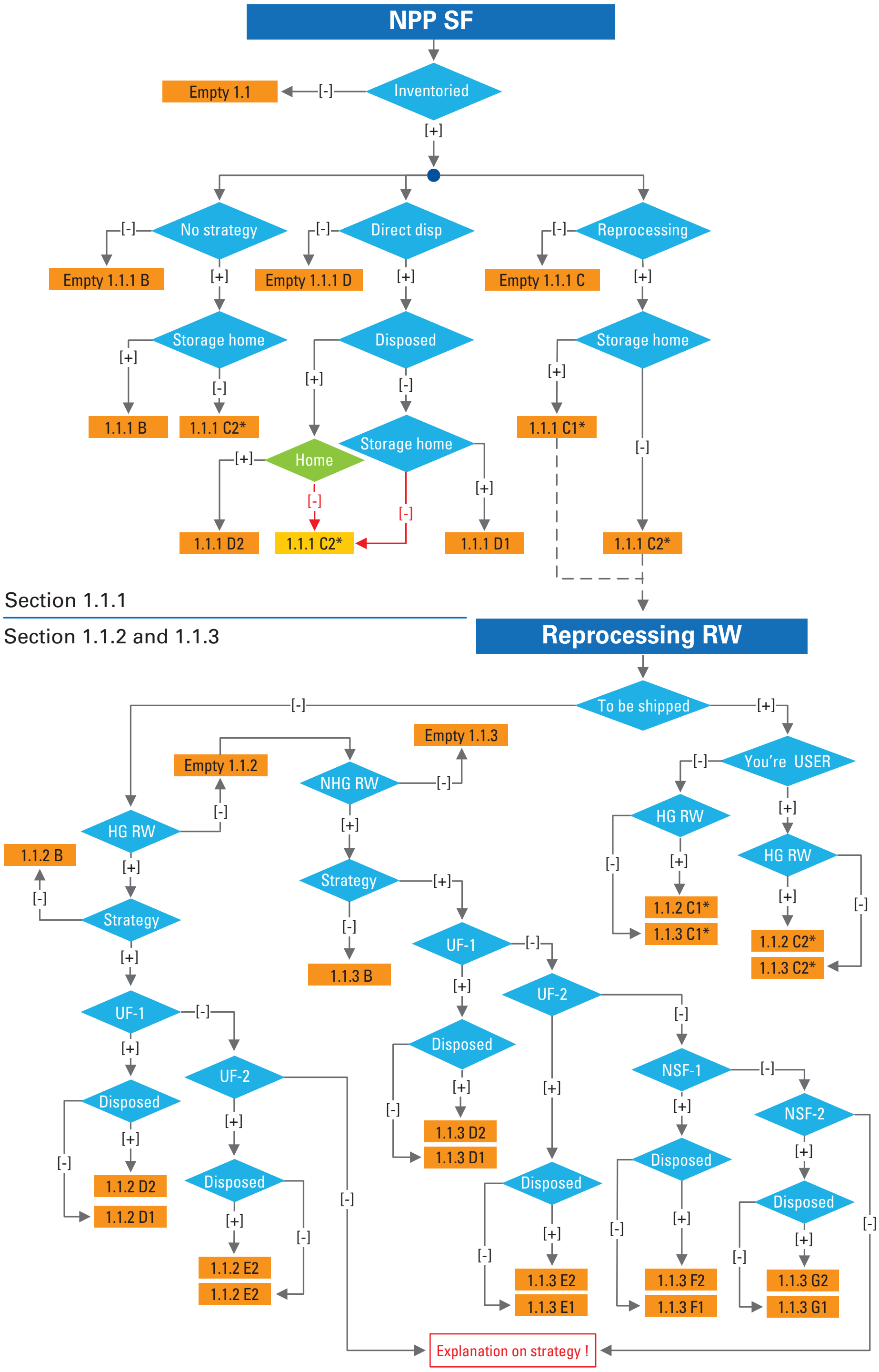

Table 2: **Types of disposal facilities**

Type of facility	Features	Radioactive waste classes (in terms of GSG-1) that can be disposed of	SSR-5 equivalent (1.14)
UF			
UF-1	- no direct, open connection with surface during construction or operation stage (i.e. ramp, shaft or borehole access); - intensive application of artificial barriers; - heat emission is considered in design; - package for SF/HLW/ILW – yes.	SF; HLW; ILW; LLW; VLLW; (NORM; TENORM) – solid	Geological disposal
UF-2	- no direct, open connection with surface during construction or operation stage (i.e. ramp, shaft or borehole access); - rather wide application of artificial barriers; - heat emission is not considered in design; - package for ILW – yes.	ILW; LLW; VLLW; (NORM; TENORM)	Disposal on intermediate depth + geological disposal
NSF			
NSF-1	- open air at construction stage; sometimes also during operation; - rather wide application of artificial barriers; - heat emission is not considered in design; - package for ILW – yes.	ILW; LLW; VLLW; (NORM; TENORM)	Near-surface disposal + disposal on intermediate depth (in some part)
NSF-2	- open air at construction stage; sometimes also during operation; - minimally reasonable application of artificial barriers; - heat emission is not considered in design; - package for LLW – yes.	LLW; VLW; (NORM; TENORM)	Near-surface disposal; landfilling
Other disposal routes			
Other disposal routes are not included in the group of recommended and widely accepted types of disposal facilities. They are discussed in Annex 1 of the forthcoming report.			

UF: underground facility; NSF: near-surface facility; HLW: high-level waste; ILW: intermediate-level waste; LLW: low-level waste; VLLW: very-low-level waste; NORM: naturally occurring radioactive materials; SF: spent fuel; TENORM: technologically enhanced naturally occurring radioactive material.

In its forthcoming report outlining the methodology, the EGIRM also provides a detailed explanation of the meaning of each column and row in the presentation scheme and gives instructions on how to fill in Table 1. Flowcharts are given to demonstrate step-by-step procedures in terms of data distribution among the cells. This report will be available later in late 2017.

The flowchart in Figure 1 is provided to support the distribution of data concerning an NPP's spent fuel and radioactive waste after reprocessing. Another flowchart has been developed for other reactors' spent fuel and radioactive waste after reprocessing and a third for radioactive waste not produced during spent fuel reprocessing.

In terms of the methodology, the EGIRM has arranged all types of disposal routes based on non-numerical technical parameters. The expert group specified four general types of disposal facilities widely represented in the world. These groups of accepted types of disposal facilities were proposed to the Status and Trends project and the joint working group accepted their implementation in future reports (see Table 2).

Other types of disposal routes were also considered by the expert group. However, some of these routes are currently banned and others are not widely used or only used by a few countries. This group of disposal routes is proposed therefore only for cases when countries need to present their radioactive waste disposed of at sea or when countries have implemented non-traditional disposal practices listed in the additional table. Still other disposal routes are described in the forthcoming EGIRM report.

The methodology was tested on national programmes of different sizes. Expert group members from Belgium, Canada, France, Germany, Italy, Russia and the United States applied the methodology and presentation scheme to reflect the situation of spent fuel and radioactive waste management in their countries. The form of the presentation scheme was designed to address all possible scenarios including those not implemented or rarely implemented today.

The testing demonstrated a good workability of the developed scheme and methodology. The expert group's work has therefore been completed in accordance with its mandate, with a presentation scheme – focusing on spent fuel and all types of radioactive materials – that has been included since June 2017 in the national profiles in the Status and Trends project.

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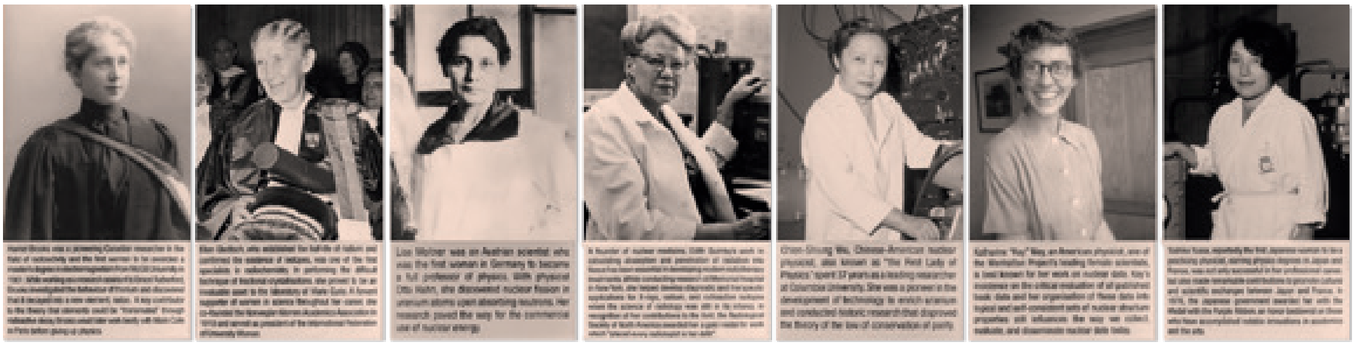
Women who helped shape the history of nuclear science and technology*



From left to right: Harriet Brooks, Ellen Gleditsch, Lise Meitner, Edith Quimby, Chien-Shiung Wu, Katharine Way and Toshiko Yuasa.

A little over a year ago, the Nuclear Energy Agency moved its offices to a new building operated by the OECD in Boulogne-Billancourt, located in the southern suburbs of Paris. The Boulogne building was built in 1927, originally as an industrial space long used to produce telephone control units, and had recently undergone renovations to transform the interior to an office space. Because the offices were both new and undecorated, the opportunity presented itself to be creative with the new NEA meeting rooms. NEA Director-General Mr William D. Magwood, IV was thus inspired to give a personality to the seven meeting rooms and so initiated a staff survey to choose names for the rooms. The results of the survey ranged from elements of the periodic table to nuclear reactor components or to Star Trek characters, but the final decision was made to name the rooms after notable female scientists who had advanced knowledge in the nuclear field.

Seven remarkable women, with exceptional careers but who have rarely been cast into the limelight, now grace the walls of NEA meeting rooms. These women are Harriet Brooks, Ellen Gleditsch, Lise Meitner, Edith Quimby, Chien-Shiung Wu, Katharine Way and Toshiko Yuasa. Their names may not be familiar to most because the credit for the research findings or discoveries that these women made were often attributed to their male colleagues – an example of what is called the "Mathilda effect". The case of Austrian physicist Lise Meitner exemplifies this failure to recognise women's contributions to science and technology. Meitner's discovery of nuclear fission in uranium opened up a new era in the world of nuclear physics, yet she was overlooked by the Nobel committee which decided to award the 1944 Nobel Prize in chemistry to her colleague, Otto Hahn. Meitner is considered one of the most important figures in the fields of radioactivity and nuclear physics. Despite not receiving the recognition she deserved during her lifetime, her name nonetheless lives on in the element meitnerium (Mt), named as such in her honour.

During the time of Lise Meitner and Harriet Brooks, very few women were pursuing careers in science. Although a brilliant researcher in the field of radioactivity, and one of the early discoverers of radon, Harriet Brooks, born in 1876 in Ontario, Canada and the first woman to earn a Master's degree from McGill University, faced the stark reality that the world was not yet ready for women who hoped to achieve a balance between their private and professional lives. After holding a tutoring position in physics for two years at Barnard College, New York – a women's college associated with Columbia University – the Dean, Laura Gill, asked Brooks to resign when it became known that Brooks was engaged to be married. The Dean informed Brooks that she could not condone a woman who would be both a wife

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* The information for this article was assembled by Laura Quintin, who was responsible, with the NEA Graphic Designer Fabienne Vuillaume, for co-ordinating the decoration of NEA meeting rooms.

and a working professional. In her forceful reply to the Dean, Brooks wrote:

> *"I think also it is a duty I owe to my profession and to my sex to show that a woman has a right to the practice of her profession and cannot be condemned to abandon it merely because she marries. I cannot conceive how women's colleges, inviting and encouraging women to enter professions can be justly founded or maintained denying such a principle."* [1]

Thirteen years following Brooks' resignation, Edith Quimby became the first research assistant of Dr Gioacchino Failla, a physicist and pioneer in biophysics and radiobiology. Hiring a woman in 1919 was indeed a rarity, and it was Quimby who had to work to support the family while her husband earned his doctorate – an ironic situation considering the fate of Harriet Brooks some years earlier. Dr Failla never regretted his decision to hire Quimby as the two worked together for over 20 years at the Memorial Hospital in New York where they studied means to improve radiation therapy and radiological protection, as well as the medical uses of X-rays and radium, in particular in the treatment of tumours. Quimby's work in calculating absorption and penetration of radiation into tissue has been essential in developing modern radiotherapy treatments. Considered one of the founders of nuclear medicine, Quimby was the first woman and first physicist to hold the position of President of the American Radium Society. She was only the second woman to receive the Gold Medal of the Radiological Society of North America.

While Quimby may have had less of a struggle to enter and succeed in her domain, many female scientists have had to overcome a number of obstacles to reach their goals in male-dominated fields. Ellen Gleditsch and Toshiko Yuasa, for example, realised that by achieving what they did, they in turn became role models for other young women. Gleditsch, of Norwegian origin, was rejected from working in the laboratories at Yale University in 1914. Instead of looking for other alternatives, she decided to frequent the laboratory, and ultimately established the half-life of radium at this same laboratory. She later worked with the very scientists who had refused her application. Throughout her professional life and even after retirement, Gleditsch advised students and helped promote scientific study. Advancing opportunities for women in education was an important cause for her and led Gleditsch to become a co-founder of the Norwegian Women Academics' Association, as well as to serve as President of the International Federation of University Women.

Similar to Gleditsch, Toshiko Yuasa was an active role model to young female students of science. From 1945 to 1949, she was a professor at the Tokyo Normal High School for Women, where she encouraged her students to pursue their scientific studies. She served in this way as an inspiration to many young women. Widely cited as the first Japanese woman physicist, Yuasa spent a significant part of her life working in France, arriving in Paris for the first time in 1940, when she studied under Professor Frédéric Joliot-Curie at the Collège de France and developed her expertise in beta-ray spectromony. Yuasa returned to Japan for a few years during World War II and then came back to France, where she remained until her death in 1980. In 1976, Yuasa received the Medal with the Purple Ribbon from the Japanese government in recognition of her achievements and the efforts she made through her books and essays to improve cultural and scientific exchanges between France and Japan. Today, her memory lives on through a prize for young women scientists given by Ochanomizu University, which allows one female student to study in France each year.

Yuasa was not the only scientist to leave her native country to further her studies and professional experience. Chien-Shiung Wu, after receiving her bachelor's degree in physics, left China to continue her studies at Berkeley in the United States. The work she carried out at Berkeley established her as an expert in nuclear fission and led to her becoming one of the many scientists recruited to work on the Manhattan Project. Following the war, Wu was offered a position at Columbia University. She worked with colleagues to disprove a longstanding theory in physics on the law of conservation of parity, conducting experiments to demonstrate that it did not hold true during beta decay. Wu was an expert in her field and later wrote a book entitled *Beta Decay*, which is still a standard reference for nuclear physicists. Not unlike Lise Meitner, Wu was also overlooked by the Nobel Prize committee which awarded the 1957 Prize in Physics to the male colleagues with whom she worked on the theory.

It is possible that during her time on the Manhattan Project, Wu may have met and known Katharine "Kay" Way. Born in the small industrial town, Sewickley, Pennsylvania, Way is best known for her work on nuclear data and the conception of the Nuclear Data Project, an effort to collect, organise and share nuclear data. Her insistence on the critical evaluation of all published basic data and her organisation of these data into logical and self-consistent sets of nuclear structure properties continues to this day to influence the way data is collected, evaluated and disseminated. Way was remembered by her colleagues as someone who "expressed herself passionately not only about the analysis of nuclear data, but also about many issues of human fairness and social justice."[2] Although Way had contributed to the Manhattan Project, she was concerned about the morality of using the atomic bomb. Unease among a certain number of scientists about the implications of using nuclear weapons was reflected in a book of essays which Way co-edited following the war entitled *One World or None: A Report to the Public on the Full Meaning of the Atomic Bomb.*

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[1] Rayner-Canham, M. and G. Rayner-Canham (2005), "Harriet Brooks (1876-1933): Canada's First Woman Physicist", *Physics in Canada,* Vol. 61, No. 1, p. 31.

[2] Excerpt of Katharine Way's obituary, published in *Physics Today,* December 1996.

Room No. 5310 "Lise Meitner".

At the time of writing this article, the NEA had the opportunity to name one of the two main meeting rooms on the ground floor of the Boulogne building, a room that will be used by the NEA as well as various OECD elements. Like other NEA rooms, this room will also be named after female scientists who made important contributions to the nuclear field, but this time scientists who did receive the recognition they deserved during their lifetimes – these historical figures are Marie Skłodowska Curie [3] and her daughter Irène Joliot-Curie.

Determined, undaunted, passionate and brilliant are a few ways to describe these women who have made such incredible contributions to the field of nuclear science. During their careers, Harriet Brooks, Ellen Gleditsch, Lise Meitner, Edith Quimby, Chien-Shiung Wu, Katharine Way and Toshiko Yuasa may not have always received the recognition that they should have, but today the NEA has put them on a pedestal for colleagues and visitors alike to admire, with associated biographies to recount their accomplishments, and most importantly, to bring them out of the shadows of history and into the light.

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[3] Marie Curie was the first woman to receive the gold medal of the Radiological Society of North America.

Advanced reactors and future energy market needs

by H. Paillère

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Wikimedia Commons, Wolkenkratzer

Vertical view of a cooling tower at a nuclear power plant.

Because it was considered both as an affordable source of electricity generation and a means to increase security of energy supply, nuclear power developed quickly within regulated markets during the 1970s and 1980s. However, changes in relation to geopolitics, demographic and economic growth as well as financial crises and technical and scientific breakthroughs have had an impact on regulations related to technologies, the environment and public health. Over the years, the nuclear industry has gone through consolidations and mergers while the types of reactor technologies have diminished to essentially water-cooled technologies and in particular pressurised light water reactors of increasing size to benefit from economies of scale. As described in the update of the *Technology Roadmap: Nuclear Energy* (NEA/IEA, 2015), today nuclear generation continues to provide the largest source of baseload, low-carbon electricity in OECD countries, but for how long?

With many countries committed to reducing greenhouse gas emissions so as to limit global warming to "well below 2°C", nuclear energy has a clear role to play and a potentially bright future. The International Energy Agency's 2-degree scenario (2DS), outlined in *Energy Technology Perspectives 2017* (IEA, 2017), sees the share of nuclear generation and installed capacity increasing significantly in the next decades. However, several challenges need to be addressed today for nuclear energy to fulfil its role, largely in relation to the competitiveness of nuclear energy versus other power generation technologies, the financing of the high capital costs of nuclear power plants, the evolving regulatory and policy frameworks, supply chain issues, public acceptance and the availability of a skilled workforce. Given the long lead time for the development of nuclear technology, it is also very important to see how well technology under development today will be able to address future market needs and meet regulatory requirements that could be in place at the time. This question applies to future evolutions of current reactor technologies or more advanced designs such as small modular reactors or generation IV (Gen IV) reactors.


Bertrand Degove

Gallery of the underground research laboratory of Meuse/Haute-Marne.


The WPNE is examining the interaction of nuclear energy and renewables in low-carbon electricity systems.

While nuclear energy is a recognised low-carbon source of electricity, it is also a low-carbon source of heat, and one whose potential has been very much left untapped, with the exception of the limited deployment of nuclear district heating and even more limited applications to desalination. It is clear that if the energy system needs to be decarbonised, nuclear could play an important role in the heat market, including industrial process heat, large scale desalination, hydrogen or other synthetic fuel production. The rate at which the heat sector is being decarbonised is fairly slow, resulting from a limited choice of options, but electricity systems worldwide are undergoing fast transformations, in particular with the rapid deployment of variable renewables. These are already affecting the current nuclear fleet, at different levels, for example in terms of wholesale electricity prices or flexibility requirements, and they will certainly have an important impact on future nuclear power generation.

What is the future of baseload generation? Will distributed generation overcome centralised generation? Will large generators such as today's nuclear power plants still be optimum? How fast will electricity storage technologies be deployed and at what cost, and what flexibility will be required in future low-carbon electricity systems – flexibility at the level of the generators or at the level of the electric system? These are important questions that designers of future nuclear systems should take into account.

The evolution of regulatory frameworks represents an additional challenge. First, licensing frameworks for advanced reactors – in particular for reactors that are significantly different from today's light water reactor technologies – do not always exist, limiting the pace at which new technology can be deployed. The need to harmonise requirements so as to reduce regulatory risks and costs is also a well-known issue. Environmental regulations are another challenge that need to be addressed by developers, and these can include regulations concerning the use of water (for cooling), which are becoming more strict as a result of concerns regarding the environmental footprint of power plants, as well as some regulations concerning chemical products that may be used in power generation technologies. Public acceptance for future nuclear generation will require not only meeting high safety standards but also having a reduced impact on the environment.

The NEA organised a very well attended international workshop on "Advanced Reactor Systems and Future Energy Market Needs" on 12 April 2017 that touched upon many of the topics mentioned above. It is clear that future nuclear systems will operate in an environment that will be very different from the electricity systems that accompanied the fast deployment of nuclear power plants in the 1970s and 1980s, alongside mainly coal-fuelled generation.

The workshop discussed how energy systems are evolving today towards low-carbon systems where technologies such as nuclear and variable renewables will need to co-exist, trends in future energy market needs, the changing regulatory framework from both the point of view of safety requirements and environmental constraints, and how reactor developers are taking these into account in their designs. In terms of technology, the scope covered all advanced reactor systems under development today, including evolutionary light water reactors (LWRs), small modular reactors (SMRs) – whether LWR technology based or not – and Gen IV systems.

Based on the results of this conference, the NEA is now embarking on a two-year study with a group of experts from its member countries, with the objective of analysing evolving energy market needs and requirements, as well as examining how well reactor technologies under development today will fit into tomorrow's low-carbon world. The outcome of the study will provide much needed insight into how well nuclear energy can fulfil its role as a key low-carbon technology.

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For more details on the "Advanced Reactor Systems and Future Energy Market Needs" conference, please visit www.oecd-nea.org/ndd/workshops/arsfem2017.

Argentina and Romania to join the NEA family*

Signing Ceremony at the OECD château, 7 June 2017.

Within the context of their national energy policies, Argentina and Romania are active players in the nuclear energy field, with significant research capacities. Both have been participating in NEA activities for a number of years, whether in NEA standing technical committees, as in the case of Romania, or in NEA subsidiary bodies in the case of Argentina.

Argentina and Romania expressed their interest in applying for membership in the NEA and its Data Bank in autumn 2016. A fact-finding mission was therefore organised, with a small team of NEA representatives, led by the NEA Deputy Director-General and Chief Nuclear Officer Daniel Iracane, to gather information concerning national nuclear energy policies and programmes, and to evaluate the potential benefits of Argentina and Romania becoming members of the NEA. The results of these missions were presented in the form of background documents to the NEA Steering Committee for Nuclear Energy so that members could review the analysis of nuclear-related policies and civil nuclear programmes of the applicant countries.

On 17 May 2017, upon recommendation of the Steering Committee, the Council of the Organisation for Economic Co-operation and Development (OECD) agreed to invite Argentina and Romania to become full members of the NEA and its Data Bank. The accessions were formalised during a ceremony officiated by NEA Director-General William D. Magwood, IV on 7 June 2017 through an official exchange of letters between each country and the OECD Secretary-General Angel Gurría.

The ceremony took place in the presence of the Romanian Prime Minister Sorin Grindeanu and the Minister of Public Finance Viorel Stefan, as well as the Argentine Minister of Foreign Affairs and Worship Susana Malcorra and the Minister of Energy and Mining Juan José Aranguren. OECD Secretary-General Gurría stated at the time that: "Today is a milestone not only for Argentina, Romania and the whole NEA 'family', but also for the OECD. It is a fruit of our constant efforts to make this Organisation more global, more inclusive."

Argentina and Romania possess strong and highly experienced nuclear technology infrastructures that will enable them to be vibrant contributors to the mission of the NEA. They share similar values with other NEA member countries, particularly with regard to nuclear safety, and these accessions highlight their commitments to implement the highest standards in their national nuclear energy policies and programmes.

As members of the NEA, each will be able to tap into the vast policy experience, dialogue and analysis that the NEA can offer in areas such as nuclear technology and science, safety, radioactive waste management and stakeholder involvement. Both countries will also gain from exchanging with other member countries and from the continuous benchmarking provided through NEA committees and working groups.

The addition of Argentina and Romania to the NEA will bring its membership to 33 countries that co-operate through joint research, consensus-building among experts and developing best practices. The accession of Argentina and Romania to the NEA will be mutually beneficial for NEA membership, particularly in terms of know-how and research activities related to pressurised heavy water reactor technology. Synergies are also expected in activities related to electricity market design, high-level waste management and scientific research infrastructures.

In the words of the NEA Director-General William D. Magwood, IV: "We are pleased to have Argentina and Romania join the NEA family to take part in collaborations related to the application of nuclear science and technology, and in the global debate on the energy mix required to meet the security of energy supply, socio-economic and environmental goals of the future. We look forward to working closely with both countries and are confident that the work of our agency will become even more relevant and more effective with their membership." The rights and responsibilities of Argentina and Romania as NEA members take effect officially on 1 September 2017 for Argentina and on 15 October 2017 for Romania.

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* The information for this article was assembled by Gülfem Demiray.

The NEA and IAEA: A long-standing partnership

by T. Lazo, L. Chanial and G. Piccarreta

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Shutterstock, Anastasiia Vasylyk

Abu Dhabi will be host to the International Ministerial "Conference on Nuclear Power in the 21st Century".

The Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA) have been partnering over the years in a number of areas after having signed a co-operation agreement in 1960 establishing that "the two agencies will act in close co-operation with each other and will consult each other regularly in regard to matters of common interest". Co-ordination meetings take place regularly between the senior management of the two agencies.

Since signing the co-operation agreement in 1960, the two agencies have continued to develop common activities. The IAEA/NEA International Reporting System for Operating Experience (IRS), for example, was initially conceived to collect information on potential safety related events at nuclear power plants and to provide this information to regulatory authorities. It has since evolved to address not only power installations, but also research reactors and fuel cycle facilities around the world. Another example is the International Nuclear and Radiological Event Scale (INES), developed as a means to communicate promptly to the public the safety significance of events reported at nuclear power plants. It has also been subsequently expanded to address events at all types of nuclear installations, as well as occurrences associated with the transportation of radioactive materials and the use of radioactive sources. The NEA has continued to work with the IAEA on both systems, jointly managing the IRS and as a member of the Advisory Committees for the IRS and INES.

The NEA was also active in the development of IAEA requirements on radiological protection (General Safety Requirements [GSR] Part 3) and emergency management (GSR Part 7), and cosponsors both documents. The NEA/IAEA Information System on Occupational Exposure (ISOE) was launched in 1992 to improve the management of occupational exposures at nuclear power plants through the collection and analysis of occupational exposure data and trends, and through the exchange of lessons learnt among utility and national regulatory authority experts. Since 1993, the IAEA has co-sponsored the ISOE programme to allow the participation of utilities and authorities from non-NEA member countries.


ENEC

Barakah NPP, units 3 and 4, United Arab Emirates, September 2016.

The two agencies regularly produce joint publications as well. The Joint NEA/IAEA Group on Uranium, which held its 50th meeting in 2013, produces one of the most widely read publications in the nuclear field today: *Uranium: Resources, Production and Demand*. The IAEA also awards financial support on a yearly basis to professionals from its member states to participate in the NEA International School of Nuclear Law (ISNL). In addition, the two agencies are both part of an international network of data centres in charge of the compilation and dissemination of basic nuclear data.

The NEA and IAEA actively participate in each other's committee meetings and conferences on a regular basis. A continuous flux of shared information and cross-participation in each other's conferences and committee and working group meetings guarantees, for the benefit of their membership, the optimisation of the agencies activities in areas related to the safe operation of reactors, the nuclear fuel cycle, as well as the scientific and legal areas underlying nuclear technology.

A prime example is the upcoming International Ministerial "Conference on Nuclear Power in the 21st Century". Organised by the IAEA in co-operation with the NEA, the conference will take place in the United Arab Emirates (UAE) from 30 October to 1 November 2017, and will be hosted by the UAE Ministry of Energy and Federal Authority for Nuclear Regulation.

The conference will provide an opportunity to generate high-level dialogue on the role of nuclear power in meeting future energy demand, contributing to sustainable development and mitigating climate change as well as ensuring energy security. It will feature special presentations, panel sessions, keynote speeches and round table discussions, with Ministerial level participants from the 168 IAEA member states, and representatives from 31 – soon to be 33 NEA member countries (see page 25 regarding Argentina and Romania joining the NEA). The IAEA Director-General Yukiya Amano and the NEA Director-General William D. Magwood, IV, will be speaking at the event, along with renowned experts from around the world. A joint NEA/IAEA side event is also planned in Abu Dhabi.

For more information on the conference, please visit the official event website at www.iaea.org/events/nuclear-power-conference-2017.

NEA
NUCLEAR ENERGY AGENCY

The NEA mission

To assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes; and to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to OECD policy analyses in areas such as energy and the sustainable development of low-carbon economies.

IAEA
60 Years
Atoms for Peace and Development

The IAEA mission

To accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.

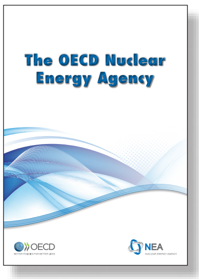
General Interest

Annual Report 2016

NEA No. 7349. 68 pages.

Rapport annuel 2016

AEN n° 7350. 72 pages.

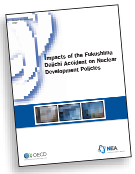


The OECD Nuclear Energy Agency

8 pages. Brochure.

Also available in French, Chinese and Russian.

Nuclear development and the fuel cycle



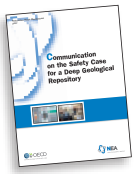
Impacts of the Fukushima Daiichi Accident on Nuclear Development Policies

NEA No. 7212. 68 pages.

Available online at: http://oe.cd/1Sr

The Fukushima Daiichi nuclear power plant accident has had an impact on the development of nuclear power around the world. While the accident was followed by thorough technical assessments of the safety of all operating nuclear power plants, and a general increase in safety requirements has been observed worldwide, national policy responses have been more varied. These responses have ranged from countries phasing out or accelerating decisions to phase out nuclear energy to countries reducing their reliance on nuclear power or on the contrary continuing to pursue or expand their nuclear power programmes. This study examines changes to policies, and plans and attempts to distinguish the impact of the Fukushima Daiichi accident from other factors that have affected policymaking in relation to nuclear energy, in particular electricity market economics, financing challenges and competition from other sources (gas, coal and renewables). It also examines changes over time to long-term, quantitative country projections, which reveal interesting trends on the possible role of nuclear energy in future energy systems.

Radioactive waste management

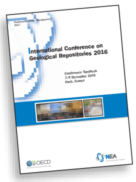


Communication on the Safety Case for a Deep Geological Repository

NEA No. 7336. 88 pages.

Available online at: http://oe.cd/1NJ

Communication has a specific role to play in the development of deep geological repositories. Building trust with the stakeholders involved in this process, particularly within the local community, is key for effective communication between the authorities and the public. There are also clear benefits to having technical experts hone their communication skills and having communication experts integrated into the development process. This report has compiled lessons from both failures and successes in communicating technical information to non-technical audiences. It addresses two key questions in particular: what is the experience base concerning the effectiveness or non-effectiveness of different tools for communicating safety case results to a non-technical audience and how can communication based on this experience be improved and included into a safety case development effort from the beginning?



International Conference on Geological Repositories 2016

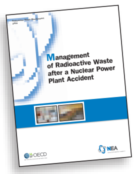
Conference Synthesis

NEA No. 7345. 40 pages.

Available online at: http://oe.cd/ICGR2016

Worldwide consensus exists within the international community that geological repositories can provide the necessary long-term safety and security to isolate long-lived radioactive waste from the human environment over long timescales. Such repositories are also feasible to construct using current technologies. However, proving the technical merits and safety of repositories, while satisfying societal and political requirements, has been a challenge in many countries.

Building upon the success of previous conferences held in Denver (1999), Stockholm (2003), Berne (2007) and Toronto (2012), the ICGR 2016 brought together high-level decision makers from regulatory and local government bodies, waste management organisations and public stakeholder communities to review current perspectives of geological repository development. This publication provides a synthesis of the 2016 conference on continued engagement and safe implementation of repositories, which was designed to promote information and experience sharing, particularly in the development of polices and regulatory frameworks. Repository safety, and the planning and implementation of repository programmes with societal involvement, as well as ongoing work within different international organisations, were also addressed at the conference.



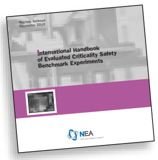
Management of Radioactive Waste after a Nuclear Power Plant Accident

NEA No. 7305. 226 pages.

Available online at: http://oe.cd/1Fq

The NEA Expert Group on Fukushima Waste Management and Decommissioning R&D (EGFWMD) was established in 2014 to offer advice to the authorities in Japan on the management of large quantities of on-site waste with complex properties and to share experiences with the international community and NEA member countries on ongoing work at the Fukushima Daiichi site. The group was formed with specialists from around the world who had gained experience in waste management, radiological contamination or decommissioning and waste management R&D after the Three Mile Island and Chernobyl accidents. This report provides technical opinions and ideas from these experts on post-accident waste management and R&D at the Fukushima Daiichi site, as well as information on decommissioning challenges.

Nuclear science and the Data Bank



International Handbook of Evaluated Criticality Safety Benchmark Experiments

NEA No. 7328. DVD.

This handbook contains criticality safety benchmark specifications that have been derived from experiments performed at various critical facilities around the world. The benchmark specifications are intended for use by criticality safety engineers to validate calculation techniques used to establish minimum subcritical margins for operations with fissile material and to determine criticality alarm requirements and placement. Many of the specifications are also useful for nuclear data testing. Example calculations are presented; however, these do not constitute a validation of the codes or cross-section data.

The evaluated criticality safety benchmark data are given in nine volumes. These volumes span over 70 000 pages and contain 570 evaluations with benchmark specifications for 4 913 critical, near-critical or subcritical configurations, 45 criticality alarm placement/shielding configurations with multiple dose points for each, and 215 configurations that have been categorised as fundamental physics measurements that are relevant to criticality safety applications.

New to the handbook are 15 critical experiments with highly enriched uranium in an iron matrix performed to support the design of a repetitively pulsed reactor called the Sorgenta Rapida Reactor (SORA) at the Eurotom Research Centre in Ispra, Italy. A photograph of this experiment assembly is shown on the front cover.

International Handbook of Evaluated Reactor Physics Benchmark Experiments

NEA No. 7329. DVD.

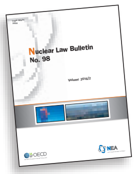
The International Reactor Physics Experiment Evaluation (IRPhE) Project was initiated as a pilot in 1999 by the Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC). The project was endorsed as an official activity of the NSC in June 2003. While the NEA co-ordinates and administers the IRPhE Project at the international level, each participating country is responsible for the administration, technical direction and priorities of the project within its respective country. The information and data included in this handbook are available to NEA member countries, contributors and to others on a case-by-case basis.

This handbook contains reactor physics benchmark specifications that have been derived from experiments performed at nuclear facilities around the world. The benchmark specifications are intended for use by reactor designers, safety analysts and nuclear data evaluators to validate calculation techniques and data. Example calculations are presented; these do not constitute a validation or endorsement of the codes or cross-section data.

This edition of the *International Handbook of Evaluated Reactor Physics Benchmark Experiments* contains data from 151 experimental series that were performed at 50 reactor facilities. To be published as approved benchmarks, the experiments must be evaluated against agreed technical criteria and reviewed by the IRPhE Technical Review Group. A total of 146 of the 151 evaluations are published as approved benchmarks. The remaining five evaluations are published as draft documents only.

The front cover of the handbook shows the MINERVE reactor in Cadarache, France. Evaluation was completed of the CERES Phase II validation of fission product poisoning through reactivity worth measurements, which includes 13 fission products.

Nuclear law



Nuclear Law Bulletin, Volume No. 98

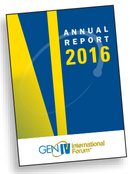
NEA No. 7313. 104 pages.

Available online at: www.oecd-nea.org/law/nlb

The *Nuclear Law Bulletin* is a unique international publication for both professionals and academics in the field of nuclear law. It provides readers with authoritative and comprehensive information on nuclear law developments. Published free online twice a year in both English and French, it features topical articles written by renowned legal experts, covers legislative developments worldwide and reports on relevant case law, bilateral and international agreements as well as regulatory activities of international organisations.

Feature articles in this issue include "Strengthening the international legal framework for nuclear security: Better sooner rather than later"; "Brexit, Euratom and nuclear proliferation"; and "McMunn et al. v Babcock and Wilcox Power Generation Group, Inc., et al.: The long road to dismissal".

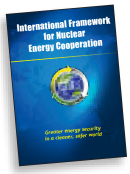
Publications of NEA-serviced bodies



Generation IV International Forum (GIF) Annual Report 2016

GIF report. 124 pages.

This tenth edition of the *Generation IV International Forum (GIF) Annual Report* highlights the main achievements of the Forum in 2016 under the new Chair of the GIF Policy Group. The Framework Agreement, formally extended for ten years in February 2015, was signed by the remaining countries in 2016. The GIF is set to continue actively engaging in R&D on Generation IV systems with the extension of the four System Arrangements (sodium-cooled fast reactor, gas-cooled fast reactor, supercritical water-cooled reactor and very high temperature reactor) until 2026. Australia became the 14th country to join the GIF after signing the Charter in June 2016 and initiating the process to accede to the Framework Agreement. This annual report also provides a detailed description of progress made in the eleven existing project arrangements and under the Memorandum of Understanding governing R&D exchanges on molten salt reactors and lead-cooled fast reactors. In addition, it outlines the 2016 activities of the methodology working groups and the two dedicated task forces, one on the development of safety-design criteria and the other on education and training.



International Framework for Nuclear Energy Cooperation

IFNEC brochure. 8 pages.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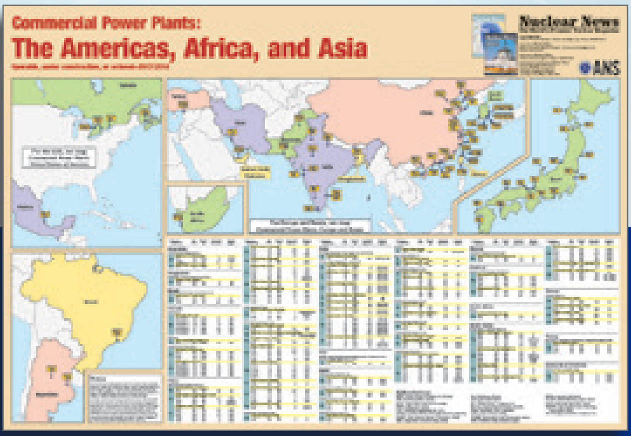
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