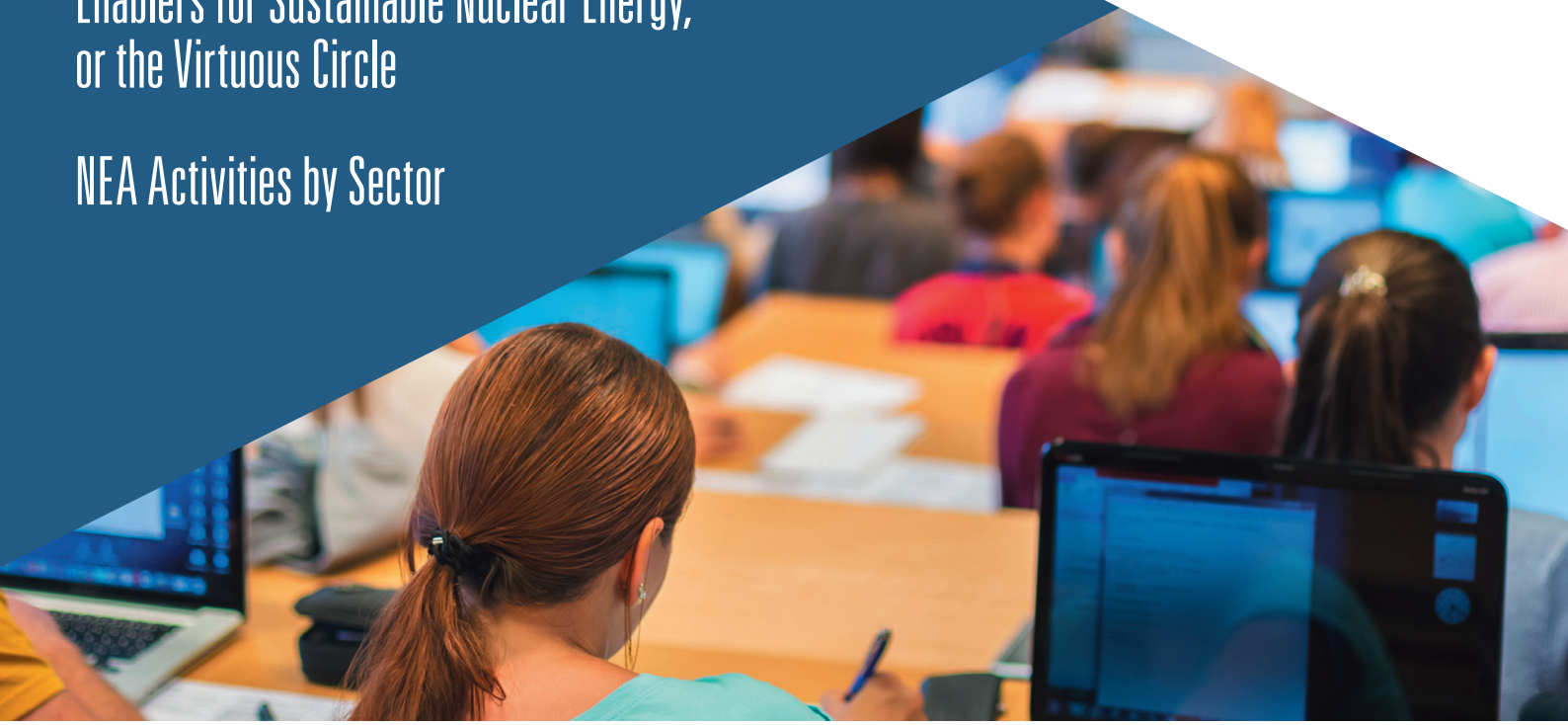
2017 NEA Annual Report

Nuclear Power in 2017

Innovation and Education: Necessary Enablers for Sustainable Nuclear Energy, or the Virtuous Circle

NEA Activities by Sector



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NEA
NUCLEAR ENERGY AGENCY

2017 NEA

Annual Report

NUCLEAR ENERGY AGENCY
Organisation for Economic Co-operation and Development

The NEA in Brief – 2017

Governing body: The Steering Committee for Nuclear Energy

The NEA and its mission

The Nuclear Energy Agency (NEA) is a semi-autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD), located just outside Paris, France. The objective of the Agency is 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.

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Nuclear Multilateralism

When the first and second generation of nuclear power plants were designed and built, it was the norm for many countries to conduct this work as a national endeavour. Much of this, of course, was pursued in the context of the Cold War; in general, early infrastructures and skill development focused on the nuclear technology supported both civilian and military applications. Because of the strategic value of nuclear technology, research was very well-funded and provided high priority in many countries.

This national approach led to the advent of lineages of nuclear energy technology that were as distinctive as the cultures that produced them. Light water reactor (LWR) technology in the United States, first developed for submarine applications, was quickly adapted for commercial power generation. Canada developed an expertise in heavy water moderated reactors in the aftermath of World War II and went on to build CANDU plants. The United Kingdom developed the Magnox graphite moderated gas-cooled reactors for both military and civilian purposes and followed this technology with the advanced gas-cooled reactors in operation today. Around the same time as the Magnox reactors were built, and with similar missions, Russia designed and built the graphite-moderated, water-cooled RBMK reactors.

These national programmes provided a global diversity that, as is the case with nearly everything in the modern, globalised world (from the desktop computers we use to where we buy our coffee), has been greatly reduced today. While a few countries plan construction of new CANDU reactors, the light water reactor has in large part become a global standard. Many different LWR designs are available from China, France, Korea, Japan, India, the Russian Federation, and the United States, but they are essentially the same basic technology, with very similar benefits and shortcomings.

While technology diversity has been reduced, globalised nuclear energy has provided substantial benefits. The similarity of technologies allows nuclear operators and regulators around the world to engage in exchanges of experience and processes today that is unprecedented in previous history. Countries that choose to build nuclear plants — both experienced countries such as the United Kingdom and newcomers such as the United Arab Emirates — may choose from a range of suppliers without the need to consider whether the technology is viable. They can select technologies on a commercial basis with the knowledge that hundreds of reactor-years of operating experience exists to support future operation.

Moreover, when plants are built, and as new parts and components are required during their operating lives, the supply chain is now globalised. Whereas Generation I and Generation II plants were built in many countries with entirely national supply chains, Generation III plants draw from a wide range of suppliers in many countries. The very large foundries and fabrication facilities needed to supply massive components such as pressure vessels and steam generators exist in few places. The number of plants being built in most countries cannot justify the cost of establishing domestic capabilities.

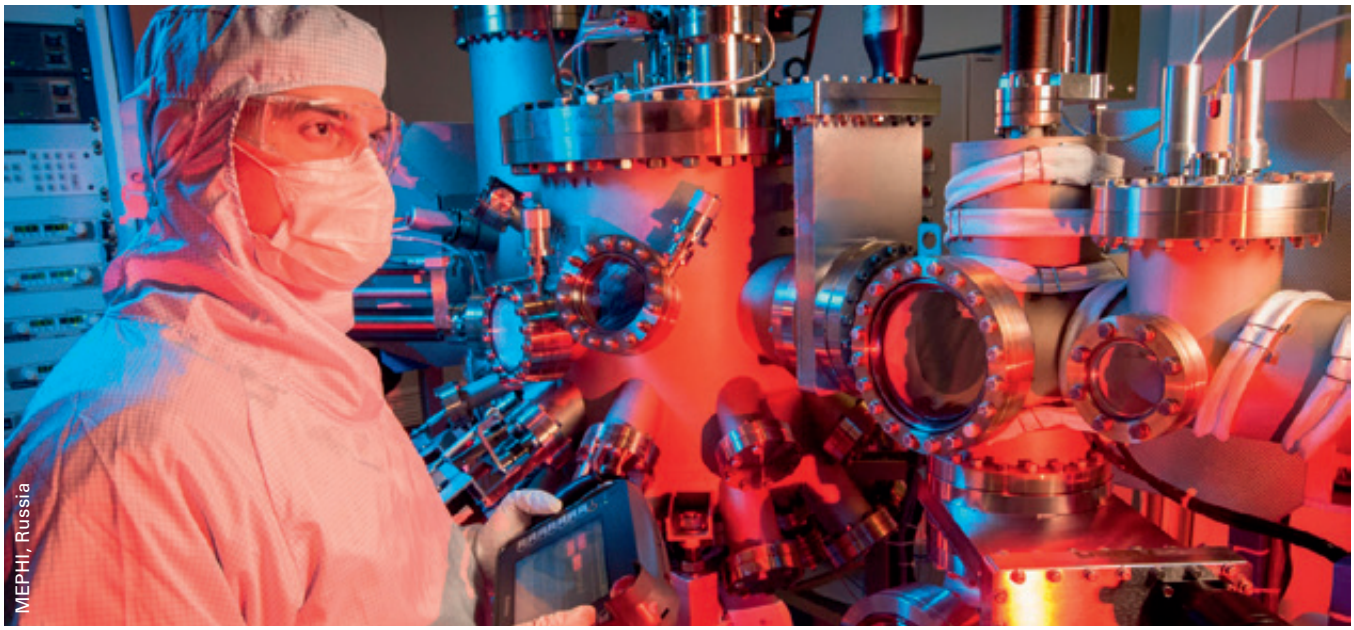
This globalisation is today extending increasingly to research and development. Whereas governments led the development of nuclear energy for many decades, commercial companies now have much of the burden to advance nuclear technology. Even when government laboratories are engaged in supporting research and development, the capabilities of these institutions in many countries have been diminished over the years. Today, few countries have the full suite of experimental and test facilities needed to explore and develop technologies. A key example: the only operating fast neutron test reactors in the world are in Russia. Far more than in the past, developers of advanced fission reactors, fusion technology and other fields must travel across borders to perform vital experiments. Further, the cost and complexity of developing nuclear technologies encourages the consideration of collaboration to share expertise and costs.

While the need is present, the institutional and policy framework to support globalised research and development is often lagging. A January 2018 workshop held under the umbrella of NEA's Nuclear Innovation 2050 (NI2050) framework highlighted the problems associated with transporting samples of nuclear fuels for irradiation in other countries and the complexities associated with appropriately characterising and managing the resulting materials. While the Multinational Design Evaluation Programme (MDEP) has had important successes, it is not a framework for multinational licensing. Codes and standards for nuclear components should be converging but are often proliferating.

Started on strong national grounds, nuclear energy is now facing a major paradigm shift and is becoming a multilateral undertaking. At the NEA, we are working to identify the barriers and issues that make the global nuclear technology enterprise less effective than it could be. The situation is very challenging; but the need to address it is greater still. The NEA is working with its members to pursue the positive conditions and multilateral solutions to keep nuclear technology a viable option for the long-term future.

William D. Magwood, IV,
Director-General, Nuclear Energy Agency

Innovation and Education: Necessary Enablers for Sustainable Nuclear Energy, or the Virtuous Circle



Education-Research Center "Nanocenter" training in the method of pulsed laser deposition.

Societies across the world have relied on access to electricity from different sources for more than a century and are expected to become even more reliant on this form of energy in the decades to come. To ensure the reliable availability of electric and other modern forms of energy, governmental policies need to find and maintain the right balance between environmental protection, generally by minimising the emission of pollutants into the atmosphere; security and reliability of supply; and economics based on the full cost of production, distribution and others externalities.

Policy makers around the world thus have the difficult task of orienting the evolution of global and national energy portfolios to allow societies to better balance these three factors in the coming decades. This must be done at a time when the future is very uncertain. Regulations related to CO_2 and air pollution are changing the landscape for fossil technologies in many countries, impacting the power, heat and transport sectors; and the rapid deployment of intermittent renewable technologies is having a strong, disruptive impact on the electricity markets. As a result of these and other factors, such as the advent of very inexpensive natural gas in some parts of the world, it has become increasingly challenging to anticipate future developments.

However the future develops, there are no certain scenarios that achieve all of the goals of the global community without a sizeable contribution from low-carbon, dispatchable technologies, among which nuclear energy.

The 2015 edition of the IEA/NEA *Technology Roadmap: Nuclear Energy* demonstrates the important role that nuclear fission technology can play as a contributor to a resilient low-carbon future. While not all countries intend, or need, to apply nuclear energy, the collective global community has set very ambitious goals for the energy sector that will prove very difficult to achieve on a sustainable basis without contributions from nuclear energy.

A focus of NEA activities is to contribute to creating the positive conditions necessary for the development of the safe technologies that correspond to societal needs today and tomorrow; in short, supporting the efforts of member countries that wish to incorporate nuclear technology in their

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energy mix as the global energy picture continues to evolve in the coming decades.

With this goal in mind, the extensive discussions driven by the NEA's Nuclear Innovation 2050 (NI2050) initiative have shown that there is great value in both pursuing active research and development with the concrete objective of reaching market deployment, and attracting and involving young people in the field so as to ensure the transfer of the extensive knowledge base (i.e. the "know-why" that is beyond the "know-how") associated with decades of nuclear development and its adaptation to rapidly evolving markets and requirements. If we are to ensure the ability to make fully informed decisions in the future regarding the global energy mix, handling of nuclear waste and decommissioning of old facilities, it is essential to ensure that the necessary critical mass and combination of comprehensive knowledge, technological progress and competent people will remain available, with the fundamental tools and information required to analyse and respond to changing circumstances.

Innovation is therefore not only important to reach precise technical or industrial goals, but it is an essential process to maintain intellectual capacities. Innovation in nuclear must be a central focus for both the interested community and for policy makers. Such a positive vision can provide the appeal necessary for younger generations and universities to engage in this sector of activity, thus boosting the innovation process and creating a virtuous circle. The need to involve youth in the nuclear sector brings us to a second initiative being promoted by the NEA in the field of education: "The Nuclear Education, Skills and Technology" (NEST) initiative.

A breakthrough is needed in the nuclear innovation process to allow the development of innovative technologies and processes, and to bring them to the market economically and in time frames that are compatible with sustainability challenges. In other words, such processes must be faster and less expensive than what has been observed over the last two decades. A central element of this reflection is the necessary complementarity – and not opposition – between "safety" and "economics". Innovation will support the evolution of technologies that allow safety to progress, while at the same time leading to a reduction in costs.

A number of national initiatives have been launched over the years in different countries with the aim of boosting innovation in nuclear fission and ultimately trying to overcome the "headwinds" that have slowed the innovation process. Some of these headwinds have been related to the following areas:

- Research infrastructures and expertise: much of the global nuclear research infrastructure was built more than 40 to 60 years ago and is shrinking steadily. A large pool of competent and experienced people will be retiring and thus will contribute to this phenomenon.
- Regulatory framework: regulations and regulatory processes have become well optimised for existing technology through decades of accumulated experience. But when the time comes to welcome innovation, which will include a significant potential for increased safety and performance, the process of reaching a consistent state of readiness and maturity in the innovative technology and in its related regulation framework may be unclear and can generate a perception of having to overcome barriers for both the researcher and industry, and even at times for the regulator.
- Economics: the cost and risks associated with innovation have become prohibitive in a number of countries where a weakening of major historical industrial players can be observed.

Given the financial constraints in most developed economies, both at governmental levels and at the level of industry operating in a global market, it is difficult, and sometimes even impossible, to address such headwinds at the national level.

An international framework could create the opportunity to launch initiatives aimed at tackling the challenges described above since working at the international level creates confidence, mutualises costs and limits or mitigates the risks.

To accelerate the readiness of innovative technologies and their competitive deployment within a time frame that would allow them to contribute to the sustainability of nuclear energy in the medium (2030) to long term (2050), NI2050 is selecting and promoting large scale R&D and market uptake programmes of action (a sequence of concrete projects and infrastructures). It is pooling the interest of stakeholders (R&D bodies, industry, technical support organisations [TSOs], regulators and waste agencies) around these programmes of action, and proposing them to governments, financial institutions and other stakeholders for further implementation. The "double 2030/2050 time frame" covers both evolutionary and revolutionary innovations, thus capturing the interests of both industry and research communities.

University workshop.
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Such an initiative will help overcome current segmentation, with industry on the one side and laboratories on the other, working in their respective corners. On the contrary, while industry is taking a naturally pivotal role in developing evolutionary technologies, labs should be involved in bringing ideas "out of the box" and into the innovation process. And while developing revolutionary technologies, these laboratories must consult with industry to get prospective views and to secure the link to the future market.

A central element of NI2050 is therefore to foster the early, continuous and synchronised interaction between stakeholders involved in innovation, a factor that was lacking in a number of instances in the recent past and that needs to be reactivated in a context where the overall technological, economic and regulatory environment has also drastically evolved. Helping to ensure a better parallelism between technology readiness levels (TRLs) and licensing readiness levels (LRLs) will also help to reduce the risk of failures in later stages of the development process and accelerate innovation, both of which are critical factors to foster the engagement of stakeholders. With that prospect in mind, the mandatory early involvement of the safety community can be made possible, without jeopardising the independence of the national regulatory body, through international co-operation.

The NEA provides the right international framework to help ease this process by creating confidence, sharing costs and broadening market perspectives through a bottom-up harmonisation process. The NI2050 initiative is being shepherded by the NEA Nuclear Development Committee (NDC), focusing *inter alia* on the economic aspects of nuclear energy and the interaction with industry. Any innovation based on scientific evolution needs to advance both nuclear safety objectives and improved economics.

Under the guidance of the NI2050 Advisory Panel, priority areas and topics have been identified where innovation is necessary, and R&D focused roadmaps have been developed by experts with in-depth knowledge in these areas, ensuring synergies with existing research roadmaps at national and international levels.

In addition to the well-known topics of nuclear safety, advanced reactor systems, nuclear fuel and fuel cycle technologies, some of the issues selected by NI2050 are going beyond "pure nuclear technology" and are linking with the broader technological and innovation ecosystem, such as materials and their manufacturing, digitalisation and IT, applications beyond the power sector and flexibility in energy production and usage.

The time has come to share these roadmaps within the NEA framework, with the scientific community through the NEA Nuclear Science Committee (NSC), with the safety community through the Committee on the Safety of Nuclear Installations (CSNI) and the Committee on Nuclear Regulatory Activities (CNRA), and with industry, for example through co-operation with organisations such as the Electric Power Research Institute (EPRI). The sharing of these roadmaps will result in dedicated programmes of action within NEA member countries, and possibly via NEA joint projects.

Such programmes should tackle not only the shared bases of technology innovation, but even more importantly, the related process of the qualification and licensing of a new technology. If indeed an international consensus could be reached on a process of qualification and licensing that might serve as a common basis for application in different countries, it would greatly help to reduce the time and the risks to deployment while broadening confidence in the new products.

To develop the technical bases and the qualification process of new technologies, collaborative approaches at the international level can be manageable in terms of the intellectual property and far more effective than processes developed at the national level.

Making the link between NI2050 and NEST is another key to success. It is crucial to engage youth in the innovation process, for example by attracting and involving universities in concrete innovation programmes connected to real-world challenges, based on hands-on training and offering multidisciplinary networking opportunities. Such factors will allow nuclear education curricula to stay alive and attractive to students who become the researchers and engineers of tomorrow. Captivating talented, young engineers and scientists, and training them in relation to the innovation process will be critical to advancing the safe and effective use of nuclear technology.

A requirement: Innovation in safety

The evolution of technology is an integral part of global safety. Advances in nuclear energy are largely driven by lessons learnt from past experience such as accidents or by the obsolescence of technologies, which provide momentum towards the development of new technologies that can optimise safety. Society's demands for optimal safety can encourage technological developments since the performance requirements that are being emphasised may not be able to be met without a breakthrough in the current technology. Research on new technologies expected to provide added safety, as well as overall value to society in general, include accident tolerant fuels (ATFs), digitalised technologies that can replace obsolete instrumentation and control systems, innovative reactor designs (small modular reactors or high temperature gas-cooled reactors), and the expanded use of new analytical methodologies, such as probabilistic safety assessments of fires, external events and human reliability.

It is important, however, that the innovation process ensure that technologies are at once reflective of high levels of nuclear safety and demonstrated to be feasible for industrial deployment. All too often, the standard licensing process as it is usually practiced today, with its sequential scheme of research, industrial development and then licensing, is not always responsive to such an innovation process. On the one hand, the timescales involved are prohibitive, with industry anticipating a high level of risk in the regulatory process, primarily as a result of expected requests for a redesign of certain elements during the licensing phase. Such requests would in effect result in a freeze in technological investment. On the other hand, regulatory authorities may also lack confidence in the face of a technology that has been pushed through the licensing process from scratch, without having had sufficient time to mature.

Regulatory bodies and their technical support organisations should therefore be involved from the early stages of technology development to help build in safety during pre-licensing activities. To ensure a smooth and efficient licensing process, joint efforts to allow new technologies to adequately mature are in fact essential, since a shared awareness of the challenges that may arise during the innovation process will inexorably reduce the risks for both industry and the regulatory body. It is also important to define a shared vision of the expected benefits of the new technology for the sake of all the stakeholders involved (i.e. improved safety and economic performance).

Early exchanges concerning the safety demonstration of an innovative technology should thus be undertaken so as to identify related safety criteria, scenarios and the associated qualification strategy. Long-term actions will also be needed to address the different aspects of innovation development in parallel and to limit unreasonable risks and delays. While limitations may arise during the pre-licensing stage, these limitations can be overcome in a transparent and co-operative manner.

The pre-licensing approach requires investments from industry, from the regulatory body and from research. To ensure the success of the technology, investments must be better synchronised, especially in terms of the resources engaged. In former days, the development of nuclear technologies was embedded in consistent national policies that in essence provided this synchronisation. Today, however, despite general agreement on the need for innovation (e.g. accident tolerant fuels), there is little guarantee that resources from the regulatory side can be invested in due time and at the right level far before the deployment decision, which leads to a "chicken and egg" effect that jeopardises the maturing of new technologies.

It is difficult to imagine that in our day and age a breakthrough technology could be developed in a single country, in isolation from the global market. In doing so, the innovative technology would inevitably face unreasonable risks and delays in its market penetration, resulting in a collapse of research and development activities. Synchronisation of the regulatory process among several potentially interested countries thus represents a major stake in today's world.

While pre-licensing activities may require interaction between the development process and the regulatory process, the full independence of the regulatory body must nonetheless be guaranteed when the licensing process begins. For such a guarantee to exist, a fully transparent framework that does not jeopardise the due responsibility of each stakeholder must be in place.

International collaboration among regulatory bodies and associated TSOs provides a means of rectifying the limitations outlined above. Such collaboration is the best way to synchronise involved players in promising technologies and to ease the necessary decision-making processes for public organisations. It also mutualises the overall means and decreases the risks for investing resources in promising but still uncertain technologies. Collaboration provides reference materials (the safety scenario, safety criteria and scientific results) for a reinforced and shared confidence in the new technology, which is an important asset when the time comes for a sovereign decision on the part of the regulatory body at the national level.

Ultimately, international co-operation can provide the transparent framework necessary to allow interactions between developers and future implementers, while at the same time ensuring the independence of the national regulatory process.

A strategic case: Enhancing experimental support for advancements in nuclear fuels and materials

During the last decade, major improvements have occurred in the fields of materials science, instrumentation and large-scale simulation, while the ability to evaluate the merits of innovations proposed by these improvements has been lagging behind. New developments proposed to improve safety and economics have been met with a long path to deployment and licensing. The development and qualification of nuclear fuel, for example, can take up to twenty years, with much of this time associated with long irradiation tests, as well as with obtaining data from post irradiation examinations.

Over the last decade, significant progress has been made in the development of novel simulation tools to enable rigorous modelling of physical phenomena. To be used to their full potential, they will require a more complex suite of validation experiments as a result of the multiple energy, spatial and temporal scales, as well as the number of physical phenomena being simulated. They will also require accurate measurements of all terms, in situations where the appropriate experimental techniques and facilities might not exist today.

In this context, experimental data has been playing and will continue to play a key role, providing the basis for validation, verification and uncertainty quantification, design and safety support, and for the study of material performance and system behaviour. The ability to conduct experiments, however, has for certain applications progressed at a slow pace, or in some cases it has significantly regressed because of problems in relation to the research infrastructure. The outlook for the next fifteen years indicates that the total number of experimental facilities will decrease. At the same time, the creation of rare, new state-of-the-art facilities, as well as the replacement of outdated instrumentation at older facilities with more advanced instrumentation, will mean an increase in the quality of infrastructure in some cases.

How best to utilise existing and new experimental capabilities in order to support the deployment of innovations remains key to improving the safety and economics of nuclear power. In the context of limited expertise, manpower and funding, there is also a need for a concerted effort to harmonise approaches being used in experimentation and to optimise resources and deployment times. In addition, a combined effort signals a readiness for investment. The dividend of this investment is a shared systematic approach to validation providing "international confidence" – a valuable asset for decision making and licensing.

Building on the success of its activities and ongoing joint projects, the NEA is attempting to reduce the barriers associated with deploying novel concepts, by coupling advances in science so as to improve experimentation. The design of "smart" experiments, together with advanced methods for interpretation and extrapolation of experimental measurements, is a means to improve the assimilation of experimental data directly into code validation, thereby smoothing the development process and qualification programmes that underpin licensing.

As a part of cross-cutting NEA efforts to enhance innovations in the nuclear arena in order to move new technologies to application more rapidly, the NEA Nuclear Science Committee (NSC) has launched an initiative to strengthen experimental capabilities that test evolutionary and innovative nuclear fuels and materials. The goals of the new activity are to: 1) reach a consensus on how best to reduce the time required to deploy evolutionary and novel fuel and material concepts in commercial nuclear reactors, while in parallel maintaining or strengthening safety; 2) establish mechanisms for enhancing communication between industry, regulatory bodies, technical support organisations, research organisations and experimentalists in order to reach a mutual understanding of the requirements of the validation/qualification process for fuel/materials testing; 3) identify drivers in industry, safety and economics for evolutions and innovation; 4) determine the potential added value of state-of-the-art instrumentation and the interaction between the data and advanced modelling and simulation; 5) outline scientific and technological advances, issues and gaps in experimental infrastructure, and techniques; 6) promote the optimal use of existing infrastructure in support of testing and the qualification of fuels and materials; and 7) identify a role for the NEA and other international organisations in developing an international consensus on best practices in the area of fuels/materials testing and qualification.

A necessary condition: The virtuous circle of innovation and education

In order to best enable nuclear energy to contribute to a sustainable energy future, innovation and education – in the broader sense of developing competencies and skills – can be seen as essentially two sides of the same coin. They are each a necessary condition for policy makers to make informed and sound decisions about future energy mixes.

In the last decades, the interest of students and universities for nuclear technologies in some countries has been fading. If this trend is not reversed, the nuclear research community, the nuclear industry and regulators in many nations will very soon be faced with the growing problem of maintaining the current, high level of competencies, skills and activities in the domain. In addition, without innovative activities, talented young people may not find careers in nuclear energy as attractive as other options. Even more critically, they will not have access to the personal, in-depth experience and understanding necessary for the effective transmission of the appropriate know-how.

It is for this reason that the NEA launched the NEA Nuclear Education, Skills and Technology (NEST) initiative in parallel to Nuclear Innovation 2050 (NI2050). The current talent base in nuclear technology around the world today has been built over several decades through multiple, challenging projects that characterise the rapid maturing of nuclear technology from research to industry. The most experienced core of nuclear experts was involved in nuclear research and projects as far back as the late 1960s, until the 1980s. However, a very large portion of this generation of experts is nearing retirement. While such a turnover of different generations of experts exists in every technological field, new generations generally benefit from the mentoring of previous generations while new technologies are evolving in that particular area. In most fields, therefore, when the life cycle of a technology is faster than the life cycle of generational changes in staff, the retirement of experts does not raise any systemic issues. In the nuclear field, however, the technology life cycle has slowed to a point where the turnover of staff – generally within timeframes of approximately 20-30 years – is taking place within the same ranges of time or possibly even more quickly than generational changes in technologies. Under these circumstances, new generations of experts will benefit very little if at all from those who have developed the existing technologies.

This type of situation creates a major risk for the continued use of nuclear energy where highly-trained scientists and technologists are necessary to support the current technology, to develop technologies of the future and to manage nuclear legacies over decades to come. An urgent need has thus arisen, for the most part independent from national energy policies, which must be addressed at the international scale.

On a world scale, it is still possible to identify innovative projects that will offer the right opportunities to develop skills and experience. As a multinational framework between interested countries, NEST is designed to energise young engineers and scientists to pursue careers in nuclear technology by providing demanding and innovative research and training opportunities, by offering them hands-on activities in multidisciplinary and multinational real-world projects alongside experienced practitioners, by establishing links between universities, research institutes, industry and regulatory bodies, and by providing them with tailored training sessions to broaden their nuclear culture and build co-operative networks.

Technology evolution is mandatory not only to meet evolving societal needs but also to attract and train new generations through the challenges of today's world. Complementary to academic education, and to classical training through research, training through innovation is the primary objective of the NEST framework. ■

Nuclear Technology in 2017

Atucha I - II Nuclear Power Plant, Argentina.

Developments in nuclear power generation

At the end of 2017, there were 446 operational reactors worldwide, representing 389 GW of capacity, with NEA member countries operating 351 units, representing 322 GW, or 83% of the total world capacity.

Four reactors were connected to the grid in 2017 – three in China and one in Pakistan. Construction began on three reactors worldwide, bringing the total number of reactors under construction to 58 (20 in NEA member countries), with the construction of two reactors ceasing at Virgil C. Summer in the United States.

Nuclear plant construction is most vigorous in non-NEA member countries, and this trend appears likely to continue. Countries anticipating strong growth in demand for electricity feature prominently among those planning to build additional plants. China is currently constructing 18 reactors (19 GWe), down from the 29 under construction in 2012 and 2013, but still one third of total construction.

The Russian Federation has been active with seven reactors under construction, including two small modular reactors on a floating barge. The Russian state-owned corporation, Rosatom, signed more than ten agreements with entities outside Russia in 2017. Many of these agreements focused on exploratory or feasibility studies, or general co-operative development activities, but others represent more advanced discussions or firmer agreements.

At the same time, several currently operating nuclear power plants in NEA countries were set on a path for early decommissioning as a result of non-technical factors, such as economic challenges or policy decisions.

In terms of global development, two thirds of reactors under construction are in non-NEA countries, with China, India and the United Arab Emirates accounting for almost half. Significant developments in nuclear energy generation in NEA member countries during the year 2017 are described below:

- Argentina, which joined the NEA in September 2017, signed a general contract with the China National Nuclear Corporation (CNNC) for the construction of one Candu-6 reactor beginning in 2018 and one Hualong 1 reactor to begin construction in 2020.
- Belgium received a favourable decision from the European Commission (EC), confirming that the country's measures related to the long-term operation of Doel 1 and 2, as well as Tihange 1, were in line with the European Union's state aid rules. Belgium had concluded two agreements with Engie-Electrabel and EDF Belgium in 2014 and 2015, with the companies committing to invest more than EUR 1 billion in the plants on the condition that the operation of the three units was extended for an additional ten years. Belgium agreed to provide financial compensation if the units were forced to shut down before this time.
- Canadian Nuclear Laboratories (CNL) received 80 responses to a "Request for Expressions of Interest"

Cernavodă Nuclear Power Plant, Romania.

to build a small modular reactor at the Chalk River site. The responses emanated from over 380 organisations and individuals, including 27 companies involved in the nuclear supply chain and 5 utilities. In addition, Terrestrial Energy Inc. completed the vendor design review with the Canadian Nuclear Safety Commission (CNSC) for its integrated molten salt reactor design.

- In Finland, cold functional tests were completed on the Olkiluoto 3 EPR reactor and hot functional tests have begun. In October, Teollisuuden Voima Oyj (TVO) announced that commercial operation would be delayed until May 2019, rather than late 2018 as initially planned. Based on the progress of the Finnish Radiation and Nuclear Safety Authority (STUK) to date, Fennovoima decided to revise its expectations to receive a construction licence for Hanhikivi 1 in 2019 rather than 2018.
- The French government announced that it would abandon the 2025 target date for reducing the nuclear share of electricity from 75% to 50%, noting that 2030 or 2035 was "more realistic", since the 2025 target would likely have required the closure of one fourth of the French nuclear fleet. The EC approved EDF's planned investment in "New NP", Areva's nuclear reactor business, with EDF taking a 75% stake in New NP, subsequently renamed "Framatome".
- In Hungary, the environmental licence for two new units at the Paks site was upheld after a challenge to the licence was brought by two non-governmental organisations. In March 2017, the Hungarian Atomic Energy Authority (HAEA) issued the site licence for Paks II. Ltd. The initial site work is planned for early 2018. In March, the EC approved state aid arrangements on the basis of commitments that Hungary had made to limit the impact of state aid on energy market competition.
- In Japan, 13 reactors have now been approved by the Nuclear Regulation Authority (NRA), while only 5 have resumed operation. Two of the other eight reactors, Ohi 3 and 4, received the final local government approval but have not yet restarted. A High Court lifted an injunction on Takahama units 3 and 4, while another High Court suspended the operation of Ikata 3 because of concerns that safety risks had not been adequately considered.
- In Korea, the total number of nuclear reactors in operation has reached 24, with an installed capacity of 22.5 GWe, accounting for 30.3% of the country's total generating capacity in 2017. Five reactors are currently under construction, and the earliest grid connection of Shin-Kori-4 is expected to occur in September 2018. In June 2017, the first nuclear power plant in Korea underwent permanent shutdown of a reactor, the 580 megawatt Kori-1. It began commercial operation in April 1978, and its first life extension was approved in 2007.
- In Romania, which joined the NEA in October 2017, the reactor operator Nuclearelectrica SA received shareholder approval to begin the life-extension project for the Cernavoda nuclear power plant (which operates two CANDU reactors). Nuclearelectrica also signed a memorandum of understanding with the China General Nuclear Power Corporation (CGN) for the construction of units 3 and 4 at Cernavoda.
- In Russia, the first VVER-1200, Novovoronezh 6, began commercial operation. The first units of Leningrad Phase II and Rostov 4 received operating licences. Construction continued on the MBIR multi-purpose fast neutron research reactor, a 150 MWth sodium-cooled fast reactor, with fabrication of the reactor pressure vessel beginning.
- In the United Kingdom, the contract for difference (CfD) agreement for Hinkley Point C has continued to face criticism, particularly with the current low electricity market prices. UK government support for nuclear power remains strong, but at least one major reactor vendor – GE Hitachi's subsidiary, Horizon Nuclear Power – indicated that it would not be able or willing to take on the full construction cost in a future project, as EDF and China's CGN did with Hinkley Point C. Korea Electric Power Corporation (KEPCO) has been selected as the preferred bidder for the Toshiba subsidiary, NuGen, which was planning to build an NPP in the UK. Toshiba had put NuGen up for sale as part of its wider restructuring efforts in the wake of financial difficulties triggered by losses in its US nuclear business, Westinghouse.
- In the United States, the reactor vendor, Westinghouse Electric Company, filed for bankruptcy under rules that allow a restructuring of the company rather than its liquidation. As a result of significant project cost and schedule overruns, the construction of two AP1000 reactors ceased at the VC Summer site. However, after a lengthy evaluation and decision process, construction of two other AP1000 reactors continued at the Vogtle site. Some states have taken action to provide financial incentives so as to keep existing plants operating. The US Department of Energy formally proposed that the Federal Energy Regulatory Commission (FERC) take action to address reliability and resiliency threats to the electric grid, including early closure of nuclear reactors, but the request was rejected by the FERC. In early 2018, Toshiba announced the sale of its subsidiary, the Westinghouse Electric Company, to the Canadian investment group, Brookfield Business Partners, for a price of USD 4.6 billion. Federal courts upheld the extension of zero-emission credits to nuclear power in New York and Illinois, and other states are considering implementing similar incentives.

Aerial view of the McArthur River uranium mine, Canada.

Among non-NEA countries, China continues to lead new reactor construction, connecting three reactors to the grid in 2017. However, construction seems to have slowed for the third time since 2005 – as China did not start construction on any new power reactor units. The China National Nuclear Corporation (CNNC) did, however, begin construction on a fast neutron demonstration reactor, the 600 MWe sodium-cooled, pool-type design being built at Xiapu. India's current five-year plan for 2012-2017 projects an ambitious expansion from the current 6 GWe to more than 60 GWe by 2050. India has four pressurised heavy water reactors, one VVER 412 and one sodium fast reactor under construction. The country has also completed agreements with Russia's Atomstroyexport in 2017 for two more units at Kudankulam. The United Arab Emirates (UAE) is building four new reactors, designed and led by Korea's KEPCO, and they appear to be progressing well. The first unit is awaiting an operating licence to begin fuel loading, and all four units are on schedule to be operating by 2020, which would represent a five- to six-year construction time for each of the reactors.

Developments in nuclear fuel supply

Uranium production slowed in 2017 at several mining facilities following continued depressed market conditions. The most significant of these changes were the plans announced to suspend mine production at McArthur River/Key Lake in Canada, production cuts in Kazakhstan, and plans to cease development of new wellfields at many in situ leach mines in the United States (e.g. Nichols Ranch and Lost Creek). The Husab uranium mine in Namibia began production in December 2016 and is expected to reach full production in the coming years. Uranium was produced in eight NEA member countries in 2017, with Australia, Canada, Russia and the United States accounting for a significant share of global production (about 40%).

Commercial uranium conversion facilities were in operation in Canada, France, Russia and the United States. However, most converters are currently running their plants at between 50%-70% capacity as a result of continued oversupply and low demand in recent years. The construction of the new Comurhex II conversion plant continued in 2017 at the Malvesi and Tricastin sites in southern France. Areva ceased operations at the Comurhex I facility in December. In the United States, Honeywell announced in early 2017 that it would reduce the capacity of the Metropolis conversion plant from 15 000 tU to 7 000 tU, and then in late November announced that production would be completely suspended at the Metropolis plant until market conditions improve.

Two recently built, high-efficiency uranium centrifuge enrichment plants – Areva's Georges Besse II plant in France and Urenco's facility in the United States – continued commercial operations through 2017. Poor market conditions have caused enrichers to gradually phase out older centrifuges and to make greater use of capacity through underfeeding and tails re-enrichment. In the United States, development of the GE Hitachi laser enrichment technology has slowed, reflecting market conditions. Centrus Energy Corp. received a one-year extension contract from the US Department of Energy's Oak Ridge National Laboratory (ORNL) to continue work on American Centrifuge technology.

Nuclear safety and regulation

In 2017, NEA member countries continued their efforts to enhance the robustness of nuclear installations and regulatory frameworks. The international focus on accident management has led to significant progress in strengthening the availability and diversity of mitigation equipment and in improving emergency procedures and strategies. NEA member countries have also continued to co-operate on better understanding the risks associated with natural hazards and external events, such as earthquakes, tsunamis and river flooding. In addition, they have recognised the vital importance of developing and sustaining a strong safety culture in both operating organisations and regulatory bodies.

Technical support organisations and regulatory bodies of NEA member countries have continued to expand their knowledge in many important technical areas with co-operative research activities. Through international research, increased knowledge has been gained in severe accident phenomenology and thermal-hydraulics; computer codes and modelling; fire propagation; and fuel and material properties.

The NEA and its member countries are initiating near-term research activities at the Fukushima Daiichi site to address safety knowledge gaps and to support timely decommissioning. These near-term research activities will help to expand the technical knowledge base of fuel and fission-product behaviour during a severe accident and to improve understanding of the various computer codes used for accident analyses.

The NEA and its member countries remain focused on ensuring the safe operation of nuclear facilities. Efforts related to the long-term operation of nuclear power plants, such as the ageing of plant components and materials, will continue to be an active area of international collaboration among NEA member countries. Additionally, regulatory bodies of NEA member countries are working together to address the increased use of digital technologies in nuclear installations and to ensure quality in the supply chain of nuclear components.

International collaboration and sharing of experiences at the NEA will continue to support the safe construction and commissioning of new reactor designs, as well as the regulatory reviews of advanced reactor designs. As some nuclear power plants transition to the decommissioning phase, the regulatory issues and challenges that arise are likewise presenting opportunities for NEA member countries to further share experiences and best practices.

NEA collaborative activities and projects aimed at addressing knowledge gaps and sharing best practices in many technical and regulatory areas throughout the life cycle of nuclear installations will continue to contribute to the advancement of nuclear safety and regulation.

Human aspects of nuclear safety

The NEA considers the human aspects of nuclear safety to be essential factors in the safe operation of nuclear installations, as well as in the effectiveness of regulatory authorities. In 2017, NEA member countries continued to enhance efforts in this regard by addressing the human aspects associated with safety culture, organisational factors, personnel training, safety-related public communication and stakeholder engagement as related to nuclear safety, waste management and other issues.

NEA member countries continued to implement measures in relation to safety culture, by reinforcing regulatory requirements, and by further developing guidelines and guidance documents. Recognising that the safety culture of regulatory authorities has an important bearing on the safety culture of not only licensees, but also governmental entities and other stakeholders, it is today considered imperative that regulatory authorities possess specific characteristics and embody the behaviours and attitudes that effectively support safety. The following activities have thus been conducted in member countries to ensure that regulators develop and maintain a healthy safety culture:

- In Canada, the Canadian Nuclear Safety Commission (CNSC) carried out a comprehensive safety culture self-assessment that was completed at the end of 2017. The findings will be used to determine further areas for improvement, adding to those already underway that focus on building a shared, common understanding of safety culture, greater engagement and transparency in internal decision-making processes, and modelling desired CNSC behaviours.
- Following the publication of the NEA "green booklet" *The Safety Culture of an Effective Nuclear Body* (NEA, 2016), the Radiation and Nuclear Safety Authority (STUK) of Finland carried out a SAFEX questionnaire in all of its departments in 2017. It also implemented safety culture training for its staff. STUK's newly published strategy focuses on oversight culture and emphasises the need for all staff to be knowledgeable and understand the impact of regulatory activities on safety.
- The Nuclear Regulation Authority of Japan (NRA) has started activities to foster internal safety culture involving all staff, with the aim of increasing awareness on this subject within the organisation. The activities include seminars, self-learning, individual safety culture cards, workshops, questionnaires and dialogues between commissioners and staff.
- The Korea Institute of Nuclear Safety (KINS) and the Nuclear Safety and Security Commission (NSSC) have progressed in the implementation of their processes for safety culture development, through the development of safety culture principles, attributes and management procedures. They have also developed e-learning content for an online safety culture course and are conducting a self-assessment to help identify further areas for continuous improvement.
- In Russia, the regulatory authority Rostechnadzor has implemented policy statements on technological safety culture and on safety culture for the regulation of atomic energy use, which define the concept of safety culture and underline that leadership for safety should be demonstrated at all levels of the regulatory body.

Instrumentation and control.
Canada Nuclear Laboratories (CNL).

Education-Research Center "Nanocenter" training in the method of pulsed laser deposition.
MEPHI, Russia

Protective clothing.
Areva, France

- The Swiss Federal Nuclear Safety Inspectorate (ENSI) published a report on oversight culture in 2017. The report shares insights into a self-reflective process on oversight culture. It describes the approach, methods and results of such a process.
- The regulatory authority in Spain, the Spanish Nuclear Safety Council (CSN), published a Safety Culture Policy and has undertaken a series of actions to enhance its safety culture. These include conducting a self-assessment, delivering safety culture training to staff, incorporating the Safety Culture Policy in the management system, and implementing a graded approach to safety in CSN decisions and actions.
- In the United Kingdom, the Office of Nuclear Regulation (ONR) has developed regulatory effectiveness indicators, mapped out the NEA safety culture characteristics of an effective regulatory body, and developed a competency framework for leadership and management. The regulatory effectiveness indicators are grouped under competency, capability and capacity; regulatory guidance, decision making and delivery; clarity, transparency and insight; and peer review, assurance and continuous improvement. The ONR has also followed up on its 2017 staff survey – which focused on leadership and culture – with roadshows, task groups and an action plan outlining progress that is regularly communicated to all employees.

Radiological protection

The focus of radiological protection efforts during 2017 continued to be on managing the consequences of the Fukushima Daiichi NPP accident. Recovery of living conditions in affected areas remains a priority in Japan, and understanding the lessons that can be learnt and applied in other socio-economic circumstances remains a universal goal. As the complex exercise of addressing post-accident recovery situations improves, a stepwise but growing effort to be better prepared for future events also continues to evolve. National organisations in Japan, such as environmental ministries and regulatory authorities, as well international organisations such as the NEA, the IAEA and the EC, have initiated projects to better understand and be prepared to address the potential concerns expressed by affected stakeholders.

It has become increasingly evident that while affected individuals may initially be unaware of the scientific details of radiation and its possible effects, they are nevertheless motivated to learn what to do to protect themselves and their families. Governments should therefore make it a priority to support affected individuals in understanding their situations. This support will involve addressing concerns in an informed yet plain, "jargon-free" language, and significant resources may be required to do so. Post-accident food management is an example of circumstances where such plain language could more effectively support stakeholders in making informed decisions.

Because it is almost impossible to predict the nature of post-accident consequences, planning for recovery situations should address the mechanisms needed to gather the necessary resources to address the psycho-social effects of both accident circumstances and consequence management choices when making radiological protection decisions. In view of the low probability of accidents causing large-scale radiological contamination, an integrated, all-hazards approach is being pursued internationally. Trust in the agencies providing such support is key to its effectiveness. National and international co-ordination of information has also emerged as an area of particular importance in this regard.

While significant radiation-biological and epidemiological research is underway to better understand the effects of low-dose radiation exposure, to a certain extent much of the progress depends on long-term projects.

The availability of educated and trained experts – in research but also in virtually all areas of radiological protection – is uncertain, with a scarcity of overall training for non-specialist RP professionals, and particularly with the anticipated retirement of many experienced RP experts worldwide over the next decade. Efforts to ensure continuity in terms of available expertise are thus underway in several international and national organisations.

Radioactive waste management

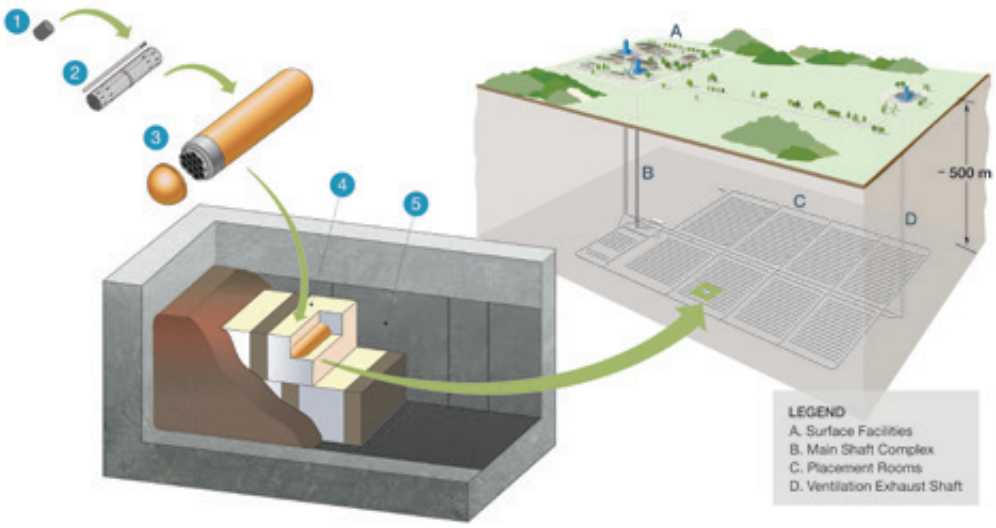
In 2017, NEA member countries continued to work on the safe management of spent fuel and radioactive waste. With the objective of bringing greater clarity to address the risks associated with radioactive waste management practices, the owners of radioactive waste are increasingly recognising the importance of transparency in terms of information and decision making. EU members completed the first round of reporting on their national waste management programmes to the European Commission (EC) in accordance with EC Directive 2011/70/Euratom. Such efforts improve public confidence, provide a European overview of radioactive waste management and allow for better management strategies to be defined.

The revision and development of legislation in the field of radioactive waste management is an important trend in radioactive waste management developments. New laws, ordinances, national radioactive waste management plans and other relevant documents are being developed or updated in NEA countries. In addition, the evolution or updating of funding mechanisms for radioactive waste and spent fuel management is ongoing in some countries.

In 2017, construction continued on the first permanent repository for high-level radioactive waste in Olkiluoto, Finland. This work will ultimately provide important waste management expertise to other countries developing geological repositories for radioactive waste.

Other highlights are as follows:

- In Canada, the Nuclear Waste Management Organization (NWMO), the organisation responsible for the final disposal of high-level waste, continues to move forward with its nine-step siting process in order to find a safe, secure and suitable disposal site in an informed and willing community. As of March 2017, nine areas in Ontario remain the focus of the NWMO's site selection process. On the technical side, a revised conceptual container design has been developed that is specific to CANDU fuel bundles. The first full-scale prototype containers have been manufactured and have been subjected to failure testing to confirm their design capacity.
- In the Czech Republic, a new set of nuclear laws came into effect in early 2017. Decree No. 377/2016 outlines the requirements for the safe management of radioactive waste and the decommissioning of nuclear installations. In November 2017, the process of updating the Czech conception was completed and the government approved a document entitled "The Concept of Radioactive Waste and Spent Nuclear Fuel Management in the Czech Republic". The Concept was subjected to a process of strategic environmental assessment, including a cross-border public consultation with neighbouring countries. The siting process for a spent fuel repository is still being defined, with the implementer – the Radioactive Waste Repository Authority (SÚRAO) – focusing on dialogue with pre-candidate municipalities. SÚRAO has been conducting surface geological surveys at nine potential sites since 2015. Based on survey results from 2015, SÚRAO decided to focus the site selection process in 2018 on four potential sites. A site should be selected by 2025, and the on-site underground research facility is being planned for 2030-2045.
- In Finland, Posiva entered a new phase of repository development and construction in Olkiluoto, with construction beginning in December 2016. The Finland Radiation and Nuclear Safety Authority (STUK) had granted permission in late November 2016 to begin construction of the deep geological repository (DGR) for high-level waste (HLW), and an operational disposal facility is foreseen for 2023. Posiva issued its latest Safety Case Plan for the Operating Licence Application (POSIVA 2017-02) in 2017.
- In France, the Cigéo Project continued to develop a DGR for high-level and long-lived, intermediate-level waste in the Meuse-Haute Marne area. In 2017, the "Safety Options Dossier", setting out the objectives, concepts and safety principles of disposing intermediate, long-lived and high-level radioactive waste in Callovo-Oxfordian (COX) formations, was released. Andra, the French National Radioactive Waste Management Agency, also presented the Cigéo Operations Master Plan, which covers details of waste inventories and the current status of various milestones. Andra plans to submit a licence application for the project in 2018.



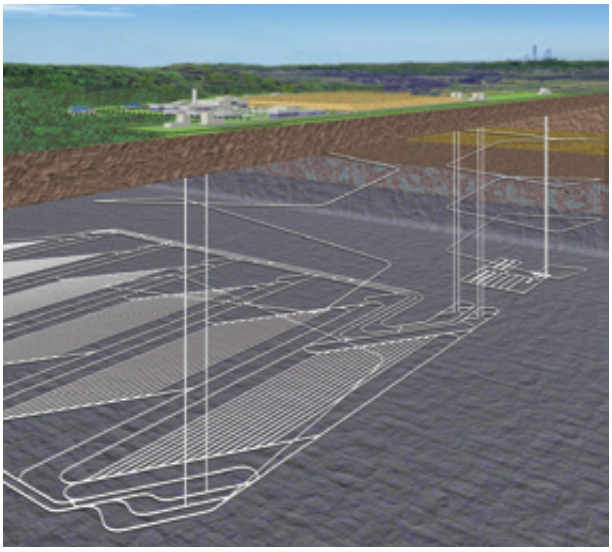
The five barriers work together to safely contain and isolate the used nuclear fuel from people and the environment.

Nuclear Waste Management Organization, Canada

Radioactive waste storage.
BfS, Menkhaus, Germany

- In Germany, the "Act on the Organisational Restructuring in the Field of Radioactive Waste Management", which came into force in July 2016, has reorganised the roles and responsibilities of various federal offices. The German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS) is now responsible for the supervision and licensing of nuclear fuel transport, interim storage of radioactive waste, disposal site selection and disposal facility surveillance. The management responsibilities of nuclear waste are assigned to the Federal Company for Radioactive Waste Disposal (Bundlesgesellschaft für Endlagerung mbH, BGE), while the responsibility of interim storage of radioactive waste lies with Bundesgesellschaft für Zwischenlagerung (BGZ). The Repository Site Selection Act was amended and became effective in May 2017 and will continue to serve as the selection basis for the siting of a radioactive waste disposal facility.
- In Japan, the work of the geological disposal research programme is ongoing while a policy for HLW management is being debated among several national organisations. After the government had revised its basic policy in 2015 on the disposal of HLW, underlining the importance of consensus building between the government and local communities, as well as of reversibility and retrievability, the Ministry of Economy, Trade and Industry (METI) then published the "Nationwide Map of Scientific Features for Geological Disposal" in 2017 in order to enhance communication with the public.
- In Korea, the Ministry of Trade, Industry and Energy (MOTIE) is working on a basic plan for the management of spent fuel based on 2015 recommendations submitted by the Public Engagement Commission on Spent Nuclear Fuel Management (PECOS). These recommendations stipulated that a site should be found for an underground research laboratory (URL) by 2020 to undertake in situ experiments from 2030 and initiate operation of a DGR from 2051.
- In Russia, the design process continued for the development of a DGR for high-level and long-lived waste in the region of Krasnoyarsk. The first stage of the project consists of building a URL by 2021, with a planned test and demonstration of disposal for different types of radioactive waste. The final decision on the DGR is expected by 2025. Significant progress has also been made in establishing disposal facilities for low and intermediate-level waste (LILW) (i.e. class 3 short-lived, intermediate and long-lived low-level waste, and class 4 short-lived, low-level waste and very low-level waste). Disposal facilities are planned for classes 3 and 4 waste in the Tomsk and Chelyabinsk regions.
- In Sweden, the nuclear regulator, along with the Land and Environment Court in Stockholm and the municipality of Östhammar, are continuing their review of general licence applications for spent fuel disposal. In June 2016, the Swedish Radiation Safety Authority (SSM) determined that the licence application from the Swedish Nuclear Fuel and Waste Management Company (SKB) for an encapsulation plant and Forsmark repository had the potential to comply with its requirements, and subsequently recommended that the Land and Environment Court grant SKB permission to carry out activities in accordance with the Swedish Environmental Code. The main hearing for the SKB's application in the Swedish Land and Environment Court took place in autumn 2017. On 23 January 2018, the court submitted its review statement to the government, and the Swedish Radiation Safety Authority will present its review conclusions to the government for a decision.
- In Switzerland, stage 2 of the sectoral planning process for deep disposal of radioactive waste is currently underway. A government decision on a stage 2 proposal concerning two or more sites for LILW and HLW is anticipated by the end of 2018. Following the instructions of the Swiss Federal Nuclear Safety Inspectorate (ENSI) to continue

Conceptual figure depicting a deep geological repository.
Nuclear Waste Management Organization, Japan



The Onkalo spent nuclear fuel repository.
Posiva, Finland

development without delay, the National Co-operative for the Disposal of Radioactive Waste (NAGRA) carried out a 3D seismic campaign in Nördlich Lägern and submitted drilling licence applications in 2017. Areas for potential siting of deep geological waste repositories for HLW or LLW have been identified from a technical point of view. Stage 3 will examine logistical and economic aspects with the relevant communities and cantons in view of reducing the number of identified sites.

- In the United States, further to the Nuclear Regulatory Commission (NRC) supplement concluding negligible impacts on groundwater and surface discharges, the Department of Energy (DOE) is now on a path forward to accelerate progress on the disposal of nuclear waste as indicated in the Presidential Budget Blueprint for 2018. The DOE is thus restarting licensing activities in relation to the Yucca Mountain nuclear waste repository.

Low- and intermediate-level waste

Progress has also been made in the area of the safe management of low and intermediate-level waste (LILW). Highlights are provided below:

- In Belgium, the Belgian Agency for Radioactive Waste and Enriched Fissile materials (ONDRAF/NIRAS) has provided all the necessary details to address outstanding questions in relation to the Dessel disposal project. The organisation plans to update its safety case in 2018 and is preparing its encounter with the Scientific Council of the Federal Agency for Nuclear Control in late 2018 or early 2019.
- In Canada, Ontario Power Generation (OPG), the nuclear operator in Ontario, Canada, continued with the development of a geological repository for LILW in Bruce County, Ontario. A public review was held in 2017 following OPG's submission of additional information in response to a request from the Minister of Environment and Climate Change in late 2016. An environmental assessment decision from the Minister is required to continue with the proposed project.
- In Germany, the construction of the waste transport shaft (shaft 2) and the emplacement field continued at the former Konrad mine. By 2023, up to 303 000 m^3 of radioactive waste with negligible heat will be permanently stored in this former iron ore mine.
- In Korea, the LILW repository in Wolsong was licensed in late 2014 and started operation in 2015. The LILW disposal facility at Yangbuk-myeon, Gyeongju city, with a total capacity of 800 000 drums (200-litre size) in an area of 2 100 000 m^2, started operation in 2015. The construction of the second phase facility is expected to be completed by 2019 with near-surface disposal having a capacity of 125 000 drums.
- In Russia, a regional LILW repository system is in the development stage and the siting process is ongoing. In 2017, operations continued at the first LILW near-surface repository that began operation in Novouralsk in 2015.
- In the United States, the NRC is in the process of preparing a regulatory basis for the disposal of greater than class C (GTCC) waste since the current regulation (10 CFR Part 61) does not contain general criteria for the disposal of this class of waste, or for transuranic (TRU) waste.

Nuclear Decommissioning

Significant progress continues to be made on decommissioning and environmental remediation projects across NEA countries. A brief summary of ongoing decommissioning efforts in 2017 is provided below:

- In Canada, a private-sector organisation, Canadian Nuclear Laboratories (CNL), is now responsible for decommissioning and waste management of radioactive waste owned by Atomic Energy of Canada Limited (AECL). The CNL is planning an operational near-surface disposal facility at Chalk River Laboratories for the disposal of LLW by 2020. CNL is also working to accelerate the decommissioning and closure of the Nuclear Power Demonstration prototype reactor in Ontario and Whiteshell Laboratories in Manitoba.
- In Finland, the Technical Research Centre of Finland Ltd (VTT) is preparing an operating licence application for decommissioning the FiR 1 Triga Mark II research reactor that was shut down in 2015. STUK, the Finnish regulator, will oversee the first decommissioning and dismantling of a nuclear facility in Finland.
- In Japan, the Nuclear Regulation Authority (NRA) revised the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, which now requires licensees to publicise their "decommissioning policies" for their nuclear facilities before commencing operation.
- In Russia, the decommissioning of four units at the Novovoronezh and Beloyarsk NPPs, and another four nuclear and radiation hazardous facilities, continued in 2017. Units 1 and 2 of the Leningrad NPP, units 1-4 of the Bilibino NPP, as well as units 1 and 2 of the Kola NPP, were undergoing preparation for decommissioning in 2017.

Aerial view of the Sellafield site, Sellafield, United Kingdom.

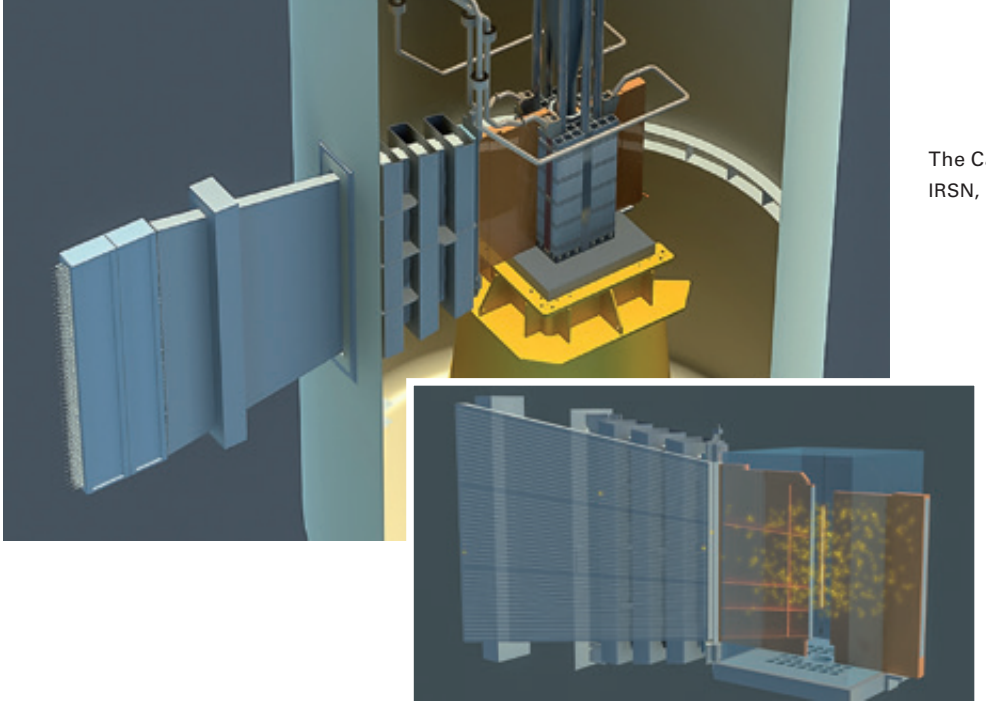
- In Sweden, the final dismantling of Studsvik's R2 material test reactor continued in 2017, and the work is expected to be completed in 2019. Dismantling of the Agesta pressurised heavy water reactor (PHWR) is planned for 2020. To accommodate decommissioning waste from these dismantling projects, a new storage building for low and intermediate-level decommissioning waste is being planned at the Studsvik site. Nuclear plant licensees were also preparing for the shutdown of the four oldest reactors in Oskarshamn (units 1 and 2) in 2017 and Ringhals (unit 1 and unit 2) in 2020. Along with two units in Barsebäck and Agesta, a total of seven reactors are scheduled for decommissioning in the coming years. The remaining six operating reactors at Oskarshamn, Ringhals and Forsmark will continue in long-term operation, their lifetimes having been extended to 60 years.
- In Switzerland, the Swiss Federal Nuclear Safety Inspectorate (ENSI) is reviewing the first decommissioning plan for the commercial nuclear power plant of Mühleberg submitted to the Swiss Federal Office of Energy (SFOE).
- In the United Kingdom, since the Nuclear Decommissioning Authority (NDA) became the owner of the Sellafield site in 2016, a 350-tonne machine has been installed to retrieve radioactive waste out of the storage silo, and the retrieved waste will be packed into nuclear skips while awaiting disposal in the UK's geological disposal facility. The NDA has estimated that it will take 20-25 years to complete the clean-up at Sellafield.
- In the United States, clean-up work at the Plutonium Finishing Plant (PFP) in Hanford, Washington, and building demolition and waste disposal at Oak Ridge, Tennessee, as well as at other DOE sites (e.g. Savannah River), continued in 2017. The NRC continues to oversee 20 permanently shut down power reactor units in various stages of decommissioning. Of these 20 reactors, 6 are undergoing active decommissioning (DECON) and 14 have elected to defer decommissioning (SAFSTOR). Permanently shut down reactors have 60 years to complete decommissioning, in accordance with 10 CFR 50.82(a)(3). Additionally, the NRC continued with licensing and oversight activities at 4 research and test reactors; 13 complex material decommissioning facilities; 2 fuel cycle facilities; 22 title 1 uranium milling sites and 11 title 2 uranium recovery facilities. Since the issuance of advance notice for proposed rulemaking (ANPR) in November 2015, the NRC has conducted public meetings to seek external stakeholder input and has initiated the research activities required to support decommissioning rulemaking, which is expected to be completed by 2019.

Nuclear science and technology

The nuclear industry has begun positioning itself to make definitive long-term choices in the face of scientific concepts and technological options. This positioning has required recognition of shared issues across multiple parties, including fuel vendors and utilities, regulators, research and development organisations, and experimental facilities. One of the main concerns is the development and qualification of innovative fuels and materials, as well as the pathways to accelerated deployment and to the industrial setting. National programmes on accident-tolerant fuels (ATFs) for light water reactors (LWRs) have identified both evolutionary and revolutionary concepts that can offer significant benefits in terms of both safety and economic value. In order to bring about these innovations in a reasonable time frame, cross-party dialogue has become more commonplace.

Another example is the collaborative work being carried out between reactor designers for novel small modular and molten salt reactors in order to clarify the acceptable licensing process early on. These issues are also inextricably tied to further concerns over resource limitations, including the development of advanced modelling and simulation tools, rejuvenation of experimental infrastructure and the knowledge transfer to a younger generation of experts. The balanced usage and focus on each of these resources are central to the future tenability of adapting the nuclear industry.

In recent years, there has been a notable increase in the use of computing innovations to boost the efficiency of power plant maintenance and engineering. Data science has also emerged as a tool capable of providing physical insights into fluctuations previously dismissed as noise. Advances in data science were necessitated by the vast amounts of data currently being generated with modern data acquisition techniques and high-fidelity simulation. Within the International Reactor Physics Experiment Evaluation (IRPhE) Project, experts have analysed differences between predicted and measured signals from thousands of fission chambers at nuclear power plants. These differences have begun yielding insights into fundamental nuclear data such as neutron cross-sections and fission yields. As data sets become more expansive, pressure will increase to pool data so as to maximise the statistical power of these techniques. Additionally, given the expense of generating new experimental data in some domains, big data will provide incentive to collect and digitise the immense data sets garnered during legacy campaigns. Reanalyses of historical data sets with modern simulations will also allow



The Cabri hodoscope.
IRSN, France

analysts to glean insights into areas that were previously overlooked. This trend is expected to greatly improve the predictive power of the tools available to nuclear engineers.

In terms of important national and international nuclear science infrastructure, the restart of a key element was completed at the end of 2017. After an extended shutdown lasting more than 23 years, the Transient Reactor Test Facility (TREAT) in Idaho, United States, successfully achieved its first criticality on 14 November 2017. The US Department of Energy (DOE) has been working on this restart programme since 2013 as part of the project to develop, test and qualify accident-tolerant fuels (ATFs), and ultimately enable their deployment in an industrial setting. Initial commissioning activities are now underway to prepare the facility for the start of experimental campaigns. These preparatory activities will include operator qualifications, instrument testing, radiological characterisation and detailed calibration of the core's operational characteristics, including heat balance, reactivity control and rod worth measurements, as well as trial transients. In addition, experimental vehicles that will contain test samples and their specific instrumentation, while providing bespoke environmental conditions, are under design and engineering at the Idaho National Laboratory (INL). The first experimental results from TREAT are expected before the start of 2019.

From an international perspective, TREAT is a fundamental asset that will be a strong complement to other facilities, including the Cabri facility, located in the south of France in Cadarache, and owned and operated by the French Alternative Energies and Atomic Energy Commission (CEA). After ten years of major refurbishments, the Cabri reactor is now equipped with a new configuration that will enable the NEA Cabri International Project (CIP) to study the behaviour of advanced fuels in more fully representative pressurised water reactor (PWR) conditions. The Cabri facility is a pool-type research reactor dedicated to studying reactor-initiated accidents (RIAs) on a section of highly irradiated fuel in a water-cooled reactor. Following changes in the conditions for using fuel in reactors, the French Institute for Radiation Protection and Nuclear Safety (IRSN) – which had been given priority to use the reactor by government decree for its research programme on fuel safety, and thus funded the Cabri refurbishment, the reactor operation and all the experimental work necessary to complete the CIP tests – launched CIP under the auspices of the Nuclear Energy Agency in 2000. The first test in the water loop was being planned for the first quarter of 2017.

There is a growing trend towards a deeper sensitivity analysis and completeness of uncertainty techniques in relation to the application of nuclear data to reactor core simulation. Recent releases of new evaluated nuclear data libraries – JEFF3.3 and ENDF/B-VIII – have responded to calls by the community for a more detailed representation of the underlying covariances across a more complete range of isotopes. Additional parameters for inclusion in such analyses, such as secondary distributions of energy and angle, are increasingly becoming an expectation as

Photos looking down into the reactor pool showing the Cherenkov radiation characteristic of the different core powers.
IRSN, France

100 kW 2 MW 7 MW 14 MW 23 MW

part of uncertainty justifications and testing or validation studies. As a result, many efforts are ongoing to modernise the supporting calculational tools. Such efforts include the writing and testing of new processing codes and the creation of a new storage format, which is capable of handling many new types of information and structures that current formats cannot. NEA viewing and manipulation tools are evolving to cope with these additional demands. The benefit of such advances is an improved ability to quantify operational and safety margins, which in turn leads to better decision making in relation to their economic value.

Nuclear Law

Notwithstanding the best efforts to ensure high levels of nuclear safety, the possibility remains that an accident may occur in a nuclear installation (i.e. not only at nuclear power plants but also at installations storing nuclear fuel, nuclear substances, radioactive products or waste) or during the transport of nuclear substances to and from a nuclear installation. Experience has shown from Three Mile Island (1979), Chernobyl (1986) and Fukushima Daiichi (2011) that severe accidents can have varying and potentially far-reaching consequences, affecting both people and property.

A wide consensus exists on the importance of providing nuclear liability regimes, which address the concerns of all countries that might be affected by a nuclear accident, in order to provide appropriate compensation for nuclear damage. To date, 27 out of the 33 NEA member countries have adhered to one or more of the international nuclear liability conventions. The trend since the Fukushima Daiichi accident has been for countries, especially newcomer or potential newcomer countries (such as Jordan, Kazakhstan and Saudi Arabia), to adhere to the enhanced Vienna Convention regime, i.e. the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (the "1997 Protocol"). Romania and the United Arab Emirates have opted to join the enhanced conventions – i.e. the 1997 Protocol, the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention on Third Party Liability in the Field of Nuclear Energy (the "Paris Convention"), and the Convention on Supplementary Compensation for Nuclear Damage (CSC) – in order to have treaty relations with the widest number of countries. Canada, already a nuclear country, joined the CSC in 2017.

NEA member countries that have signed the 2004 Protocols to amend the Paris Convention and the Brussels Convention Supplementary to the Paris Convention continue to work towards implementing the provisions of these protocols into their national legislation, to significantly increase the amount of compensation made available, to broaden the scope of damage for which compensation may be granted and to ensure that more victims are entitled to compensation. A decision of the European Council (2004/294/EC) of 8 March 2004 requires that the 11 contracting parties to the Paris Convention that are also EU member states take the necessary steps to deposit simultaneously their instruments of ratification or accession to the 2004 Protocol to amend the Paris Convention. Italy is finalising the related ratification and implementation legislation, which should allow signatories to ratify the 2004 Protocols, while others (such as Belgium, Finland, France, the Netherlands and Spain) have already adopted transitory legislation that transposes into national legislation higher compensation levels as provided in the 2004 Protocols, pending their entry into force. More information on the Paris Convention is available at www.oecd-nea.org/law/paris-convention.html.

Not only have nuclear liability amounts been increasing over time, but modernised conventions (i.e. the Paris Convention as amended by the 2004 Protocol, the 1997 Protocol and the CSC) have also, among other improvements, extended the prescription and extinction period for actions brought with respect to loss of life and personal injury from 10 to 30 years from the date of the nuclear incident. They also provide for a broader range of damage to be compensated. In addition to personal injury and property damage, the modernised conventions include certain types of economic loss, the cost of measures to reinstate a significantly impaired environment, loss of income resulting from the impaired environment and the cost of preventive measures, including loss or damage caused by such measures. To cover its nuclear liability, the operator is required by law to have and maintain a specific amount of insurance or other financial security. Operators have been faced with the insurance sector's reluctance to fully cover certain new types of damage – in particular those relating to the environment and loss of life or personal injury beyond 10 years from the date of the nuclear accident. Operators have therefore had to seek alternative financial securities and reach out to mutuals and to the state. In view of the entry into force of the 2004 Protocol amending the Paris Convention, Belgium, for example, worked on a state guarantee to be provided to the operators of nuclear installations located in Belgium that have been unable to find sufficient nuclear liability coverage in private insurance markets. The European Commission (EC) confirmed on 14 July 2017 that the proposed Belgian state guarantee does not constitute state aid. The EC found that, in the case of the scheme notified by Belgium, the premium to be paid by the nuclear operators to benefit from the state guarantee was set at such a level that it would not constitute an economic advantage. The Commission also found that the premium is expensive enough to avoid crowding out the private insurance market and that there are sufficient incentives for private players to develop competitive offers to replace the need for a state guarantee. For more information on this decision, see http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=3_SA_46602.

Nuclear Development

The goal of the NEA in this sector is to provide governments and other relevant stakeholders with authoritative, reliable information on current and future nuclear technologies. It is also to provide information and analyses to decision makers regarding the future of nuclear energy – including on economic and resource analyses, public opinion, advances in nuclear power and fuel cycle technologies, and electricity production data – as well as to offer forecasts on the future role of nuclear energy in a sustainable development perspective and within the context of national and international energy policies aiming to ensure low-carbon electricity cost-effectively and at high levels of security of supply. The staff works closely with the Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) and its expert groups. The nature of this area is such that some efforts are necessarily cross-cutting, and the staff thus ensures co-ordination with other NEA sectors, committees and working parties as needed.

Highlights

- The NEA published *Nuclear Energy Data 2017* in November, providing official information on NEA member countries' nuclear energy programmes;
- *Impacts of the Fukushima Daiichi Accident on Nuclear Development Policies* was published in April, assessing the varied responses to this accident.
- Four reports neared publication, one on measuring employment generated by the nuclear power industry, one on the role of nuclear cogeneration in future low-carbon energy systems, one on the full costs of electricity provision and a study on system costs in decarbonising energy systems.
- Three new projects were launched in 2017 to be carried out by ad hoc expert groups: one to assess how advanced reactors can meet future energy market needs, one to provide an overview of national strategies for the fuel cycle and one to assess the economic impact of uranium mining activities.

Report on nuclear energy data

Nuclear Energy Data 2017 was published in November 2017 and contains official information provided by member countries on nuclear energy developments. The report includes projections of total electrical and nuclear generating capacities and fuel cycle requirements to 2035. Based on actual data through to 2016, the report reveals that total electricity generation in NEA countries declined from 2015 to 2016 (by 1.5%), while the share of electricity production from nuclear power plants increased slightly (by 0.1%).

Impact of the Fukushima Daiichi accident on nuclear policies

In April, the NEA published a report entitled *Impacts of the Fukushima Daiichi Accident on Nuclear Development Policies*. This study examines changes to policies and plans, attempting to make a distinction between the different factors, including the impact of the Fukushima Daiichi accident, that may have affected policy making as related to nuclear energy. 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. The study found that, 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.

The Full Costs of Electricity Provision

The commercial costs of generating and providing electricity, which are captured in market prices, are only part of the full social costs of electricity provision. The NEA Division of Nuclear Technology Development and Economics has thus undertaken a collaborative project to collect and synthesise research and insights on external costs and to allow for more informed decision making. Topics include socio-economic issues such as system costs, security of supply, employment effects or impacts on technology development, as well as environmental and public health issues, such as atmospheric pollution, climate change, land use or major accidents. One of the findings of this project is that atmospheric pollution and system costs constitute the largest uninternalised costs of electricity provision.

System costs in decarbonising electricity systems

The continued decrease in the cost of variable renewable sources and the ongoing effort to decarbonise the energy system of OECD member countries are likely to change the electricity landscape in the next decades. The subsidisation of technologies and the deployment of a growing share of intermittent energy sources have significant impacts on the level and volatility of electricity market prices and on the ability to invest in new dispatchable generation capacity. The NEA has undertaken an extensive modelling effort in collaboration with the Massachusetts Institute of Technology (MIT) Institute for Data, Systems, and Society (IDSS) with the objective of comparing the total system costs for electricity systems with a common carbon constraint but with different shares of variable renewables, nuclear energy and other generating technologies. A final report will be published in 2018 and will provide greater insight into the dynamics and economics of introducing growing shares of variable renewables in the generating mix and into the operations of conventional dispatchable plants. It will also provide an analysis of policy instruments to internalise system costs.

Cogeneration in a low-carbon future

A final report on cogeneration in a low-carbon future, following a two-year study carried out by a NDC expert group, is in preparation and will be published in 2018. The outcome of the study shows that nuclear cogeneration, whether with existing reactors or more likely with advanced reactors, can play an important role in reducing greenhouse gas emissions from the industry, transport or building sectors. Indeed, nuclear energy provides not only low-carbon electricity but also low-carbon heat, which can be used for a wide range of industrial processes, from district heating to hydrogen generation and desalination. Case studies provided by the expert group cover both existing applications and feasibility studies.

Measuring employment

The nuclear energy sector employs a considerable workforce around the world. The NEA and the International Atomic Energy Agency (IAEA) have been collaborating on activities in relation to employment implications in the nuclear power sector for many years, and a report, *Measuring Employment Generated by the Nuclear Power Sector,* has grown out of these activities. Using the most available macroeconomic model to determine total employment – the "input/output" model – the Nuclear Energy Agency and International Atomic Energy collaborated to measure direct, indirect and induced employment from the nuclear power sector in a national economy. The report will be published in early 2018.

Engagement with other elements of the OECD

The NEA works closely with the International Energy Agency (IEA) on in-depth reviews (IDRs) of member countries' energy policies, with existing or planned nuclear power capacity. During 2017, the NEA participated in IDRs for Switzerland and Finland. IDR reports from previous years were published for the Czech Republic, France, Hungary and Poland. NEA participation in these reviews is critical in providing expertise on nuclear power. The NEA Division of Nuclear Technology Development and Economics also provided expertise on investment in nuclear capacity for the IEA's *World Energy Investment 2017.*

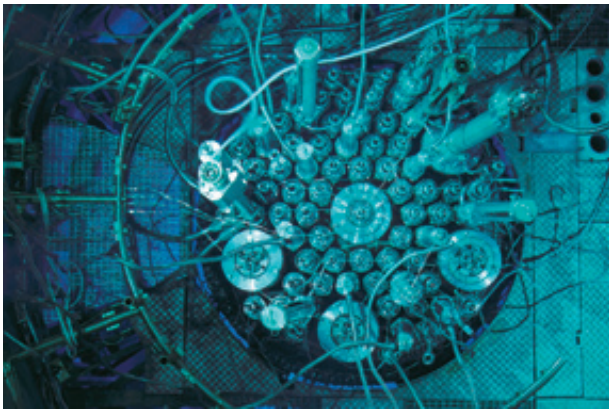
Nuclear Innovation 2050

The NI2050 Initiative aims at accelerating the readiness of innovative technologies and their competitive deployment in order to contribute to the sustainability of nuclear energy. The survey of public funding for nuclear fission R&D over the period 2010-2015 was consolidated, and national country reports were drafted and reviewed by the member countries so as to provide a global picture. Public funding for nuclear R&D has decreased significantly compared to some decades ago, but has stabilised over the last ten years. Today, observers have noted a balanced share of funding for nuclear energy, renewables and energy efficiency. Funding is not the sole necessary condition for innovation, but ensuring the effective transfer of R&D results to market deployment is central. Programmes of action (the sequence of projects, timelines and necessary infrastructures) have therefore been developed for some priority topics selected by the NI2050 Advisory Panel. They will serve as the basis for launching the interaction with industry and the regulatory community on the ways and means for implementation.

Security of supply of medical radioisotopes

In 2017, the NEA High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) continued its efforts to help ensure the global security of supply of molybdenum-99 (^{99}Mo) and its decay product, technetium-99m (^{99m}Tc), the most widely used medical radioisotope. The NEA issued the report, "2017 Medical Isotope Supply Review: ^{99}Mo/^{99m}Tc

BR2-reactor of SCK•CEN.
Photo courtesy of SCK-CEN and Nordion



Market Demand and Production Capacity Projection 2017-2022", reconfirming that market demand for $^{99}Mo/^{99m}Tc$ remains relatively flat at around 9 000 6-day ^{99}Mo curie per week at the end of processing. The report points out that capacity levels from existing supply chain members have increased for the second year in succession and that the current supply chain capacity, if well maintained, planned and scheduled, should be able to manage an unplanned outage of a reactor or a processor throughout the entire period to 2022. New projects for the production of $^{99}Mo/^{99m}Tc$, both from conventional and alternative technologies, continued to make progress, but many projects have also suffered delays. As of the end of 2017, production from alternative technologies had yet to be commercialised.

The third self-assessment of the global $^{99}Mo/^{99m}Tc$ supply chain was also issued. The report evaluates progress made by supply chain participants with the implementation of HLG-MR policy principles, in particular the implementation of full-cost recovery throughout the supply chain and the establishment of sufficient paid outage reserve capacity to ensure continuous availability of products for patients. The report examines the role of governments in the $^{99}Mo/^{99m}Tc$ market, in particular the need to ensure the conditions needed for establishing an economically sustainable market. It also makes comparisons to earlier self-assessments in 2012 and 2014, respectively, and identifies the main issues that continue to delay achievement of long-term economic sustainability.

The NDC approved the extension of the fourth mandate of the HLG-MR for a 14-month period ending in December 2018.

Nuclear fuel cycle: Strategies and considerations for the back end

The Expert Group on Back-end Strategies (BEST) held its first meeting on 3-4 May 2017. The group was created to examine the aspects that play an important role in countries' decisions on whether and how to deploy partially and fully closed nuclear fuel cycles. Through meeting discussions and country presentations, it became clear that decisions on fuel cycle paths are heavily influenced by aspects other than technical feasibility or maturity. The group will produce a report that will be useful to decision makers identifying areas of technical consensus and key distinctions between fuel cycle systems.

Advanced reactors and future energy market needs

After organising a very well-attended international workshop in April 2017, the NEA launched a two-year study on advanced reactors and future energy market needs under the auspices of the Nuclear Development Committee (NDC). The first meeting of the ad hoc expert group met on 5-6 July 2017, gathering experts from Canada, France, Italy, Japan, Korea, Poland, Romania, Russia and the United Kingdom. The objective of the study is to analyse rapidly evolving energy and electricity markets and to see how well reactor technologies under development today – evolutionary Gen III reactors, small modular reactors, as well as Gen IV reactors – 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, and it will help to identify challenges related to new operational, regulatory or market requirements.

Ensuring the adequacy of funding arrangements for decommissioning and spent fuel disposal

The majority of working nuclear reactors will reach their originally planned operational lifetimes in the coming two decades. There is thus strong social demand to ensure sustainable solutions for decommissioning and spent fuel disposal. This new project aims at assisting member countries in ensuring that their funding arrangements are appropriate, both in terms of the provisions being constituted and the institutional processes that ensure equivalence between assets and liabilities over time. While the study does not question existing cost estimates, particular attention is given to financial risks, both on the funding and the costing side, in a rapidly evolving economic environment. The project includes two workshops with member countries and the European Commission designed to exchange experiences and identify best practices.

Contribution of uranium mining to economic development

On 9-10 October 2017, the new NEA Expert Group on Uranium Mining and Economic Development (UMED) held its first meeting. Participants discussed case studies in various countries in order to understand the impact of uranium mining on employment, royalties and tax revenues, local business development, infrastructure, education and medical care. They also noted, however, that partnerships and good governance are essential to achieving long-term sustainable development.

Economics of long-term storage

The Expert Group on the Economics of Extended Storage of Spent Nuclear Fuel (EGEES) has selected four scenarios in relation to the extended storage of irradiated fuel: i) open-cycle, extended on-site dry storage (with repackaging), ii) open-cycle, extended off-site centralised dry storage, iii) open-cycle, extended off-site centralised wet storage, and iv) closed-cycle. The economic analysis of each of these scenarios will be carried out according to the recommendations of the following groups: the Committee on the Safety of Nuclear Installations (CSNI) Working Group on Fuel Cycle Safety (WGFCS) and the Radioactive Waste Management Committee (RWMC) Expert Group on Pre-disposal Management of Radioactive Waste (EGPMRW).

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Secretariat-serviced bodies

Generation IV International Forum (GIF)

Established in 2001, the Generation IV International Forum (GIF) brings together 13 countries – among which Canada, China, France, Japan, Korea, Russia, South Africa, Switzerland and the United States are the most active, as well as Euratom, representing the 28 European Union members – to co-ordinate R&D on advanced nuclear energy systems. The Framework Agreement was extended on 26 February 2015 for an additional ten years. Australia became the 14th GIF member in June 2016 after the signature of the GIF Charter by the Chief Executive Officer of the Australian Nuclear Science and Technology Organisation (ANSTO). Australia acceded to the Framework Agreement on 13 December 2017.

Six conceptual nuclear energy systems were selected in 2002 for collaborative R&D: the sodium-cooled fast reactor (SFR), the very-high-temperature reactor (VHTR), the supercritical water-cooled reactor (SCWR), the gas-cooled fast reactor (GFR), the lead-cooled fast reactor (LFR) and the molten salt reactor (MSR). These six Generation IV systems were confirmed in the *Technology Roadmap Update for Generation IV Nuclear Energy Systems* published in 2014. GFR, SCWR, SFR and VHTR research activities within GIF are organised into four system arrangements, under which project arrangements have been set up (nine at the end of 2017, covering areas such as safety and operation, fuel, materials, thermal-hydraulics, hydrogen production and system integration and assessment). Two projects expired in 2017: 1) the SFR advanced fuel project; and 2) the Global Actinide Cycle International Demonstration (GACID) Project. The four system arrangements were extended for another ten years in 2016 by agreement of the signatories. MSR and LFR activities are not yet organised into system arrangements and projects, and these activities operate under memoranda of understanding that govern information exchanges between the signatories and observers. However, in 2017, the MSR provisional System Steering Committee agreed to move towards a system arrangement.

During 2017, GIF continued to work on the goals of achieving the highest levels of safety for Generation IV systems, with the development of safety design criteria (SDC) and safety design guidelines (SDG) that incorporate lessons learnt from the Fukushima Daiichi nuclear power plant accident. Initially developed for the SFR, the SDC and SDG are being adapted to the LFR and VHTR systems. GIF also continued in its efforts to engage with regulators in discussions on reactor safety criteria and objectives, whether at the national or the international levels, and particularly through the NEA Ad hoc Group on the Safety of Advanced Reactors (GSAR) under the aegis of the NEA Committee on Nuclear Regulatory Activities (CNRA) and the Committee on the Safety of Nuclear Installations (CSNI).

Through its Education and Training Task Force, GIF has addressed the need to reach out to students and researchers by setting up a series of monthly webinars that started in September 2016. By December 2017, 16 webinars had been organised, with participation extending beyond the GIF membership to universities and industry. The material from these webinars is available on the GIF website. GIF also re-engaged with industry through the feedback of the GIF Senior Industry Advisory Panel (SIAP). The SIAP provided the GIF Policy Group with a proposal to review the technology readiness level of Gen IV concepts, and the associated market aspects and challenges, through a design review questionnaire sent to all system developers.

The NEA has continued to provide support to the technical bodies in charge of the development of the six systems and the three methodology working groups, as well as to the SIAP at the request of the Policy Group (PG). It also maintains the GIF public website and the password-protected area, and organises and hosts one of the two yearly PG meetings, with the other one hosted by a GIF member country (South Africa hosted the October 2017 PG meeting). The NEA is fully compensated for its support to GIF through voluntary, financial and in-kind contributions made by individual GIF members.

Policy Group meeting in South Africa, October 2017.

International Framework for Nuclear Energy Cooperation (IFNEC)

The International Framework for Nuclear Energy Cooperation consists of 34 Participant countries, 31 Observer countries and 4 Observer organisations (Euratom, GIF, the IAEA and the NEA). Of the 33 NEA member countries, 26 are members of IFNEC.

After approval by the NEA Steering Committee, the IFNEC Steering Group formally initiated the transition of the Technical Secretariat to the NEA at its June 2015 meeting with the understanding that it was to be funded solely through voluntary, financial and in-kind contributions made by individual IFNEC members.

While IFNEC has experienced some significant changes in 2017, its mission has remained the same since its inception in 2010:

"The International Framework for Nuclear Energy Cooperation provides a forum for cooperation among participating states to explore mutually beneficial approaches to ensure the use of nuclear energy for peaceful purposes proceeds in a manner that is efficient and meets the highest standards of safety, security and non-proliferation. Participating states would not give up any rights and voluntarily engage to share the effort and gain the benefits of economical, peaceful nuclear energy."

The most significant change in 2017 was the transfer of leadership of IFNEC from the United States to Argentina. Having served seven years as the Chair of the IFNEC Steering Group (SG), Mr Edward McGinnis joined the SG members in their unanimous support and welcome of Mr Julian Gadano as the new Chair on 29 June. One of the new Chair's priorities is to reach out to developing countries so as to invite and involve qualified newcomer countries that are taking their very first steps in a nuclear programme. In addition, with the support of member countries and observer organisations, the focus of IFNEC was expanded in 2017 to include supply chain issues under the newly formed Ad Hoc Nuclear Supplier and Customer Countries Engagement Group (NSCCEG) co-chaired by Japan and Argentina. The NSCCEG held its first meeting on 28 June, followed by a Conference on Global Supply Chain and Localisation Issues on 7-8 November. The Conference provided an opportunity for stakeholders to discuss the critical issues of global supply and localisation in an interactive format. The Conference proceedings will be made publicly available in spring 2018.

On 9-10 May 2017, the Infrastructure Development Working Group held the Resources and Gaps Workshop entitled "Industry View of Nuclear Security and Stakeholder Engagement for Radioactive Waste Management", which was hosted by the Government of Romania in Bucharest. More than 70 experts from the region gathered at the workshop to exchange with internationally recognised leaders in industry, academia and government.

The Reliable Nuclear Fuel Services Working Group (RNFSWG) continued its work in two key areas: discussions on the costs associated with the development of a multinational repository, and the feasibility of technologies and costs associated with long-term storage.

The three working groups continued to have open discussions with SG and Executive Committee members during their meetings held on 6-9 November, particularly with regard to possible areas of synergy and the importance of avoiding duplication, both internally within the IFNEC structure and externally with other entities that are addressing similar issues.

IFNEC Conference on the Global Supply Chain and Localisation Issues, November 2017, Paris, France.

Nuclear Safety and Regulation

The goal of the NEA in this sector is to assist member countries in their efforts to ensure high standards of safety in the use of nuclear energy, by supporting the development of effective and efficient regulation and oversight of nuclear installations and activities, and by helping to maintain and advance the associated scientific and technological knowledge base. The staff works closely with the Committee on the Safety of Nuclear Installations (CSNI), the Committee on Nuclear Regulatory Activities (CNRA) and their expert groups in this area.

Highlights

- "Safety Research Opportunities Post-Fukushima – Initial Report of the Senior Expert Group" was issued in 2017.
- Several international workshops or conferences were held in 2017, addressing topics such as regulatory oversight of new licensee organisational capability and operating experience, and enabling experts from member countries to share experiences and establish best practices.
- The 4th Multinational Design Evaluation Programme (MDEP) Conference on New Reactor Design Activities was held in September, attracting 150 participants from 16 countries.
- Also in the framework of MDEP activities, part of the internal vibration tests of the reactor pressure vessel conducted during the commissioning of the first EPR, Taishan unit 1 in China, were witnessed by French, Finnish and UK regulators, with the results potentially benefitting follow-on units constructed in other countries.

Nuclear safety

Analysis and management of accidents

The NEA Working Group on Analysis and Management of Accidents (WGAMA) has continued to focus on the in-vessel behaviour of degraded cores, the thermal-hydraulics of the reactor coolant system, containment behaviour and protection, computational fluid dynamics, and fission-product release and transport.

The WGAMA completed four activities in 2017. First, a report was produced on the use of analytical simulations of reactor accident scenarios to improve severe accident management and guidance. Secondly, a summary was undertaken of the state of knowledge in relation to potential steam explosions in deep cavities when molten corium is released following failure of a reactor pressure vessel. Lastly, two reports were completed on the use of computational fluid dynamics in modelling reactor performance during accidents.

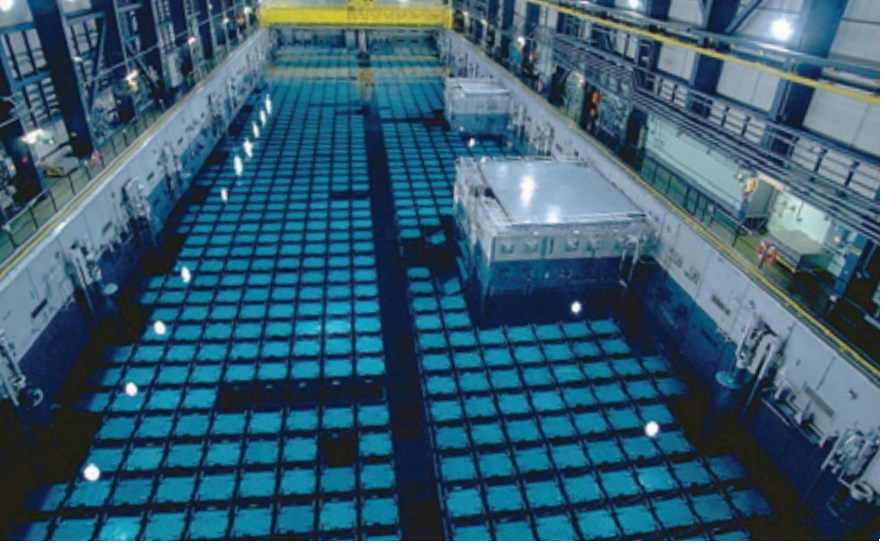
Ageing and structural integrity of reactor components

The NEA Working Group on Integrity and Ageing of Components and Structures (WGIAGE) focuses on the integrity, ageing and seismic behaviour of metal components and concrete structures.

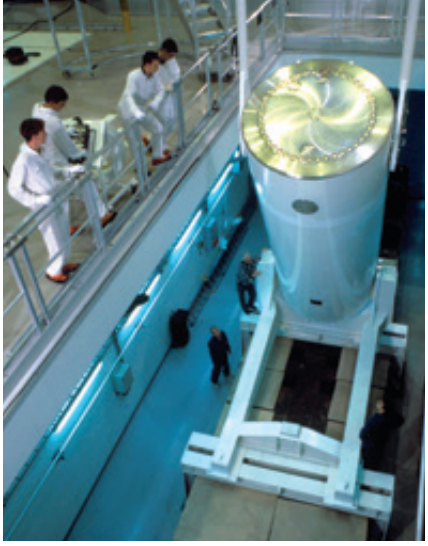
In 2017, three reports were completed. The first summarises the results of a benchmark on the fracture mechanic parameters K and J for different components and loads. The second report describes the analysis and benchmark work of metallic component margins under high seismic loads, concluding that despite the margins on seismic loads being very large, the dominant failure mode (fatigue-ratcheting) is not fully addressed in NPP design codes. The report therefore recommends developing more precise criteria in the piping design codes for prevention of fatigue-ratcheting damage to NPPs. The third report describes the results of a simulation benchmark on predicting the effect of Alkali Aggregate Reaction (AAR) on the behaviour of structural concrete. The benchmark showed that using accelerated AAR samples may not be reliable in evaluating structural performance. The next benchmark phase will concentrate on validation of the calculation models with specimens taken from a real structure.

Risk assessment

The main objective of the NEA Working Group on Risk Assessment (WGRISK) is to advance the understanding and use of probabilistic safety assessment (PSA) as a tool to support nuclear safety decision making in member countries. A report was completed in 2017 on the status of practice for the use of level 3 PSA analysis to determine the off-site radiological consequences of reactor accidents. Ongoing tasks of the WGRISK focus on the use of human reliability analysis in external PSA events, developments in the application of the PSA at the site level, an update on the general use and development of the PSA in member countries, updates of technical opinion papers on fire and seismic PSA, and approaches for modelling the behaviour of digital instrumentation and controls (I&C) in PSA. A joint workshop on the use of NEA database information in PSA studies is also under preparation.



Wet storage of spent fuel.
Nuclear Energy Institute (NEI), USA



Spent fuel cask transfer.
Teollisuuden Voima Oy (TVO), Finland

Fuel safety

The NEA Working Group on Fuel Safety (WGFS) focused its work in 2017 on three activities. The first was a joint workshop with expert groups of the Nuclear Science Committee on advanced modelling of fuel behaviour in support of safety and performance. This two-and-a-half-day event attracted 80 participants from 18 member countries, mostly from research and development (R&D) organisations, nuclear utilities and fuel vendors. A second activity focused on the completion of a joint WGFS-WGAMA task on research priorities in relation to spent fuel pools under loss-of-cooling or loss-of-coolant accident conditions using the approach of a phenomena identification and ranking table (PIRT). The PIRT identified 20 single phenomena having a high safety impact, but for which little knowledge is available. Lastly, the activity to supplement the 2009 state-of-the-art report (SOAR) on fuel behaviour in loss-of-coolant conditions with new material was successfully launched in early 2017. In fact, this activity identified such a large amount of additional material – and attracted such a large number of contributors – that the WGFS decided to redefine the scope of the activity to become a full update of the SOAR report.

Fuel cycle safety

The NEA Working Group on Fuel Cycle Safety (WGFCS) brings together regulatory and industry specialists to address a broad range of interests, including safety assessments, nuclear criticality safety, PSAs, safety management, decommissioning, site remediation, chemical hazards, human factors and fire protection. The working group follows and periodically reviews the joint International Atomic Energy Agency (IAEA)/NEA Fuel Incident Notification and Analysis System (FINAS), which is the only international system providing regulators and government bodies with information about lessons learnt from safety-significant events at fuel cycle facilities.

In 2017, the group finalised a report on the Workshop on Developments in Fuel Cycle Facilities (FCFs) after the Fukushima Daiichi Nuclear Power Station (NPS) Accident. The workshop concluded that the defence-in-depth concept, applied with a graded approach according to the risk posed by an FCF, is useful for ensuring safety in design and in defining management systems, quality methods and working procedures for FCFs. The report also noted the utility of testing emergency operating procedures (EOPs) of FCFs during annual emergency exercises.

External events

The NEA Working Group on External Events (WGEV) works to improve the understanding and treatment of external hazards to support the continued safety performance of nuclear installations and improve the effectiveness of regulatory practices. The initial focus of this group has been on severe weather events with high winds and flooding, and the proceedings of a workshop held on this subject were completed in 2017.

The WGEV is currently working on two activities, first to identify best practices and knowledge gaps in the use of science-based screening approaches to external hazards, for further consideration in NPP risk assessments. The second activity will identify key issues related to the deterministic and probabilistic approaches associated with the riverine flood hazard assessment, as well as the adequacy of protection against riverine floods. The WGEV also initiated a new activity to develop insights into the concepts used to establish effective protective measures to cope with flooding hazards, and to develop a common understanding of the terminology used to discuss protective measures related to flooding.

Robustness of electrical systems

The NEA Working Group on Electrical Power Systems (WGELEC) collaborates on enhancing the robustness of electrical systems, improving the analysis of electrical system performance and addressing safety challenges associated with electrical systems. The WGELEC has three ongoing activities on the early identification of electrical failure mechanisms that affect nuclear safety, on the identification of good practices for advancing electrical power system robustness, and on the comparison of simulation methodologies for electrical systems. An additional activity was identified in 2017 to establish measures against accelerated degradation and failure of batteries that affect safety at nuclear facilities.

Control room.
Shutterstock, Nordroden

Nuclear regulation

Operating experience

The NEA Working Group on Operating Experience (WGOE) continued to share information and follow-up actions related to national trends and lessons learnt from national events. In April 2017, the WGOE held an international workshop in Madrid, Spain, on best practices derived from regulatory operating experience databases. This workshop provided an opportunity for the participants to discuss techniques and methods for the collection, assimilation, review and analysis of incidents in order to improve event response and inspection procedures, and to enhance assessment capabilities for preventive or corrective actions.

The WGOE continued to examine events submitted to the joint IAEA/NEA International Incident Reporting System (IRS) for Operating Experience, which is the only international system that provides regulators with information about safety-significant events at NPPs. The IAEA is preparing the release in early 2018 of Nuclear Power Plant Operating Experience from the IAEA/NEA Incident Reporting System (the "Blue Book") for operating experience between the years 2012 and 2014.

The WGOE also updated the guidance and template used to identify and share among members information about non-conforming, fraudulent and suspect items (NCFSI). The group will issue a report in early 2018 reviewing operating experience, comparing regulatory requirements and identifying lessons learnt with regard to more than 100 heavy load lifting events reviewed by the working group in 2017.

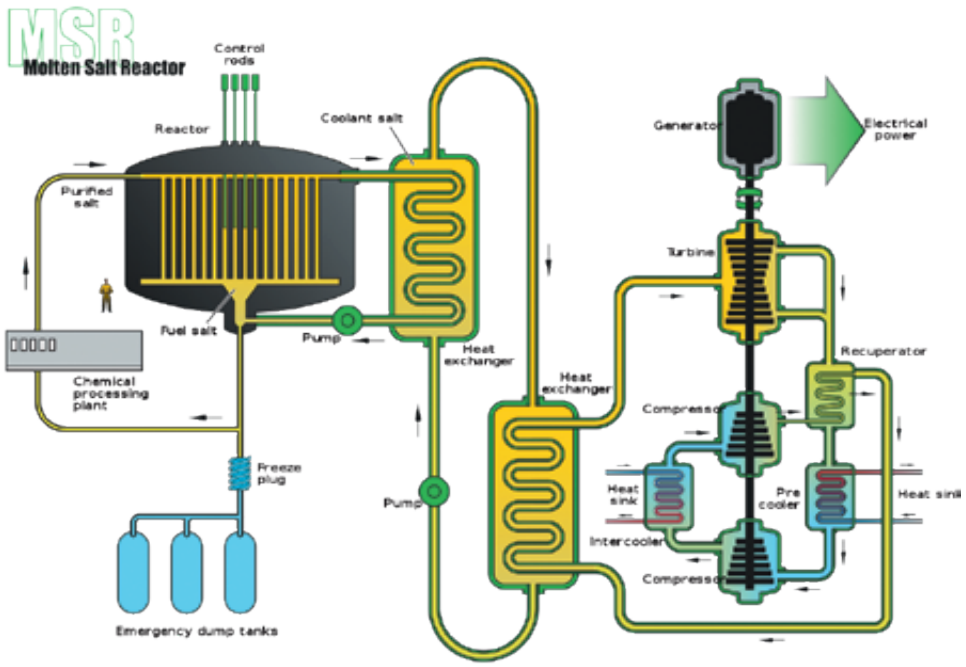
Regulation of new reactors

The NEA Working Group on the Regulation of New Reactors (WGRNR) focuses its activities on regulatory activities in the area of siting, licensing and overseeing new commercial NPPs. In 2017, group members reported four events in the Construction Experience Database. It was also decided in 2017 that the database would undergo a migration to the IRS database in the near future.

The group developed the fifth volume of the "Report on the Survey of the Design Review of New Reactor Applications", dealing with the classification of structures, systems and components, and it is currently developing the sixth volume, covering engineered safety features. The group also finished the stage 1 report for "Regulatory Practices for Passive Safety Systems" in 2017, which was endorsed at the 37th CNRA meeting. In March 2017, the WGRNR organised a workshop in Chester, United Kingdom on Regulatory Oversight of New Licensee Organisational Capability. This workshop was organised jointly with the NEA Working Group on Human and Organisational Factors (WGHOF) in collaboration with the UK's Office for Nuclear Regulation (ONR). Workshop participants discussed cross-cutting issues that arise when a prospective nuclear licensee develops its organisational capability, and a regulatory body prepares itself for and delivers the regulatory oversight of a prospective licensee's organisational capability.

Regulatory inspection practices

In 2017, the NEA Working Group on Inspection Practices (WGIP) published its first triennial report on WGIP



Generation IV Molten Salt Reactor (MSR).

US Department of Energy

benchmarking on inspection practices. The report documents commendable practices and lessons learnt regarding the six observed inspections conducted by the WGIP between 2013 and 2016. The group co-ordinated the NPP benchmarking inspections hosted in 2017 by Finland, with the participation of Canada, the USA and the United Kingdom; and by the United Kingdom, with the participation of the Czech Republic, Germany and Japan. By participating in and observing planning, performance and inspection enforcement actions, member countries assist in overall improvements to inspection techniques. The WGIP also began to prepare the next benchmarking inspection, which will take place in Canada in 2018. It continued as well with the preparations for the next international workshop that will be held in Germany in 2018.

Ad hoc Group on the Safety of Advanced Reactors

The NEA Ad hoc Group on the Safety of Advanced Reactors (GSAR) provides regulatory perspectives on selected, advanced reactor designs, including the identification of required safety research. It focuses on areas such as severe accident prevention and mitigation measures, neutronics and criticality safety, and analytical codes and fuel qualifications. The final draft of the technical report on severe accident prevention and mitigation measures was prepared and discussed in October 2017. GSAR members are examining comments from the United States Nuclear Regulatory Commission and will finalise the report by April 2018. Three additional draft reports are being finalised for release in 2018. GSAR members also discussed comments on the Generation IV International Forum (GIF) Safety Design Guidelines on the Safety Approach and Design Conditions for Gen-IV SFR Systems in 2017, and these comments were transmitted to GIF during the October 2017 meeting.

In 2017, the CNRA and CSNI decided to transform this ad hoc group into the Working Group on the Safety of Advanced Reactors (WGSAR).

Digital Instrumentation and Control

The NEA Working Group on Digital Instrumentation and Control (WGDIC) was created under the CNRA in 2017 to build upon related work transferred from the Multinational Design Evaluation Programme. The WGDIC will address regulatory issues associated with the use of digital technologies in existing and new nuclear installations, and will hold its first meeting in 2018.

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Joint Projects

▶ Nuclear safety research

The Halden Reactor Project

The Halden Reactor Project, operated by the Norwegian Institute for Energy Technology (IFE), was established in 1958 and is the largest ongoing NEA project. It brings together an important international technical network in the areas of nuclear fuel reliability, integrity of reactor internals, plant control/monitoring and human factors. The programme is primarily based on experiments, product prototype developments and analyses carried out at the Halden establishment in Norway. It is supported by approximately 130 organisations in 20 countries. The project benefits from a stable and experienced organisation and a technical infrastructure that has undergone substantial developments over the years. Its objectives have been continuously adapted to users' needs.

Work in the fuel area has included continued testing of high burn-up fuel under loss-of-coolant accident (LOCA) conditions. These are the only LOCA tests that are currently being performed in-pile worldwide, and they complement the work done at laboratory scale in other institutions, notably in Japan and the United States.

Long-term irradiations have been carried out with advanced and standard nuclear fuel at high initial rating conditions. Corrosion and creep behaviour of various alloys have been studied. The experimental programme continued to examine the effect of water chemistry variants on fuel and reactor internals materials. Tests to investigate the cracking behaviour of reactor internals materials in boiling and pressurised water reactors also continued, with the aim of characterising the effect of water chemistry and material ageing. The project also contributed to international Generation IV research in the areas of instrument development and materials testing.

The programme on human factors has focused on experiments in the Halden man-machine laboratory, related data analyses, new control station designs, evaluations of human-system interfaces, process and instrumentation optimisation, and digital instrumentation and controls (I&C). These activities involve the use of the Halden Virtual Reality Centre, among others. Progress has been made in the area of human reliability assessment (HRA), which aims to provide data suitable for probabilistic safety assessments and to improve the validity of HRA methods.

The current phase of the Halden Reactor Project was completed at the end of 2017, and the official process for signing the agreement for the next three-year phase, from 2018 to 2020, began in December 2017. The Fuels and Materials programme continued work on fuel safety and operational margins, as well as on plant ageing and degradation. In the Man, Technology, Organisational programme, research continued in the areas of human factors, digital instrumentation and controls, and maintenance, outage and decommissioning.

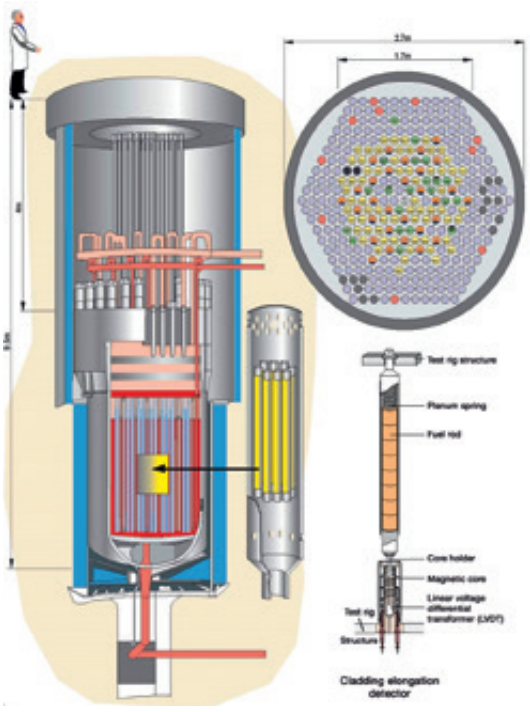


Illustration of the Halden reactor showing the cross-section of the core (top right) and indicating how an instrumented fuel rod (bottom right) is placed within the reactor.

Institute for Energy Technology, Norway

View of the ATLAS experimental loop.
KAERI, Korea

The ATLAS Project

The Advanced Thermal-hydraulic Test Loop for Accident Simulation (ATLAS) is a thermal-hydraulic integral effect test facility for advanced light water reactors (LWRs) located in Korea. It was commissioned in 2006 and has been carrying out this joint project through beyond-design-basis accident (BDBA) tests since 2012.

Phase two of the ATLAS project is aimed at topics identified by the participants as having high safety relevance for both existing and future nuclear power plants. The following topics will be addressed:

- long-term coolability with partial core blockage;
- passive core makeup during station blackout and small break loss-of-coolant accidents;
- intermediate break loss-of-coolant accidents, including the risk-informed break size definition;
- design extension condition scenarios such as steam line break, followed by steam generator tube rupture and shutdown coolability without a residual heat removal system;
- open tests to address scaling issues by performing counterpart tests to previous integral effects tests.

The experimental programme is devised to allow for an open test, which is to be defined in consultation with project members and which might cover the above issues or other safety-relevant issues. The experimental programme is to provide an integral effect experimental database, which will be used to validate code predictive capability and accuracy of models. The experimental programme and associated analytical activities will help to create a group among OECD/NEA member countries which share the need to maintain or improve the technical competence in thermal-hydraulics for nuclear reactor safety evaluations.

The ATLAS Phase 2 project runs between October 2017 and September 2020 and is supported by the safety organisations and industry in the following countries: Korea, Belgium, Czech Republic, China, France, Germany, Spain, Switzerland, United Arab Emirates and the United States.

The BIP

The Behaviour of Iodine Project (BIP), hosted by Canadian Nuclear Laboratories (CNL, formerly AECL) and supported by 13 member countries, started in September 2007. Phase 1 was completed in 2011 and phase 2 in 2015.

A 3-year follow-up project, BIP-3, supported by 11 member countries, started in January 2016 and is attempting to answer some of the outstanding questions raised during BIP-1 and BIP-2. Interactions between iodine and paint (i.e. primarily iodine adsorption onto paint and the subsequent production and release of organic iodides during irradiation) were investigated during BIP-1 and BIP-2. While painted surfaces are a very important iodine sink within containment, they represent a pathway that converts molecular iodine into organic iodine, which is less easily trapped than molecular iodine by conventional iodine filtration methods (charcoal, wet scrubbers). The specific technical objectives of BIP-3 are to:

- perform experiments that will resolve outstanding questions and improve the simulations of BIP and the NEA Source Term Evaluation and Mitigation (STEM) Project results, including by improving the ability to simulate iodine adsorption and desorption on containment surfaces; predicting organic iodine behaviour (formation and degradation) under accident conditions; and investigating the effects of paint ageing on these processes;
- further investigate the effects of contaminants (nitrous oxides, chlorine and other potential contaminants);
- share simulation strategies involving all partners in, for example, a code comparison exercise.

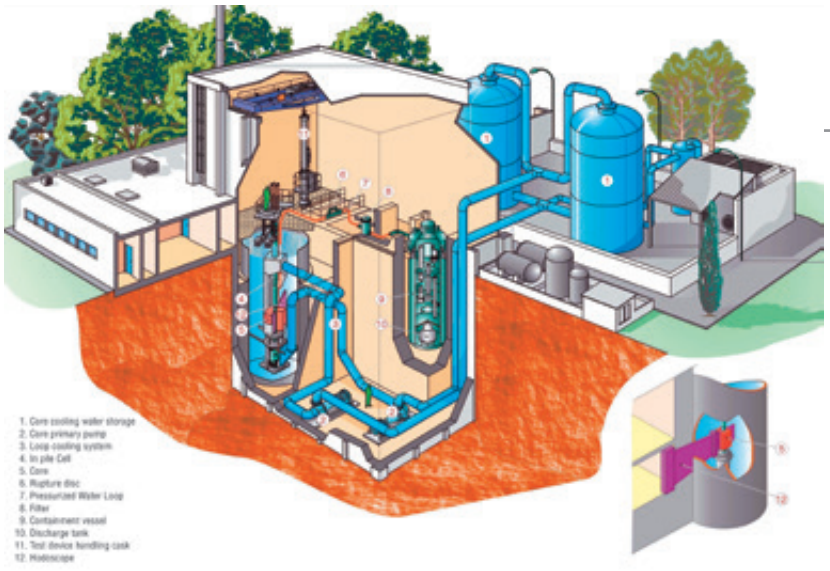
Excellent progress was made in 2017 in advancing the planned experiments on iodine adsorption/desorption and formation of methyl iodide. The testing has provided information on the effects of irradiation on methane degradation and on the effects of paint ageing and paint-layer thickness on iodine deposition. It should be noted that the BIP and STEM projects have strong scientific links with complementary objectives and many common partners.

The BSAF

The Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station (BSAF) was established among eight NEA member countries in 2012. BSAF is intended to improve severe accident (SA) codes, and to analyse accident progression and current core status in detail for the preparation of fuel debris removal as a part of R&D projects related to the mid- to long-term response for the decommissioning of the Fukushima Daiichi nuclear power plant.

The project is hosted by Japan and brings together international experts to advance the understanding of the phenomena of severe accident behaviour specific to the Fukushima Daiichi NPP accident while also improving the methods and codes for modelling such behaviour.

A phased approach is being applied in this NEA benchmark exercise. The first phase, completed in 2015, was a full-scope analysis of the Fukushima Daiichi units 1 to 3 using currently available SA integral codes, with a time span for the analysis of accident events of about six days from the occurrence of the earthquake. A complete analysis was also undertaken of a number of key phenomena such as initial transient, core heat-up, core



Cabri reactor with water loop scheme.
IRSN, France

melt, release of fission products (FPs) from fuel, core status including debris behaviour and molten debris-concrete interaction. BSAF phase 2 began in 2015 with membership expanded to 11 NEA member countries. The scope of analysis for phase 2 is approximately the first three weeks following the accident, and it includes fission-product behaviour in the reactor buildings, as well as releases into the Fukushima site and beyond the site. The fifth phase-2 meeting was held in July 2017 in Tokyo to share the latest estimations regarding plant status and new findings from the damaged Fukushima Daiichi reactors. BSAF members discussed preliminary calculation results and co-operation with other NEA post-Fukushima research activities. A joint workshop was held in parallel to provide an update on the status of the Fukushima Daiichi NPP and decommissioning activities, and to have extensive discussions on the estimation and evaluation of accident scenarios, fuel debris and FP distributions (units 1, 2 and 3).

The CIP

The Cabri International Project (CIP) is investigating the ability of high burn-up pressurised water reactor (PWR) fuel to withstand the sharp power peaks that can occur in power reactors due to postulated rapid reactivity insertions in the core, or reactivity-initiated accidents (RIAs). The project participants, from 12 member countries, intend to determine the limits for fuel failure and the potential consequences of possible ejection of fuel into the coolant environment. Different cladding materials and fuel types are being studied. The project is operated and managed by the Institut de radioprotection et de sûreté nucléaire (IRSN) and performed in the Cabri Facility, which belongs to the French Alternative Energies and Atomic Energy Commission (CEA), in Cadarache, France. The facility is operated by the CEA and funded by the IRSN. Programme execution can also involve laboratories in participating organisations, for instance, in relation to fuel fabrication and characterisation and instrumentation. The Cabri tests are complemented by additional RIA tests being performed in Japan. These tests, which constitute the in-kind contribution from the Japan Atomic Energy Agency (JAEA) for its participation in the project, are being carried out in both cold and hot coolant conditions, and using both boiling water reactor (BWR) and PWR fuel.

After 13 years of major refurbishment financed by the IRSN, the Cabri research reactor returned to criticality at low power in October 2015. Low-power tests from October 2015 to June 2016 allowed for complete neutronic characterisation of the core. In 2015-2016, qualification of the experimental equipment was completed, in particular the imagery and spectroscopy measurement station, as well as the hodoscope, which recorded its first neutrons. The pressurised water loop is also qualified at 280°C and 155 bars. High power (23 MW) operation was attained during the last quarter of 2016. This test was part of the commissioning tests in 2017, including high power pulses that reached up to 20 GW. The final phase of testing in relation to RIA-type power transients was completed in 2017 and included sixty-six power pulses of different magnitudes and durations. A request was made in late May 2017 to the French Nuclear Safety Authority (ASN) for authorisation of the first test in the water loop. The test is expected to be carried out in early 2018. In preparation for this first test in the water loop, a test rod (MOX fuel with Zr-4 cladding with burn-up of 47 GWj/t) was implemented in the experimental device in September 2017 and will undergo non-destructive pre-examination (X-ray imaging and gamma-scanning).

The procedure of obtaining approval from each project partner for a three-year extension of the project to March 2021 was launched at the end of 2017.

The HEAF Project

Massive electrical discharges, referred to as high energy arcing faults (HEAF), have occurred in nuclear power plant switching components throughout the world. These incidents have been increasing as a result of ageing infrastructures and growing energy demands. The HEAF Project was initiated in 2012 to perform experiments in order to obtain scientific fire data on HEAF phenomena through carefully designed experiments. Phase 1 of the HEAF project was completed in 2016 with a final report describing the testing and data generated. The report concluded with recommendations for areas requiring further testing.

In February 2017, an International Phenomena Identification and Ranking Table (PIRT) exercise was held to identify phenomena of the highest importance where the least amount of knowledge is available on HEAF events. This exercise tentatively identified aluminium oxidation, pressure effects, the characteristics of target structures and mitigating factors (e.g. HEAF shields) as being areas of interest for HEAF phase 2. Discussions are underway with representatives from 12 countries to initiate a second phase of the project, which is planned to start in early 2018.

The HYMERES Project

The Hydrogen Mitigation Experiments for Reactor Safety (HYMERES) Project was initiated in 2013 with the objective of improving the understanding of hydrogen risk phenomenology in containment, and of enhancing the

modelling of hydrogen behaviour in support of safety assessments that will be performed on current and new nuclear power plants. The HYMERES Project is specifically aimed at topics of high safety relevance for both existing and future nuclear power plants. It explores measured parameters as well as configurations and scales, and thus enhances the value of the data in terms of code improvements.

The unique and complementary features of the Multipurpose Integral Test Facility for LWR Safety Investigations (PANDA) in Switzerland and the Storage of Thermal Reactor Safety Investigations (MISTRA) facility in France, with their difference in size and configuration and their comprehensive instrumentation in terms of both spatial and temporal resolution, allows for high-quality experimental data. This data can be used to improve the modelling capabilities of computational fluid dynamics and advanced lumped parameter (LP) computer codes designed to predict post-accident, thermal-hydraulic conditions in containments, and thus enhance confidence in their use in plant analyses. Operating agents may also consider new experiments in response to specific participant requests during the project.

The first phase of HYMERES was concluded at the end of 2016. In July 2017, a second phase of the project started and a kick-off meeting was held in October 2017. A total of 10 countries – China, Czech Republic, Finland, Germany, Japan, Korea, Russia, Spain, Switzerland and the United States – are continuing their joint research to improve and validate safety codes for the simulation of reactor containment conditions in accident scenarios.

By means of experiments being carried out in the PANDA facility in Switzerland, the influence on containment thermal-hydraulics is being investigated during phase 2 of the project. The work programme focuses on four main topics: flow impacting obstructions and containment internal structures, radiative heat transfer, suppression pressure pool and BWR systems and the performance of safety component operations.

The LOFC Project

Following a recommendation of the CSNI Task Group on Advanced Reactor Experimental Facilities (TAREF) for gas-cooled reactor safety studies, the Loss of Forced Cooling (LOFC) Project started in April 2011 with seven countries participating. The LOFC experiments study the effects of the reduction of reactor cavity cooling system (RCCS) performance and are highly relevant for safety assessments of advanced reactors such as the high-temperature reactor. The project remains on hold with a tentative target schedule to restart the reactor now estimated in the Japanese fiscal year 2019. Experiments are to be carried out by the JAEA in its high-temperature engineering test reactor (HTTR) in Oarai, Japan.

The objectives of the project are to conduct integrated large-scale tests of LOFC in the HTTR reactor, to examine high-temperature gas-cooled reactor (HTGR) safety characteristics in support of regulatory activities, and to provide data useful for code validation and improvement of simulation accuracy. The objectives of the experimental programme are to provide experimental data to:

- clarify the anticipated transient without scram (ATWS) in case of LOFC with occurrence of reactor re-criticality;
- validate the most important safety aspects regarding reactor kinetics, core physics and thermal-hydraulics;
- verify the capabilities of the codes regarding the simulation of phenomena coupled between reactor core physics and thermal-hydraulics.

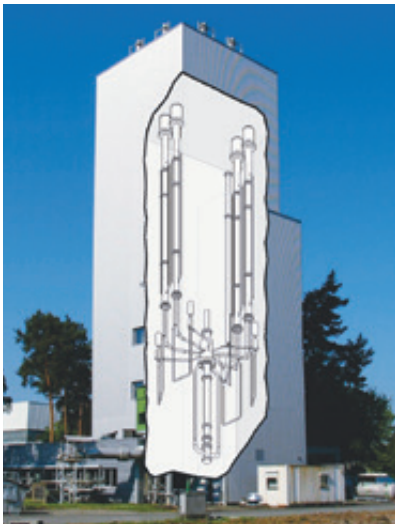
No meetings were held in 2017 and no meetings will take place until a restart is confirmed.

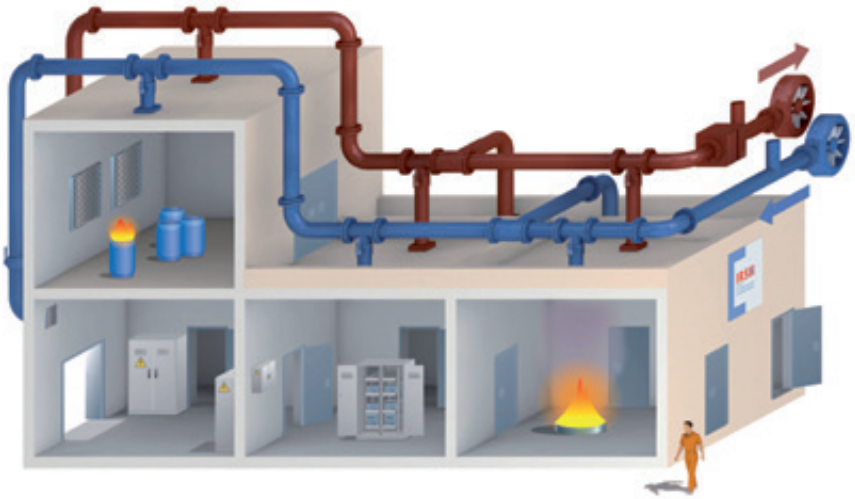
The PKL Project

The PKL-4 test programme is investigating safety issues relevant for current PWR plants as well as for new PWR design concepts and will focus on complex heat transfer mechanisms under two-phase flow, boron dilution and precipitation and on cool-down procedures. These issues are being investigated by means of thermal-hydraulic experiments that will be conducted at the Primärkreislauf-Versuchsanlage (primary coolant loop test facility) PKL. This facility is owned and operated by Areva NP and is situated in Erlangen, Germany. Areva NP have for a number of years conducted valuable experiments on reactor thermal-hydraulics in the PKL facility, including earlier experiments carried out in the framework of the CSNI Senior Group of Experts on Safety Research (SESAR) Thermal-Hydraulics (SETH) Project (2001-2003), the PKL-1 Project (2004-2007), the PKL-2 Project (2008-2011), and the PKL-3 Project (2012-2016) which included tests run in the PMK facility in Budapest, Hungary and in the PACTEL facility in Lappeenranta, Finland.

Also in the current programme, in addition to tests to be run in the PKL facility, additional tests will be run in the PMK facility in Budapest, Hungary and in the PACTEL facility in Lappeenranta, Finland. The PKL Phase 4 project started on 1 July 2016 and will end on 30 June 2020. It will focus on parametric studies on thermal-hydraulic procedures for model development and validation of thermal-hydraulic system codes, and on experimental verification of cool-down procedures and operation modes for different incidents and accidents.

Primärkreislauf-Versuchsanlage PKL Facility.
Areva, France





The Prisme Project DIVA facility for fire propagation studies.
IRSN, France

The first category addresses test subjects related to current safety issues that either suffer from the lack of a dedicated database for analysis and validation of computer codes or from uncertainties in the safety evaluation stemming from open issues or questions. The extension to already existing databases related to these subjects is the foremost goal of this first category experiments. The second category of tests mostly contains transient tests either on test subjects already investigated in the former OECD/PKL-projects as answers to questions that could not yet finally be completed or on subjects which represent current topics from the international debate on PWR safety. Complementary tests in PMK and PWR PACTEL are also considered in the test programme. Finally, two test subjects remain open, to be decided by the programme partners following the results of preceding experiments (either a confirmatory test or a test addressing specific participants' requests).

The PKL-4 project runs between July 2016 to June 2020 and is supported by safety organisations, research laboratories and industry from the following 14 countries: Belgium, Czech Republic, Finland, China, France, Germany, Hungary, Japan, Korea, Russia, Spain, Sweden, Switzerland and the United States. In 2017, two LOCA tests were completed. The first investigated the effects of nitrogen on heat removal for a small-break LOCA, and the second provided data on intermediate-break LOCAs for comparison with large-scale test facility and ATLAS tests with similar configurations.

The PreADES Project

The Preparatory Study on Analysis of Fuel Debris (PreADES) was one of the two near-term projects which were recommended by the Senior Expert Group on Safety Research Opportunities Post-Fukushima (SAREF). The main objectives of PreADES are to collect information for improving knowledge and methodologies for fuel debris characterisation that will support future fuel debris sampling at Fukushima Daiichi units 1–3, to identify the needs for fuel debris analyses that will contribute to the decommissioning of the Fukushima Daiichi plant and deepen the knowledge base on severe accidents, and to prepare a future international R&D framework on fuel debris analysis.

Following the preparatory technical meeting in Paris for SAREF near-term projects, organised by the Nuclear Regulation Authority of Japan, the preliminary meeting of the PreADES project was held in July 2017 in Fukushima and in Tokyo so as to discuss the details of the work programme proposed by the JAEA. The kick-off meeting was scheduled for early 2018.

The PRISME Project

Fire is a significant contributor to overall core damage frequency for both new and old plant designs. Some of the technical studies related to fire probabilistic safety analysis that remain open are: the propagation of heat and smoke through a horizontal opening between two superposed compartments; fire spreading on real fire sources such as cable trays and electrical cabinets; and fire extinction studies of the performance of various fire extinction systems.

Phase 2 of the Fire Propagation in Elementary, Multi-room Scenarios (PRISME) Project (from the French *Propagation d'un incendie pour des scénarios multi-locaux élémentaires)* began in July 2011 and was completed in early 2017. A summary report has been published describing the contributions of the PRISME project to the understanding of heat and smoke propagation in multiple rooms, of the effects of under-ventilation on fire behaviour, the consequences of water sprays, and the behaviour of electrical cables and cabinets subjected to fire.

The agreement for a third phase of the PRISME project was signed and is planned to run from 2017 to 2021, with eight participating countries. The project's objective is to answer questions concerning smoke and heat propagation inside a plant by means of experiments tailored for code validation purposes, mainly within the IRSN DIVA facility at Cadarache, France. The third phase will aim in particular to provide information on smoke stratification and on spreading, cable fire propagation and electrical cabinet fire spreading.

The SCIP

The Studsvik Cladding Integrity Project (SCIP) started in July 2004 and completed its first five-year mandate in 2009, when several power ramps and a hot cell programme addressing the various failure mechanisms were executed. SCIP-2 began in July 2009 with the participation of 13 countries (2 more than in the first phase). The main objective of SCIP-2 was to generate the high-quality experimental data needed for improving the understanding of dominant failure mechanisms for water reactor fuels and to devise means for reducing fuel failures. In addition to reviewing existing Studsvik ramp data, the project studied the following fuel failure mechanisms:

- pellet-clad mechanical interaction (PCMI), the mechanical driving force for pellet-clad interaction (PCI) and hydrogen-induced failures;
- PCI, notably when cladding fails due to stress corrosion cracking;
- hydrogen-induced failures, in particular as regards zirconium alloys.

The STEM Project:
The START test facility (left) and the alumina crucible (right) with RuO_2 powder in the quartz tube.

IRSN, France

The SCIP-2 project completed its mandate in June 2014, and a final project report was produced for members, as well as a summary report for wider distribution. A third phase of the project began in July 2014 and will run until June 2019. China joined SCIP-3 in 2016. The experimental campaigns of the SCIP-3 project progressed well in 2017, and at the end of the year only a few experiments remained. With the obtained results, it was possible to perform in-depth analyses and to draw the first preliminary conclusions (e.g. about a burn-up threshold for fine fuel fragmentation). In November 2017, the fourth SCIP modelling workshop was organised in Studsvik, and eight organisations presented their individual approaches.

The objectives of phase 3 are to:

- determine parameters affecting fuel fragmentation and dispersal in LOCAs;
- analyse the consequences of off-normal peak cladding temperatures and transients for the handling and storage of fuel rods;
- study the impact of power ramp rates on PCI failure risk;
- support model development and verification.

The STEM Project

The Source Term Evaluation and Mitigation (STEM) Project was initiated in 2011 to improve the general evaluation of the fission-product (FP) source term for reactor accidents in relation to two major FPs: iodine and ruthenium. The STEM Project was supported by seven countries and is conducted at the IRSN facilities in Cadarache, France. Phase 1 of the project, which ended in 2015, addressed three main issues: experiments on radioactive iodine release due to irradiation of iodine-bearing aerosols that would contribute to mid- and longer-term source in the containment; a literature survey on interactions between iodine and paints; and experiments on the transport of volatile ruthenium species through pipes. Supported by eight countries, a new four-year phase, STEM-2, started in January 2016 with the aim of conducting experimental investigations of iodine and ruthenium issues. One further country joined in 2017 while another is in the process of joining.

The following investigations concerning iodine are being undertaken:

- assessing to what extent molecular and organic iodine-release kinetics can be modified by the dose received by paint before and during an accident since paint ageing by irradiation, especially high doses, may lead to significant chemical modifications in paint;
- measuring the production of molecular and organic iodine (gas/vapour), and studying the influence of the dose, temperature and higher humidity rates on the radiolytical decomposition of iodine-oxide species (solid particulate);
- explaining the radiolytical oxidation of representative, multi-component iodine-bearing aerosols that would be produced in the reactor coolant system and lead to production of volatile iodine;
- assessing the decomposition of iodine oxides by carbon monoxide and/or hydrogen, leading to the production of volatile iodine.

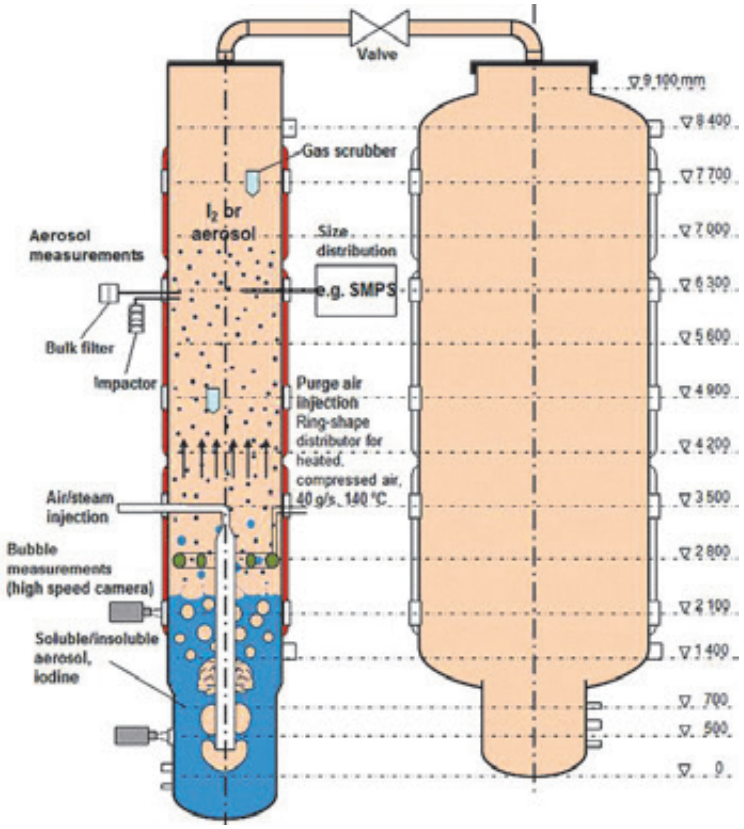
In 2017, good progress was made on experiments investigating iodine compound interactions with aged paints or with carbon monoxide.

In terms of ruthenium, experiments in more representative conditions than used in STEM are being performed on simulations of ruthenium transport in the reactor coolant system in accident conditions. In particular, this means more representativity for the deposition surface (i.e. corroded stainless steel), the use of stronger oxidising conditions like those induced by air radiolysis products (such as ozone and nitrous oxides) and the use of representative gaseous and/or aerosol "pollutants" (i.e. seed particles, silver aerosols, aerosol deposits) that could significantly influence ruthenium behaviour. Good progress was made on these experiments in 2017.

It should be noted that the STEM and BIP projects have strong scientific links, with complementary objectives and many common partners.

The THAI Project

Phase 2 of the Thermal-hydraulics, Hydrogen, Aerosols and Iodine (THAI) Project ended in 2015. A new three-and-a-half-year phase of this project, THAI-3, started in January 2016, and new experiments are once again being conducted in the THAI facility operated by Becker Technologies GmbH in Germany. The facility has been modified and now includes a second tank, narrower than the original one, which is connected by pipes at the top and the bottom to the original tank and now permits circulating flows. The agreement for phase 3 was issued in 2015 for signature to 12 NEA member and 2 non-member countries; after a number of partner withdrawals and the adherence of new partners, the agreement was finalised in late 2016



The THAI Project test set-up for fission product re-entrainment test.
Becker Technologies, Germany

with 14 partner countries. Another country joined in 2017 and, late in the year, a further country has applied to join.

The objective of THAI-3 is to address specific water-cooled reactor aerosol and iodine issues, as well as hydrogen mitigation under accidental conditions. The project is exploring open questions concerning:

- operation of passive autocatalytic recombiners (PARs) in the adverse conditions of counter-current flow;
- hydrogen combustion and flame propagation in two-compartment systems allowing simulation of natural-convection-driven flows in the containment, and looking in particular at the impact of higher flow velocities of unburned gas on flame acceleration;
- FP re-entrainment from water pools at elevated temperatures relevant to phenomena in BWR pressure-suppression pools, steam generator tube ruptures with the tube rupture submerged, wet filtered-containment-venting systems and long-term PWR accident scenarios with a flooded containment sump;
- resuspension of FP deposits (aerosol and molecular iodine) resulting from hydrogen deflagration.

Experiments on the performance of PARs were completed in 2016, and good progress on the experiments investigating FP re-entrainment from water pools was made in 2017.

► Nuclear safety databases

The CADAK Project

The Cable Ageing Data and Knowledge (CADAK) Project started in 2011 as a follow-up to the cable ageing part of the Stress Corrosion Cracking and Cable Ageing Project (SCAP).

The CADAK Project focused on the relevance of cable ageing for plant ageing assessments and the implications for nuclear safety. The main objective of the CADAK Project was to establish the technical basis for assessing the qualified life of electrical cables in light of the uncertainties identified following initial (early) qualification testing and for estimating the remaining qualified lifetime of cables used in nuclear power plants.

In November 2017, the CADAK Project, due to a lack of interest on the part of member countries, decided to stop this database project at the end of 2017. Five countries had participated in the second phase of the CADAK Project.

The CODAP

The Component Operational Experience, Degradation and Ageing Programme (CODAP) started in 2011, building on two earlier NEA projects: the Piping Failure Data Exchange (OPDE) Project that ran from 2002 to 2011 and produced an international database on piping service experience applicable to commercial nuclear plants, and the Stress Corrosion Cracking and Cable Ageing Project (SCAP), which ran from 2006 to 2010 to assess stress corrosion cracking (SCC) and the degradation of cable insulation, both of which have implications for nuclear safety and for plant ageing management.

The objectives of CODAP include:

- collect information on passive metallic component degradation and failures of the primary system, reactor pressure vessel internals, the main process and standby safety systems, support systems (i.e. ASME code classes 1, 2 and 3, or the equivalent), and components not related to safety (non-code) but with significant operational impact;
- develop topical reports on degradation mechanisms in close co-ordination with the CSNI Working Group on Integrity and Ageing of Components and Structures (WGIAGE).

At the end of the second phase (from 2015 to 2017) the CODAP database included about 4 900 records on degraded and failed metallic piping and non-piping passive components.

CODAP has finalised four insight reports analysing events in the database. The latest report, "Topical Report on Operating Experience Insights into Below Ground and Buried Piping", was finalised in 2017. The report notes that the amount and type of below ground piping systems vary significantly among nuclear power plants. As nuclear power plants age, their below ground piping systems tend to corrode, and since these systems are largely inaccessible, it can be challenging to determine their structural integrity. The report presents the results of a survey of below ground piping systems in CODAP-PRG member countries.

CODAP will continue to produce reports on a yearly basis to assess events collected in the database.

The FIRE Project

The Fire Incidents Records Exchange (FIRE) Project started in 2002, and phase 4 of the project began in 2016 for a duration of 4 years, with 14 countries participating. The main purpose of the project is to collect and analyse, on an international scale, data related to fire events in nuclear environments. The specific objectives are to:

- define the format for, and collect fire event experience (through international exchange) in, a quality-assured and consistent database;
- collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention;
- generate qualitative insights into the root causes of fire events that can then be used to derive approaches or mechanisms for their prevention or for the mitigation of their consequences;
- establish a mechanism for the efficient feedback of experience gained in connection with fire events, including the development of defences against their occurrence, such as indicators for risk-based inspections;
- record event attributes to enable quantification of fire frequencies and risk analysis.

The structure of the database has been well defined and arrangements have been made in all participating countries to collect and to validate data. The quality-assurance process is in place and has proven to be efficient on the first set of data provided. An updated version of the database, which now contains more than 490 records, is provided to participants every year.

The ICDE Project

The International Common-cause Data Exchange (ICDE) Project collects and analyses operating data related to common-cause failures (CCF) that have the potential to affect several systems, including safety systems. The project has been in operation since 1998, and was extended with a new phase-7 agreement covering the years 2015 to 2018.

The ICDE Project comprises complete, partial and incipient common-cause failure events. It currently covers the key components of the main safety systems, such as centrifugal pumps, diesel generators, motor-operated valves, power-operated relief valves, safety relief valves, check valves, control-rod drive mechanisms, reactor protection system circuit breakers, batteries and transmitters. These components have been selected because several probabilistic safety assessments have identified them as major risk contributors in the case of common-cause failures.

Qualitative insights from data will help reduce the number of CCF events that are risk contributors, and member countries use these data for their national risk analyses. Additional activities in the area of quantification are under discussion. Reports have been produced for pumps, diesel generators, motor-operated valves, safety and relief valves, check valves and batteries. Data exchange for switchgear and breakers, and for reactor-level measurements, have been completed. An ICDE Project report concerning the Lessons Learnt from Common-Cause Failures of Emergency Diesel Generators was finalised in 2017. The report concluded that the most frequently occurring causes of emergency diesel generator failures are errors related to design, manufacture or construction inadequacy.

Secretariat-serviced body

Multinational Design Evaluation Programme

The Multinational Design Evaluation Programme (MDEP) is a multinational initiative to develop innovative approaches to leverage the resources and knowledge of national regulatory authorities who are engaged in new reactor power plant design activities. The main objective of MDEP is to enable increased co-operation and establish reference regulatory practices to enhance the safety of new reactor designs. Enhanced co-operation among regulators strengthens the effectiveness and efficiency of the regulatory design reviews. MDEP co-operation is structured around its design-specific working groups. In 2017, the creation of a design-specific working group dedicated to the Chinese HPR1000 design was approved. It will become the 6th MDEP design-specific working group together with the EPR, AP1000, APR1400, ABWR and VVER working groups. Some issue-specific working groups also support the programme by addressing cross-cutting issues. One working group, for example, is dedicated to vendor inspection co-operation and another to mechanical codes and standards. The digital instrumentation and controls working group has completed its activities within MDEP; its transfer to the NEA Committee on Nuclear Regulatory Activities (CNRA) is effective as of 1 January 2018. MDEP working groups address a broad spectrum of technical issues and regulatory challenges that can arise during the licensing and commissioning phases of new reactor design, construction and early phase operation. Active, constructive engagement among member regulators has led to a productive year in terms of sharing information on regulatory decisions and identifying lessons learnt. MDEP members are regulators from Canada, China, Finland, France, Hungary, India, Japan, Korea, Russia, South Africa, Sweden, Turkey, the United Arab Emirates, the United Kingdom and the United States. In 2017, the Policy Group (PG) approved the accession of the regulator from Argentina as a 16th MDEP member. The International Atomic Energy Agency is involved in generic MDEP activities to support consistency and co-ordination.

2017 MDEP highlights

The 4th MDEP conference was held on 12-13 September 2017 in London, United Kingdom. It was attended by over 150 participants, representing national regulators, international organisations, standard development organisations and the nuclear industry. It was divided into six thematic sessions. Participants agreed on the need for continued efforts towards greater harmonisation of codes and standards and further dialogue to ensure supply chain quality, including safety culture aspects. Feedback gathered from MDEP stakeholders at the conference will help to define the future direction and structure of MDEP in terms of both design-specific and issue-specific work.

In 2017, the MDEP working groups have been very active in issuing common positions and technical reports on areas such as design comparison (APR1400 and ABWR), probabilistic safety assessments (EPR), regulatory approaches related to severe accident prevention and mitigation (APR1400, VVER), molten core concrete interaction phenomena (APR1400) and strainer performance (APR1400), as well as regulatory approaches and oversight practices related to reactor pressure vessel and primary components (VVER). The VVERWG common position addressing Fukushima-related issues was also published. Finally, the digital instrumentation and controls working group published its 13th and last common position on spurious actuation, before the group is transferred to the CNRA.

Co-operation on commissioning activities is part of the programme of work for all design-specific working groups. The EPR and AP1000 working groups are particularly active in this area, as they are overseeing 11 new reactor constructions worldwide. For the first time, a first plant only test (FPOT) on the vibration analysis of reactor pressure vessel internals was conducted at the EPR Taishan 1 plant in China. This test provided the opportunity to implement the MDEP common position on FPOT published in 2016. Part of the FPOT was witnessed by regulators from United Kingdom, France and Finland, and by the licensees of the same countries. Based on their observations, the regulators did not identify any fundamental reasons for not crediting the Taishan 1 FPOT results for other reactors.

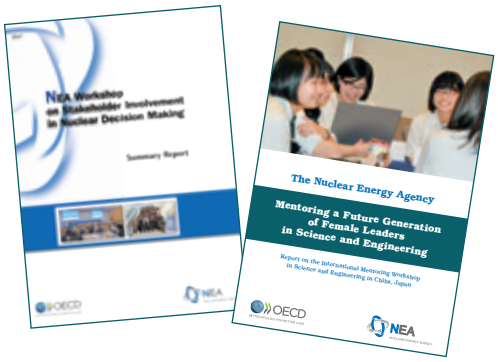
For more information on the MDEP structure, and to consult publicly available technical reports and common position papers, see www.oecd-nea.org/mdep.

Barakah Nuclear Energy Plant, United Arab Emirates, May 2017.

Provided by Emirates Nuclear Energy Corporation – ENEC

Human Aspects of Nuclear Safety

The goal of the NEA in this sector is to assist member countries in their efforts to enhance the focus on human aspects impacting nuclear safety that have been highlighted as critical elements leading to all past nuclear power plant accidents. This sector also includes issues associated with effective public communication and stakeholder engagement regarding nuclear safety, waste management and related issues. The staff work closely with all NEA committees and relevant expert groups in this area, most prevalently the Committee on Nuclear Regulatory Activities (CNRA), the Committee on the Safety of Nuclear Installations (CSNI) and the Radioactive Waste Management Committee (RWMC).



Highlights

- The Committee on Nuclear Regulatory Activities (CNRA) approved the creation of a Working Group on Safety Culture (WGSC) to serve as a senior-level regulatory forum, with a focus on improving the regulator's safety culture. The working group held its first meeting in November 2017.
- The NEA Working Group on Human and Organisational Factors (WGHOF) modified its task on HOF lessons learnt from implementation of post-Fukushima actions to increase collaboration with the International Atomic Energy Agency (IAEA).
- The NEA Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC) completed its comprehensive report on three regional, stakeholder workshops held in France, Japan and the United States.
- Following its annual meeting held in September 2017, the NEA Forum on Stakeholder Confidence held a joint workshop with the Integration Group for the Safety Case (IGSC) to focus on challenges in communicating scientific safety evidence to non-technical stakeholders.
- The "Joshikai for Future Scientists: International Mentoring Workshop in Science and Engineering" was held in Chiba, Japan, where distinguished female mentors provided advice to high school girls from across Japan on entering science and engineering fields.
- The NEA finalised the preparations for a first-of-a-kind country-specific safety culture forum to examine the national context in Sweden in early 2018.

Safety culture of the regulatory body

The Working Group on Safety Culture (WGSC) aims to facilitate an open exchange of information and experiences among regulators. The primary goal is to improve regulators' safety cultures, to address influences and factors affecting licensees' safety cultures and the wider interconnected system, and to consider the related implications on regulatory effectiveness.

During the first meeting of the WGSC held in November 2017, members shared the current status of their safety culture programmes. Two main themes emerged from the discussions. The first revolved around the need for reflection and assessment of the regulatory body, with the objective of providing member countries with comprehensive and practical guidance on ways in which regulators can be more self-aware. The second focused on building safety culture competence, with the objective of developing and promoting a healthy safety culture through guidance on good practices. The working group will continue to develop its programme of work, focusing on the goal of providing practical tools and guidance to regulatory bodies.

The 2016 NEA "green booklet", *The Safety Culture of an Effective Nuclear Regulatory Body,* demonstrates that "Leaders significantly affect an organisation's safety culture through the priorities they establish, the behaviours and values they model, the reward systems they administer, the trust they create, and the context and expectations they establish for interpersonal relationships, communication and accountability." In line with this common understanding concerning the importance of leadership in safety culture, the Committee on Nuclear Regulatory Activities (CNRA) held a special topic discussion at its 38th meeting in December on leadership and safety culture. The purpose was to share lessons learnt and discuss leadership and safety culture insights regarding specific events from the point of view of regulators and nuclear operators. A key observation that emerged from the discussions was that leadership oversight

The NEA Workshop on Stakeholder Involvement in Nuclear Decision Making on 17-19 January 2017, in Paris, France.

on safety culture presents a particular challenge for regulatory bodies. The roles, the responsibilities and the boundaries of the regulator in relation to adequate safety culture leadership vis-à-vis operators are not always easily defined. The NEA will continue to support its member countries in this area through the work of the WGSC.

Human and organisational factors

The NEA Working Group on Human and Organisational Factors (WGHOF) focuses on understanding the impact of human and organisational factors (HOF) on safety in the nuclear industry to support the continued safety performance of nuclear installations and improve the effectiveness of regulatory practices in member countries.

In a phased approach, the group has started to collect information from nuclear regulatory organisations regarding actions that have been taken in their countries since the accident at Fukushima Daiichi in an effort to improve mitigation capabilities for extreme external events and severe accidents. The group is also examining specific human and organisational factors that may have been addressed through these actions. The objective of this task is to share implementation lessons learnt so that they can be used to facilitate and enhance efforts going forward.

In the area of human factors engineering (HFE), a consensus report on "Human Factors Validation of Nuclear Power Plant Control Room Designs and Modifications" was issued on the workshop held in the United States in conjunction with the Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies (NPIC & HMIT) meetings.

Human performance plays a key role in 60% to 80% of events in high reliability industries, including nuclear activities. Research and experience has shown that the use of best practices and techniques to prevent human error does not produce lasting changes, and that a more holistic view of human performance contributes to strengthening factors that promote desirable performance. With the overall goal of increasing the general understanding of human and organisational factors and demonstrating the advantages of addressing such concepts within a systemic approach to safety, the WGHOF is working on a new task concerning human and organisational performance. The task objectives are to create a shared understanding of commonly used concepts in this area, to develop a model that visualises the dynamic relationships and interactions between human, technical and organisational factors, and to provide practical guidance on the application of the model.

In March, a joint CNRA Working Group on the Regulation of New Reactors (WGRNR) and WGHOF workshop was held in collaboration with the Office for Nuclear Regulation in the United Kingdom on the topic of regulatory oversight of new licensee organisational capability. The 12 break-out sessions generated many tangible outcomes, from commendable practices to suggestions for future work, all of which will be shared in a CNRA report. Future work identified in the area of human and organisational factors includes the provision of guidance on building and assessing organisational capabilities, and more specifically on project management guidance with a focus on safety culture; decision making; competency building; and supply chain oversight throughout the various life cycle stages of a new build project.

Given that many countries are facing the early or unplanned phase out of nuclear power plants, the CSNI also approved a new WGHOF task to consider organisational capabilities for decommissioning. With input from the Working Party on Decommissioning and Dismantling (WPDD), several challenges related to human and organisational factors during decommissioning have been identified, namely staffing issues, adaptation capabilities, organisational changes for transitioning, integrated management systems, safety culture, oversight and governance. These challenges will be further explored by the WGHOF to provide proactive safety measures and guidance that can support both operators and regulators.

In a collaborative effort, the WGHOF is working with the NEA Working Group on Risk Assessment (WGRISK) on human reliability assessments in external events so as to disseminate good practices for qualitative analysis, modelling and the quantification of operator actions in external events, as well as probabilistic safety assessments (PSAs).

Public communication and stakeholder involvement

In January 2017, the NEA held the first NEA Workshop on Stakeholder Involvement in Nuclear Decision Making. Over 130 experts from 26 countries came together to discuss international best practices and concluded that stakeholder support and involvement are essential to achieving accepted and sustainable decisions for nearly all aspects of nuclear energy.

The International Mentoring Workshop in Science and Engineering on 25-26 July, in Chiba, Japan.

Opening remarks were delivered by the OECD Secretary-General, Mr Angel Gurría, the NEA Director-General, Mr William D. Magwood, IV and United States Commissioner, Mr Stephen G. Burns from the Nuclear Regulatory Commission. An additional 37 presentations were made by experts on legal frameworks, nuclear regulation, radiological protection, radioactive waste management, the construction of new nuclear facilities, the extension of operations at existing facilities, stakeholder involvement in nuclear energy and other sectors.

In addition to sharing experiences and best practices, participants debated questions such as whom among members of the public and other stakeholders should be informed and how science should be used to address concerns regarding the choices to be made, as well as the role that social media can play in engaging stakeholders. The workshop concluded that there is no one-size-fits-all approach. A stakeholder involvement process must be adapted to the country-specific context, and organisations need to invest time to build trust, engage and debate with stakeholders. For more detailed information on this workshop, the *NEA Workshop on Stakeholder Involvement in Nuclear Decision Making Summary Report* is available free on the NEA website.

The NEA Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC) focuses on exchanging information, methods and experiences in this area. In 2017, the group produced a comprehensive report on its findings from three regional workshops held in France, the United States and Japan. These workshops provided a platform for stakeholder exchange with nuclear regulatory organisation communicators. Participants included non-profit and environmental organisations, and members of the media. The report highlights commonalities within the various regions and differences in approaches to public communication on nuclear regulatory matters. Recognising that social media has become a major source of information for the general public, the group is now focusing its efforts on how regulatory authorities are leveraging the various platforms to inform and engage with stakeholders. Risk communication is another area of focus for the group, with the goal of providing regulatory authorities with concrete practices and tools to increase effectiveness in disseminating complex technical and regulatory information to stakeholders.

The 1st meeting of the NEA Forum on Stakeholder Confidence (FSC) was held on 12-14 September 2017. Members expressed continued interest in having national workshops streamlined to focus on interactions between international experts in the area of radioactive waste management and stakeholders in member countries. Intergenerational outreach also continued to be a focus of the forum, with in-depth presentations on this topic from Belgium, Canada and Switzerland. The roles and responsibilities of regulators, policy makers and implementers was shown to heavily influence the kind of interactions each organisation has with youth. Various educational institutions may also have a role to play in engaging future generations in radioactive waste management.

The FSC produces informative flyers on a regular basis, providing highlights and guidance to members and to interested groups. The FSC has also recognised the importance of using all media, including social media – and more specifically different platforms for intergenerational outreach – so as to engage stakeholders.

International Mentoring Workshop in Science and Engineering

As part of its overall strategy and mission, the NEA is committed to supporting its members in their efforts to secure qualified human resources, nuclear skills capability building and the development of a new generation of nuclear experts. To do so, it is essential to ensure that all young people, including young women, have the opportunity to explore careers in science and technology.

It was in this spirit that the NEA partnered with Japan's National Institutes for Quantum and Radiological Science and Technology (QST) to organise a mentoring workshop on 25-26 July, in Chiba, Japan. The workshop brought together 55 female high school students from across Japan to interact directly with 9 highly accomplished female co-chairs and mentors from Canada, France, Japan, Russia and the United States. Students talked about their future careers in science and engineering, while mentors shared their real–life experiences and provided international perspectives, valuable advice and insights. The NEA is confident that the workshop had a positive impact and is open to holding similar workshops in other countries.

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Radiological Protection

The goal of the NEA in this sector is to assist member countries in the regulation, implementation and further development of the system of radiological protection by identifying and effectively addressing conceptual, scientific, policy, regulatory, operational and societal issues. The staff works closely with the Committee on Radiological Protection and Public Health (CRPPH) and its expert groups in this area.

Highlights

- In May, the NEA held the Workshop on the Management of Non-Nuclear Radioactive Waste, in Legnaro, Italy, bringing together experts from 31 countries to address the management of non-nuclear waste in all its forms.
- The International Radiological Protection School was established and planning began for the first session to be held in August 2018.
- The CRPPH continued to support the International Commission on Radiological Protection (ICRP) Phase 2 Dialogue series in Japan in 2017.
- The NEA Post-Accident Food Management Framework was examined by the FAO/WHO Codex Committee on Contamination in Food (CCCF) in April 2017, and will be considered for mention in the context of Codex Alimentarius in March 2018.
- The CRPPH began a research project on organ dose variability with gender, age and body mass index.
- The NEA participated in the 2017 ConvEx-3 Exercise in the framework of the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE) to test the Joint Radiation Emergency Management Plan (JPLAN) of international organisations. The International Nuclear Emergency Exercise-5 (INEX-5) Workshop on Notification, Communication and Interfaces Related to Catastrophic Events Involving Radiation or Radiological Materials was held in Paris in October 2017.
- Two ALARA[1] symposia, one in Japan and the other in the United States, were held in the context of the Information System on Occupational Exposure (ISOE) programme.
- The flagship publication *Towards an All-Hazards Approach to Emergency Preparedness and Response: Lessons Learnt from Non-Nuclear Events* was prepared for release in early 2018.

Radiological protection consequences of the Fukushima Daiichi accident

The recovery of areas affected by the Fukushima Daiichi accident is advancing. Evacuated areas in the 20-km zone and the zone to the northwest of the reactor site are being decontaminated and reopened for residents to return. People still living in affected areas that were not evacuated are working towards understanding the overall radiological situation and re-establishing their lives and social-economic frameworks. The return of evacuees remains a challenge. As shown by the continuing ICRP Dialogue meetings, organised primarily by local Japanese organisations, individuals remain concerned for their children, as well as for their jobs and livelihoods. The social structure of affected villages is slowly being rebuilt in many places, but significant numbers of those who left have not yet returned, and they may never do so.

Efforts are underway to revitalise society and the economy in affected areas of the Fukushima prefecture. Local Japanese NGOs, such as Ethos in Fukushima, are working to provide a venue for people to share their stories and concerns, in order to learn from each other, rebuild community and come to terms with their situation. Seven years after the accident, radiological concerns seem to be less prominent, perhaps because of the use of individual dosimeters (e.g. the locally-designed and built "D-Shuttle"). The issues of greatest concern today appear to be infrastructure issues (e.g. hospitals, stores, schools), jobs, and the social structure.

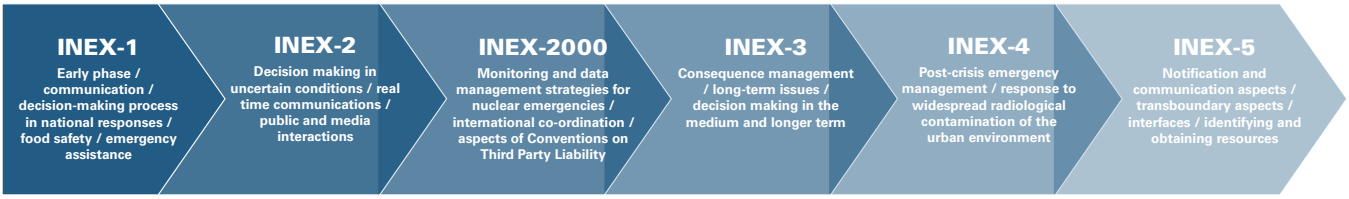
NEA staff participated in two ICRP Phase 2 Dialogue meetings during 2017. The ICRP dialogue series with Japanese stakeholders has demonstrated that people who stayed in affected territories, or returned to these territories, have developed a positive attitude towards the future, accepting that post-accident normality has become *the* normality.

1. ALARA = as low as reasonably achievable.

Supporting future RP leaders

The broad concerns of regulatory and industrial organisations regarding their capacity to hire qualified RP experts in the coming five to ten years was an instrumental factor in the NEA decision to establish the training programme entitled the International Radiological Protection School (IRPS).

A wide variety of guidance and standards documents are available. The technical facts are provided in these documents but how the different elements have evolved, and the full body of understanding that they reflect, are not well documented. Understanding the "spirit" of the RP system is an integral component of its effective application. In order to appropriately apply the RP system to existing and



emerging situations, such aspects – the nuances, history and between-the-line meanings – need to be fully understood by tomorrow's leaders in order to progress in the radiological protection field.

Hosted by the Centre for Radiation Protection Research (CRPR) of Stockholm University, and with the support of the Swedish Radiation Safety Authority (SSM), the first programme of the IRPS will take place from 20 to 24 August 2018.

Legacy management

Numerous countries with nuclear energy and related programmes continue to face issues in relation to legacy sites and installations – whether the result of accidents or neglect – that must be managed in an open and transparent manner. Because different approaches and standards may be applied in different countries, it is important to provide practical guidance on the regulation of radiological protection in such situations.

Little or no guidance has been prepared at the international level to address the application of international recommendations and standards on the disparate aspects of RP in the context of legacy site management. Practical guidance is therefore being considered in the context of NEA work on the following useful elements:

- applying recommendations from existing and planned exposure scenarios already in application on the same site, and establishing specific criteria for the management of remediation activities, including dose limits, reference levels and standards related to waste management;
- developing communication strategies for outreach (e.g. to potentially affected populations living in the vicinity of legacy sites);
- identifying the radiological protection methods needed to develop coherent and optimised approaches for regulatory oversight and site management.

The NEA is addressing these issues in a co-ordinated manner, ensuring co-operation between the CRPPH, the RWMC and other international organisations such as the IAEA and the EC. The overall goal of this work is to develop a practical and harmonised approach for the regulation of nuclear and radiological legacy sites.

Nuclear emergency management

Since the Fukushima Daiichi accident, actions have been taken at national and international levels concerning emergency response and recovery plans. The International Nuclear Emergency Exercise-5 (INEX-5) was designed to test new actions, measures and approaches developed at the regional and international levels to enhance communication and information exchange, as well as cross-border co-ordination.

The co-ordination of national responses is an important factor when accidents directly affect only one country or when they affect several countries in a region. The NEA has thereby encouraged INEX-5 participating countries to play together in regional exercises, so as to investigate how countries can improve the actions listed above.

INEX-5 was conducted from September 2015 to June 2016, with the participation of 22 countries. Three groups of countries, all from Europe, opted to play regionally. The post-INEX-5 evaluation in 2017 included an INEX-5 topical session held in Paris in January 2017, convened with the objective of allowing participants to share their national and regional INEX-5 experiences, compare approaches and analyse the implications of decision making on notification strategies, on public information and communication, and on national and international support. An International Workshop on INEX-5 was then held in Paris in October 2017. In addition to providing a valuable forum for discussion among participants, the workshop concluded with a set of key issues and related suggestions that participants felt the NEA could undertake. These issues included communication and information sharing with other countries and international partners, maintaining a particular focus on real time information sharing, improving cross-border and international co-ordination on protective measures, and elaborating new approaches to exercising in the medium and long-term aspects of a nuclear accident. Another key focus of the workshop was on the need to consider mental health impacts on populations when implementing protective measures, as well as the need to link technical experts more closely with decision makers at all levels.

Lessons learnt from non-nuclear events

Experts in the management of disasters from different fields and organisations other than nuclear energy contributed in 2017 to an NEA flagship publication, *Towards an All-Hazards Approach to Emergency Preparedness and Response: Lessons Learnt from Non-Nuclear Events*. The report confirms similarities in emergency preparedness and response (EPR) across sectors, identifies lessons learnt and good practices for the benefit of the international community, and demonstrates the value of an all-hazards approach. This cross-cutting report, released in early 2018, brought together experts from the OECD Working Group on Chemical Accidents, the High Level Risk Forum of the OECD Public Governance and Territorial Development Directorate and the European Commission's Joint Research Centre (EC-JRC). The report can be consulted online at www.oecd-nea.org/rp/pubs/2018/7308-all-hazards-epr.pdf.

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Joint Project

The Information System on Occupational Exposure

Since its creation in 1992, the Information System on Occupational Exposure (ISOE), sponsored jointly by the NEA and the IAEA, has been facilitating the exchange of data, analysis, experience and lessons learnt in occupational radiological protection (RP) at nuclear power plants worldwide. It maintains the world's largest occupational exposure database and a network of utility and regulatory authority RP experts.

As of 31 December 2017, the ISOE programme includes 76 utilities and 28 regulatory authorities from a total of 31 participating countries. The ISOE operates in a decentralised manner. Decisions and overall direction are provided by the ISOE Management Board, composed of representatives from utilities and regulatory authorities from all participating countries. The ISOE Bureau, elected by the Management Board, guides ISOE and Secretariat work between Management Board meetings. Both are supported by the joint NEA/IAEA Secretariat. Four ISOE Technical Centres (Asia, Europe, the IAEA and North America) serve the programme's day-to-day technical operations and are contact points for the transfer of information from and to participants. A national co-ordinator in each country provides a link between ISOE participants and the ISOE programme. Specialised working groups, mandated by the Management Board, are created on an as-needed basis to support the goals of the ISOE on specific topics. There are currently two active working groups: the Working Group on Data Analysis (WGDA) and the Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM). Both groups operate under their respective terms of reference (2016-2019).

The ISOE occupational exposure database contains information on occupational exposure information for 377 operating units and 72 units in cold shutdown or at some stage of decommissioning in 32 countries, thus covering more than 80% of the world's operating commercial power reactors. The ISOE database, publications, benchmarking visits and annual symposia, along with the ISOE Network website, facilitate the exchange among participants of operational experience and lessons learnt in the optimisation of occupational radiological protection.

In 2017, the ISOE programme continued to concentrate on the exchange of data, analysis, good practices and experience in the area of occupational exposure reduction at nuclear power plants, and on improving the quality of its occupational exposure database.

Key outcomes of work during 2017 include the collection and integration of 2016 data into the ISOE database and the publication of ISOE country reports for 2016, the publication of a new ISOE brochure, the organisation of four benchmarking visits and the improvement of the ISOE data analysis module (MADRAS) to facilitate the exchange of information and experience on the optimisation of occupational radiological protection in the operation and decommissioning of nuclear power plants.

The ISOE programme organised an International ALARA Symposium in Fort Lauderdale (USA) in January 2017 and a regional Asian Symposium in Japan in October 2017. These symposia serve as important venues for utilities to meet in an international setting.

Radioactive Waste Management

The goal of the NEA in this sector is to assist member countries in the development of safe, sustainable and broadly acceptable strategies for the long-term management of all types of radioactive waste and spent fuel, and to provide governments and other relevant stakeholders with authoritative, reliable information on the political, strategic and regulatory aspects of decommissioning nuclear installations. The staff works closely with the Radioactive Waste Management Committee (RWMC) and its expert groups in this area.

Highlights

- In June 2017, the NEA hosted the Technical Meeting of the Joint European Commission, the International Atomic Energy Agency (IAEA) and the NEA Working Group on Spent Fuel and Radioactive Waste for the Status and Trends Project. A methodology for presenting national radioactive waste inventory was proposed by the NEA at the meeting and was accepted by the group.
- In 2017, the NEA started the process of establishing a new standing technical committee – the Committee on Decommissioning and Legacy Management (CDLM) – to increase the visibility of such activities within the NEA, as well as the level of expertise so as to improve support provided to member countries in these areas.
- A number of NEA reports were published in 2017, including *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities; Communication on the Safety Case for a Deep Geological Repository*; *National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste*; and *Recycling and Reuse of Materials Arising from the Decommissioning of Nuclear Facilities.*

The International Workshop on the Decommissioning of Nuclear Power Plants, 30 June 2017, Tokyo, Japan.

Knowledge management activities

The Preservation of Records, Knowledge and Memory (RK&M) across Generations initiative held two meetings in 2017 to review work in progress and outstanding work. The RK&M approved the release of the RK&M Key Information File (KIF) concept report and agreed to document all key findings in two additional reports: one on the set of essential records for deep geological repositories (DGRs) and a final project report documenting the work of the group. Phase II of the RK&M initiative will come to an end in April 2018.

Regulators' Forum

The RWMC Regulators' Forum (RWMC-RF) started a new initiative called "Competency Management of Regulators", which addresses the potential loss of current regulatory knowledge and expertise relating to radioactive waste and decommissioning. The RWMC-RF developed a questionnaire on this issue for its members. The results will be analysed by the NEA and further discussed at the plenary session in 2018. The RWMC-RF also started a joint initiative with the Working Party on Decommissioning and Dismantling (WPDD) on the subject of regulation and decommissioning. A joint RF/WPDD workshop is scheduled to take place in June 2018.

The safety case for geological disposal

In 2017, the NEA Integration Group for the Safety Case (IGSC) began the Crystalline Club to focus on the characterisation of crystalline rocks for DGRs. The IGSC also continued with enhancements to safety cases for radioactive waste disposal. The Clay and Salt Clubs strengthened the scientific evidence in safety cases by introducing new knowledge on the characteristics and properties of clay and salt rocks for hosting DGRs.

The Salt Club continued with its scientific work, for example on the consolidation of crushed salt and on the thermodynamic database. The Clay Club continued work on the joint initiative with the University of Bern, Switzerland, called the CLAYWAT Project, examining the properties of pore water in clay and shale.

The NEA Expert Group on Operational Safety (EGOS) continued to work on fire risk management in underground facilities, transportation and emplacement technologies, waste acceptance criteria and operational hazard databases.

The IGSC discussed the theme of "Criticality Management and Safeguards in DGRs" during its 2017 annual topical discussion, noting the importance of designs to prevent criticality in DGRs and systematic approaches for safeguards. The IGSC will organise a Safety Case Symposium in October 2018 in Rotterdam, the Netherlands to reveal the latest progress of safety case development since the last 2013 Symposium.

Radioactive Waste Repository Metadata Management (RepMet)

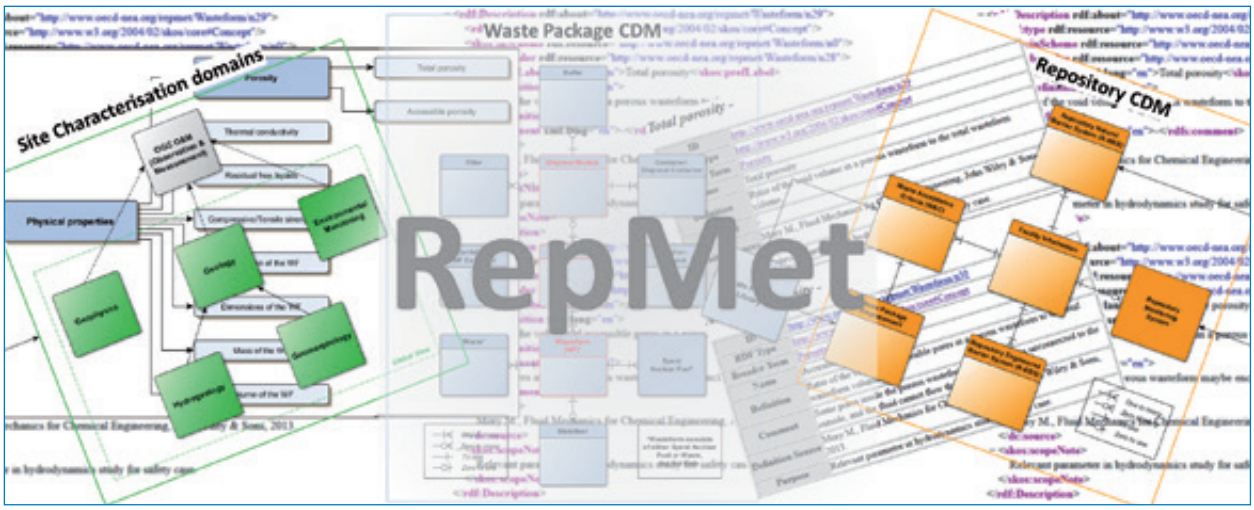
RepMet is an IGSC initiative that aims to promote a better understanding of a key aspect of data management: the identification and administration of metadata to support national programmes in managing their radioactive waste repository data in a way that is both harmonised internationally and suitable for long-term management and use.

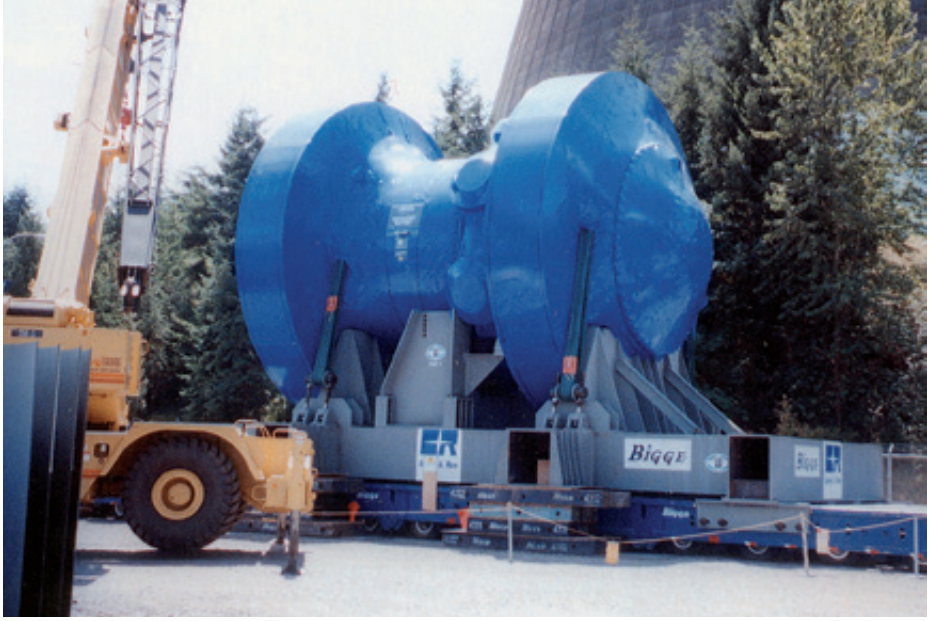
The RepMet group is developing the conceptual design for data libraries that include and support radioactive waste repository metadata. For the past four years, the initiative has been examining the use of metadata in data and information management in the context of national radioactive waste repository programmes. In 2017, the focus was on finalising libraries related to waste packages ready for disposal. With the group holding its last meeting in October, participating members are now completing i) a high-level report illustrating the importance of metadata implementation in the radioactive waste management (RWM) field, ii) three technical reports providing the conceptual design for databases on RWM relevant topics, and iii) a guide book on tools and techniques adopted for the conceptual design of such databases.

Decommissioning

The 18th annual meeting of the NEA Working Party on Decommissioning and Dismantling (WPDD) was held in October in Ottawa, Canada. Hosted by the Canadian Nuclear Safety Committee (CNSC) in co-operation with Natural Resources Canada (NRCan), the meeting was attended by more than 50 delegates from 15 NEA member countries and 2 international organisations. Experiences and challenges in understanding and incorporating social factors into the decommissioning decision-making process were addressed at the topical session called "Decommissioning and Society – Social Aspects of Decommissioning". The meeting also included a special session on the "decommissioning scene in Canada" and ended with a technical tour of Chalk River Laboratories.

In February, the Workshop on Current and Emerging Methods for Optimising Safety and Efficiency in Nuclear Decommissioning" was jointly organised by the Halden Reactor Project, the NEA and the IAEA in Sarpsborg, Norway. More than 110 participants from 26 countries and 3 international organisations attended the workshop, which assessed ongoing and future R&D needs. Participants discussed opportunities for collaboration at the international level in order to improve and optimise decommissioning implementation.





The reactor pressure vessel of a nuclear power plant undergoing decommissioning.

Nuclear Regulatory Commission, United States

The WPDD Decommissioning Cost Estimation Group (DCEG) published a joint IAEA/NEA report entitled *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities*. The group then launched a new project on benchmarking in the context of NPP decommissioning costs.

The WPDD Task Group on Radiological Characterisation and Decommissioning (TGRCD) completed its work, publishing a report on *Radiological Characterisation from a Waste and Materials End-State Perspective – Practices and Experience*. The report identifies relevant good practices and provides practical advice, covering all stages of the characterisation process.

The WPDD Task Group on Preparing for Decommissioning during Operation and after Final Shutdown (TGPFD) continued to analyse strategic approaches, issues and risks in preparing and planning for decommissioning, with particular focus on the last years of operation and the post-operational phase. A report summarising observations and recommendations relating to the development and optimisation of strategies, and preparation plans for the decommissioning of nuclear facilities, is expected to be published in early 2018.

The WPDD Task Group on Optimising Management of Low-level Radioactive Materials and Waste from Decommissioning (TGOM) continued to examine strategies and approaches that can enhance national approaches to the management of slightly radioactive materials from decommissioning. The group will study the different measures and various interrelations among drivers, identifying and presenting in a status report the mechanisms behind those drivers, along with constraints in the practical implementation of optimisation.

Radioactive waste inventorying and reporting

In 2017, the RWMC Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) completed its methodology for the universal radioactive waste and spent fuel inventory presenting scheme, and it began testing the methodology. The completed methodology is able to address the main requirements that potential implementers may be subject to, including those outlined in the Joint Convention, Euratom Direction 2011/70 and the Status and Trends Joint Project. All spent fuel and radioactive materials inventoried as waste can be presented in this scheme, in a common format, according to the waste disposal strategy established in the given country. In June 2017, the Status and Trends Joint Project, co-sponsored by the IAEA, EC and NEA, accepted the methodology and included the presentation scheme in the template for a national profile. The NEA report with the completed methodology was published in September 2017. A workshop is being planned for February 2018 to discuss the implementation of the methodology.

Fukushima waste management and decommissioning

The Expert Group on Fukushima Waste Management and Decommissioning R&D (EGFWMD) completed its work in 2016, and the outcomes have been reflected in Japanese programmes on Fukushima Daiichi decommissioning. In 2017, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) requested that a new expert group be created to focus on characterisation and categorisation of large amounts of unknown waste. The proposal was supported by members of the RWMC, and therefore its mandate and future scope of work will be discussed at the next committee meeting.

The Thermochemical Database Project

The Thermochemical Database (TDB) Project was initiated in 1984 as a joint activity of the NEA Databank and the RWMC. The project fulfils the need for a high-quality database for modelling purposes in the safety analyses of radioactive waste repositories. Implementation of the new software designed and completed in 2016 is still ongoing. The TDB project has produced 13 volumes of internationally recognised and quality-assured thermodynamic data. Work is currently in progress to complete four reviews. For further information on the TDB project and for more details on activities in 2017, see page 57.

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Joint Project

The Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects

The NEA Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD) is a joint undertaking of a limited number of organisations actively executing or planning the decommissioning of nuclear facilities. The objective of the CPD Programme, launched in 1985 and operating under Article 5 of the NEA Statute, is to exchange and share information from operational experience in decommissioning nuclear installations useful for current and future projects. Initially consisting of 10 decommissioning projects in 8 countries, the programme has since grown to the present 71 projects (41 reactors and 30 fuel cycle facilities) in 14 NEA member countries, 1 non-member economy and the European Commission (EC). The current agreement came into force on 1 January 2014 and will expire by 31 December 2018, and describes the basis of the programme. A new Agreement for the period 2019-2023 is currently under preparation.

Information exchange also ensures that best international practice is made widely available and encourages the application of safe, environmentally sound and cost effective methods in all decommissioning projects. Biannual meetings of the Technical Advisory Group (TAG) are held, during which the site of one of the participating projects is visited, and positive and less positive examples of decommissioning experience are openly exchanged for the benefit of all. In 2017, a site visit was held in Cherbourg, France.

Although part of the information exchanged within the CPD is confidential and restricted to programme participants, experience of general interest gained under the programme's auspices is released for broader use. In this context, the CPD Task Group on Recycling and Reuse of Materials (TGRRM) continued to review the various national and international approaches to the management of low-level radioactive waste from decommissioning. In September 2017, the TGRRM published a report, which concludes that many countries are developing recycling of low-level waste because of i) unavailable disposal facilities; and ii) a lack of cost information and comparative data between recycling and the disposal of low-level waste. The report further notes that stakeholders' lack of acceptance of recycling and reuse of low-level decommissioning materials acts as a barrier to enhancing the recycling and reuse of decommissioning materials.

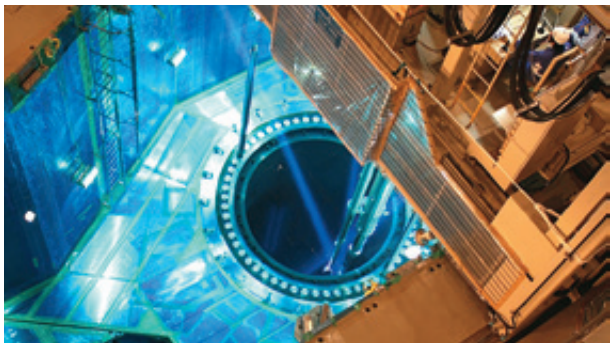
Increasing decommissioning needs worldwide have given rise to other challenges such as the dismantling and decontamination of highly contaminated tanks. To address this issue, in April 2017, the CPD initiated a new task group in order to exchange and share experiences gained among members on the dismantling of highly contaminated tanks, as well to evaluate lessons learnt and good practices.

To make use of decommissioning knowledge and experience accumulated within the CPD, a TAG Knowledge Base Database that allows CPD members to easily access the CPD reactor project and fuel facility information has been created on the NEA website, after being approved by the CPD in 2017.

Decommissioning.
Canadian Nuclear Laboratories (CNL)

Nuclear Science

The goal of the NEA in this sector is to help member countries identify, collate, develop and disseminate the basic scientific and technical knowledge required to ensure the safe, reliable and economic operation of current and next generation nuclear systems. The staff works closely with the Nuclear Science Committee (NSC) and its expert groups in this area.



Mixed oxide fuel (MOX).
Shikoku Electric Power Co, Inc., Kagawa, Japan

Highlights

- The joint project on the Thermodynamic Characterisation of Fuel Debris and Fission Products Based on Scenario Analysis of Severe Accident Progression at the Fukushima Daiichi Nuclear Power Station (TCOFF) held its kick-off meeting in July 2017.
- Three new expert groups were created within the Working Party on International Nuclear Data Evaluation Co-operation (WPEC) to cover a broad range of issues related to nuclear data validation.
- The new version of the International Database of Spent Fuel Isotopic Composition Data (SFCOMPO-2.0) was released in June 2017.
- The new International Experimental Thermal-Hydraulic Systems Database (TIETHYS) was released in July 2017 and is currently undergoing user testing.
- The joint project on the Thermodynamics of Advanced Fuel International Database (TAF-ID), launched in 2013, achieved substantial results in 2017 and was approaching completion of phase 1 in December 2017.
- A workshop on advanced modelling of nuclear fuels for safety and performance enhancement was jointly organised by the NSC and the NEA Committee on the Safety of Nuclear Installations (CSNI) in March 2017.
- A workshop on Enhancing Experimental Support for Advancements in Fuels and Materials was organised to be held in January 2018.

Reactor physics

NEA work in relation to reactor physics has been mainly devoted to the verification and validation of codes to predict both existing and advanced reactor systems. Existing reactor systems will benefit from the recent cross-code comparison of MOX fuel depletion calculations, while advanced reactor systems can take advantage of a molten salt reactivity worth benchmark, as published in the 2017 version of the International Handbook of Evaluated Reactor Physics Benchmark Experiments (IRPhE) Handbook. To complement the extensive work completed in single physics, activities have been increasingly extended to coupled multi-physics computations and the capability of coupled multi-physics computational methods to model more complex scenarios in order to meet the needs of designers, operators and safety regulators.

The Expert Group on Multi-physics Experimental Data, Benchmarks and Validation (EGMPEBV) has been tasked with addressing the above issues. Throughout 2017, the group finalised a comprehensive series of summary reports on the current status and expected needs for validation of multi-physics modelling and simulation tools. It also produced a phenomena assessment and ranking chart (PARC) to survey opinions on the adequacy of validation data for pellet-clad interaction (PCI) simulation. The second of its task forces is engaged in reviewing validation practices for multi-physics modelling and simulation tools, with a focus on challenges that are of the highest importance to both research and industry.

The third task force is identifying applications suitable for experimental benchmark studies. Specifications have been prepared for two such cases: the kick-off meetings for the Rostov-2 plant data benchmark and the Studsvik R2 pellet-clad mechanical interaction (PCMI) benchmark, which will take place as part of the combined "Uncertainty Analysis in Modelling (UAM) Workshop", in conjunction with the "Best Estimate Plus Uncertainty (BEPU) Conference" to be held in May 2018 in Lucca, Italy.

TRACY facility.

Provided by Kotaro Tonoike, JAEA, Japan

Fuel cycle physics and chemistry

Activities in this area cover all aspects of the fuel cycle from the front end to the back end, and deal with issues arising from various existing and advanced systems, including fuel cycle scenarios, innovative fuels and materials, separation chemistry, and waste disposal and coolant technologies. To contribute to the sustainable development of nuclear energy, experts of the Working Party on Scientific Issues of the Fuel Cycle (WPFC) are currently focusing their work on improving nuclear fuel performance, developing materials, fuels and fuel cycles for new, innovative nuclear systems, and on managing spent fuel through reprocessing and recycling.

With the renewal of mandates, the working party and its related expert groups have consolidated a substantial programme of work, mainly focusing on advanced fuel cycles and cross-cutting activities. Throughout 2017, expert groups finalised a number of reports.

The proceedings of several workshops held in 2016 were issued in 2017, including for the Information Exchange Meeting on Partitioning and Transmutation (IEMPT) and Technology and Components of the Accelerator-driven Systems (TCADS). "The Effects of the Uncertainty of Input Parameters on Nuclear Fuel Cycle Scenario Studies" prepared by the Expert Group on Advanced Fuel Cycle Scenarios (EGAFCS) was issued in March 2017. Several reports have been finalised and submitted for publication: the forthcoming *State-of-the-Art Report on the Progress of Nuclear Fuel Cycle Chemistry*; the report on Phase 2 of the Task Force on Benchmarking of Thermal-Hydraulic Loop Models for Lead Alloy-Cooled Advanced Nuclear Energy Systems (LACANES); and reports on user facilities for materials testing and R&D facilities for spent fuel reprocessing. Several reports are in their final stages of preparation.

New activities were also initiated on fuel properties for fast reactors in the context of the NEA Expert Group on Innovative Fuels, as well as on an international review of the recycling and reuse of components from spent fuels, and a database of extractants for spent fuel reprocessing in the NEA Expert Group on Fuel Recycling Chemistry (EGFRC).

Nuclear criticality safety

The NEA Working Party on Nuclear Criticality Safety (WPNCS) is responsible for the co-ordination and maintenance of the International Database of Spent Fuel Isotopic Composition Data (SFCOMPO) and the International Criticality Safety Benchmark Evaluation Project (ICSBEP). It is also responsible for the co-ordination of technical activities in the fields of uncertainty quantification for criticality safety assessment, use of Monte-Carlo transport, assay data of spent nuclear fuel and investigations on used nuclear fuel criticality, as well as criticality excursion analyses.

SFCOMPO-2.0, developed and maintained by the NEA in collaboration with the Oak Ridge National Laboratory (ORNL), was released in June 2017. These collaborative efforts have led to the capture and standardisation of experimental data from 750 spent nuclear fuel samples from 44 reactors. Compared to its previous version, the SFCOMPO-2.0 more than triples the amount of available data in the latest version of the database. SFCOMPO-2.0 is now available online and in DVD format from both the NEA and from the Radiation Safety Information Computational Center (RSICC) in the United States.

The new version of the ICSBEP Handbook and its Database for the International Handbook of Evaluated Criticality Safety Benchmark Experiments (DICE) were released in October 2017.

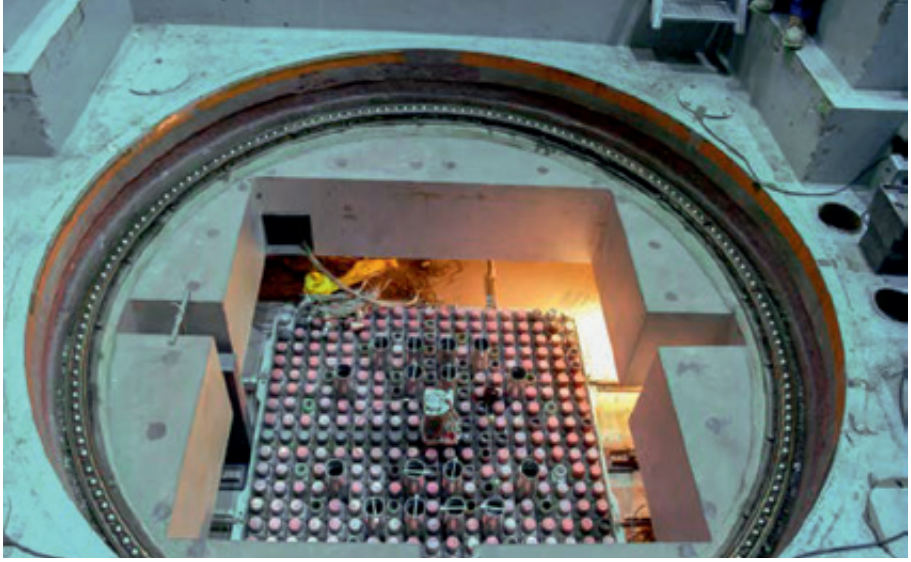
Overall benchmark activities at the NEA continued to examine the rigorous assessment and treatment of uncertainty propagation in relation to criticality safety problems.

Materials science

The NSC has consolidated a substantial programme of work on nuclear fuels and structural nuclear materials, articulated around advanced modelling, advanced materials research, and database creation and maintenance.

In 2017, the NEA Expert Group on Multi-scale Modelling of Fuels, under the auspices of the Working Party on Multi-scale Modelling of Fuels and Structural Materials for Nuclear Systems (WPMM), completed the study on the "Unit Mechanisms of Fission Gas Release: Current Understanding and Future Needs". This study assesses the capability to predict fission product behaviour during reactor operation and to design fuels with improved fission product retention.

In line with growing R&D efforts being devoted to the understanding of fuel behaviour, a new task force on nuclear fuel micromechanical behaviour and its impact on fuel multi-



Transient Reactor Test Facility (TREAT).

Idaho National Laboratory, United States

physics modelling at the macroscopic scale was created in 2017 with the objectives of reviewing current applications of micromechanics modelling for nuclear fuels; identifying limitations, microscale validation data and missing material data; and summarising expected short-term progress in micromechanics modelling in order to address key industrial issues on nuclear fuel behaviour.

The NEA Expert Group on Accident-tolerant Fuels for LWRs (EGATFL) has achieved substantial results and approached completion of its mandate. Its final report will be published in early 2018, and will summarise the fundamental properties and behaviour of fuel and core materials under normal and accident conditions. The report will also characterise the compatibility between advanced fuel and cladding design concepts, and provide an assessment of the technology readiness levels for different fuel and cladding options.

Knowledge management

The NSC establishes and maintains well-structured and highly accessible databases to preserve and evaluate information from criticality safety (ICSBEP), reactor physics (IRPhE), shielding (SINBAD), fuel performance (IFPE) and isotopic composition of spent fuel (SFCOMPO). In addition, the Nuclear Data Sensitivity Tool (NDaST) includes data on both criticality safety (DICE) and reactor physics (IDAT) databases, with access to features of the nuclear data viewing tool, JANIS. This year, the TIETHYS database of thermal-hydraulic facilities has been developed as a search tool, as well as a reference retrieval and preservation platform. The maintenance and updating of these databases and tools are performed in close collaboration with the NEA Data Bank.

The NEA suite of databases and sensitivity tools was well used by the scientific community in 2017, most notably in the context of the NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC). Contributions were also made to the Collaborative International Evaluated Library Organisation (CIELO) pilot project, the Uncertainty Analysis in Modelling (UAM) series (e.g. the sodium-cooled fast reactor [SFR] benchmark), and The Joint Evaluated Fission and Fusion (JEFF) nuclear data evaluation project for nuclear data testing and validation. NEA staff members have been actively engaged in the dissemination of these tools through presentations at major conferences (2017 International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering [ANS M&C 2017], the American Nuclear Society [ANS] 2017 annual meeting and the 4th edition of the International Workshop on Nuclear Data Covariances [CW17]).

Experimental needs

Within the Nuclear Science Committee, in-depth studies of innovated fuels and materials are routinely performed by experts from member countries; these studies provide detailed insight into the technical merits of advanced concepts, and evaluate the experimental data and computational tools underpinning these concepts. Despite significant achievements in this field, few of the advanced concepts studied have been successfully deployed in commercial reactors. The NSC has recognised the need to focus its activities in this area so as to ensure outputs that tightly align with the needs of fuel vendors, utilities, regulators and experimentalists from national and international programmes, including through the NI2050 initiative that is supported by the NEA Nuclear Development Committee. With this aim in mind, the NSC endorsed a workshop organised for January 2018 to assemble the aforementioned stakeholders so as to build a framework interconnecting the needs and requirements of each party. This is seen as a first step towards tackling the problem of the fast deployment of innovative materials that make nuclear power increasingly both safe and economical. To this end, the NEA is taking a broad look into how to better organise the interfaces of the NSC initiative with activities of the CSNI and NI2050, and it will work with a broad range of interested parties in order to collect proposals aimed at optimally co-ordinating experimental activities, with a particular focus on joint experimental projects.

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Joint Projects

The TAF-ID Project

The Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project is supported by ten organisations in seven NEA member countries. It is devoted to establishing a comprehensive, internationally recognised and quality-assured database of phase diagrams and of the thermodynamic properties of advanced nuclear fuels so as to meet specialised requirements for the development of such advanced fuels for a future generation of nuclear reactors. New versions of both the working and public database were released in 2017:

- The working version V8 features new and revised models for the following binary and ternary systems: U-Zr-O, U-Ce-O, Sr-U-O, Ba-Mo-O, Ni-Zr U-O-La, U-O-Gd, Cs-I, UO2-CaO-SiO2, ZrO2-CaO-SiO2 and Mo-U;
- The public version contains ten binary and six ternary systems. It has been updated with new systems (U-Zr-O, Np-U, and Np-Zr) and made available, free of charge, to organisations in NEA member countries.

The second phase of this project is currently under preparation with the objectives of testing the validity of the TAF-ID database by performing thermodynamic measurements on complex fuel compositions and comparing the experimental results to calculations; identifying the origin of the discrepancies between experiments and calculations that emerged within the first phase of TAF-ID; continuing the development of the database by introducing models for missing binary and/or ternary systems; and organising training sessions for users of the TAF-ID database.

The TCOFF Project

The joint project on the Thermodynamic Characterisation of Fuel Debris and Fission Products Based on Scenario Analysis of Severe Accident Progression at Fukushima Daiichi Nuclear Power Station (TCOFF), supported by the Collaborative Laboratories for Advanced Decommissioning Science (CLADS) of the Japan Atomic Energy Agency (JAEA), has been launched as part of NEA post-Fukushima activities within the Nuclear Science Committee (NSC). The kick-off meeting was held back-to-back with the meeting of the CSNI on Fukushima-related projects in Iwaki, Japan in July 2017.

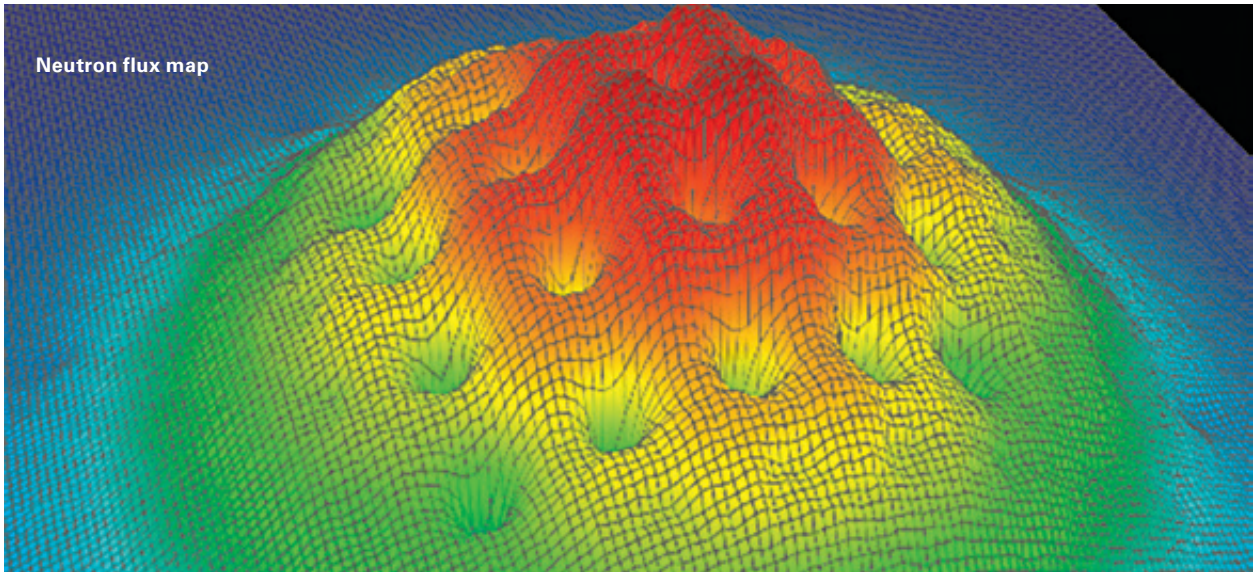
A total of 16 organisations from 9 member countries and the European Commission (EC) participate in the TCOFF Project. The objectives of the project are to improve the quality and the inventory of thermodynamic databases currently being used to model fuel behaviour in the different stages of severe accident progression and to conduct joint thermodynamic evaluations of severe accident progression at the Fukushima site. In the current phase of the project, a benchmark study is being conducted with the aim of comparing the predictive capabilities of thermodynamic databases.

Data Bank

The goal of the NEA in this sector is to serve as the premier international centre of reference for basic nuclear tools, such as computer codes and nuclear data, used for the analysis and prediction of phenomena in the nuclear field; and to provide a direct service to its users by making such tools available on request and by offering the means and methods needed to support their development, application and validation.

Highlights

- Argentina and Romania joined the NEA Data Bank on 1 September and 15 October 2017, respectively.
- Two "Nuclear Data Weeks" were held in 2017, gathering a community of nuclear data experimentalists, evaluators and expert users across diverse nuclear data projects.
- Eleven training courses and workshops were organised in 2017 by the NEA Data Bank Computer Program Service (CPS), the Nuclear Data Services (NDS) and the Thermochemical Database (TDB).
- The JEFF-3.3 nuclear data library was released in December 2017 and is available on the NEA website.
- The TDB project finalised its new electronic database, expected for release in early 2018.


Neutron flux map

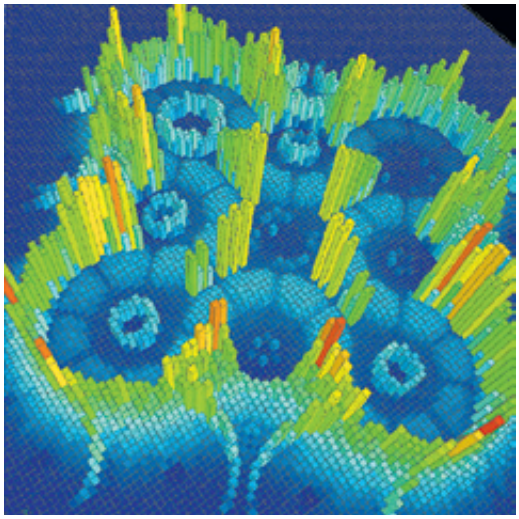
Computer program services

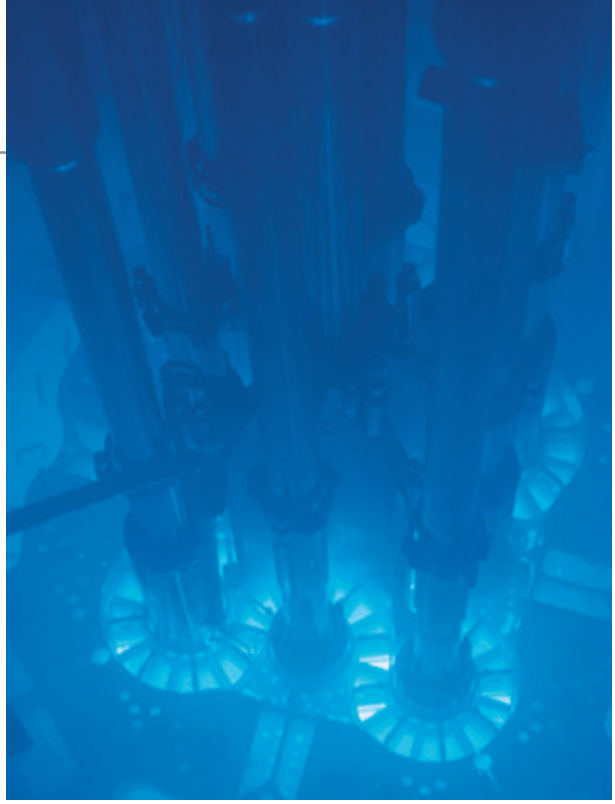
The NEA Data Bank collection contains more than 2 000 computer programs and 350 integral experiments, covering all areas related to reactor design, dynamics, safety and radiation shielding, material behaviour and radioactive waste applications. A total of 12 new or new versions of computer programs and 3 integral experiments were added to the collection in 2017.

More than 1 024 computer programs and 2 581 integral experiment packages were dispatched upon request to Data Bank participating countries in 2017. The current co-operative arrangement between the United States Department of Energy (DOE) and the NEA authorises the NEA Data Bank to also issue user licences and distribute US computer codes to Data Bank participating countries.

A total of 909 officially nominated establishments are using the Computer Program Service in NEA Data Bank participating countries. Detailed information about the material available can be accessed via the NEA website at www.oecd-nea.org/dbprog/.

Advanced Test Reactor Full-Core Model for IRPhE Evaluation – MeshTal Viewer.





The core of the Advanced Test Reactor (ATR).

Courtesy of Idaho National Engineering and Environmental Laboratory (INEEL)

Nuclear data services

The Data Bank maintains large databases containing bibliographic (Computer Index of Nuclear Data [CINDA]), experimental (Experimental Nuclear Reaction Data Retrievals [EXFOR]) and evaluated nuclear data, all of which are made available online. As a member of the international network of nuclear reaction data centres (NRDC) since 1966, the NEA Data Bank is responsible for the compilation, in EXFOR, of neutron and charged particle data arising from experimental programmes in its participating countries. In 2017, this meant processing approximately 300 new entries, following a strict verification procedure. In total, the Data Bank has compiled around 25% of all entries in the current EXFOR database, which is a compilation of worldwide experimental nuclear reaction data.

Since 1981, the NEA Data Bank hosts the Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library project, a collaborative effort among Data Bank participating countries to produce and distribute evaluated nuclear data libraries, mainly for fission and fusion applications. In 2017, JEFF 3.3 was released as a major update for all sub-libraries: neutron, thermal scattering, fission yields, radioactive data, dpa and arc-dpa sub-libraries, with inclusions from the TENDL 2017 library for charged particles and activation files. Further information on JEFF 3.3 is available at www.oecd-nea.org/dbdata/JEFF33/.

As part of its nuclear data services, the Data Bank has developed the Nuclear Data Evaluation Cycle (NDEC) – an automated software platform for the verification, testing, processing and benchmarking of nuclear data files. NDEC has been used to verify process and perform criticality benchmarking for all JEFF 3.3 neutron files, including the four test libraries that led to the 3.3 release. In 2017, the first NEA training course on nuclear data processing was organised, with the now open source code NJOY-2016.

The Data Bank provides support in the development of NEA integral experiments databases. These software tools (e.g. the Database for the International Handbook of Evaluated Criticality Safety Benchmark Experiments [DICE], the International Reactor Physics Handbook Database and Analysis Tool [IDAT], and the Spent Fuel Isotopic Composition Database [SFCOMPO]) provide users with the means to search, visualise and compare results from integral experiments, which can be used for nuclear data validation.

The Data Bank is responsible for developing the Java-based Nuclear Data Information System (JANIS), a leading cross-section visualisation tool. JANIS is designed to facilitate the visualisation, comparison and manipulation of nuclear data. It undergoes yearly revisions to incorporate recent nuclear data releases and user feedback, and to provide new features.

As part of its work in nuclear data, the nuclear data services team works in close collaboration with the NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC), which oversees the high priority request list (HPRL) for nuclear data and the specifications for a new general nuclear database structure (GNDS) format.

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Joint Project

The Thermochemical Database Project

The Thermochemical Database (TDB) Project was initiated in 1984 by the Radioactive Waste Management Committee (RWMC) to fulfil the need for a high-quality database for the purpose of modelling the safety assessments of radioactive waste repositories. The project's current Agreement runs until March 2019. A total of 15 organisations representing 12 countries currently participate in the TDB project.

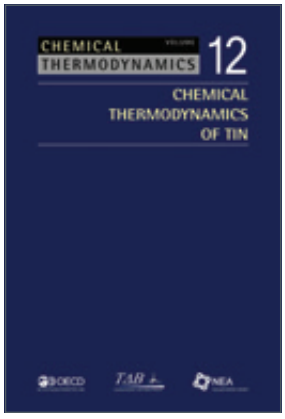
The project has thus far produced 13 volumes of internationally recognised and quality-assured thermodynamic data, and work is currently in progress to complete four reviews:

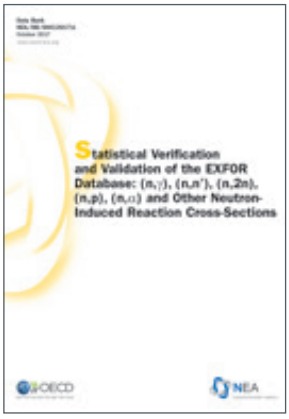
- Chemical thermodynamics of iron – second volume.
- Chemical thermodynamics of molybdenum.
- Chemical thermodynamics of selected ancillary compounds.
- A second thermodynamic data update of uranium, americium, neptunium, plutonium and technetium.

Two state-of-the-art reports are under development, and the publication of both reports is expected in 2019:

- A report on thermodynamic considerations for cement minerals;
- A report on assessing the modelling and experimental approaches of high ionic-strength solutions.

The renewal of the TDB electronic database was completed in August 2017. The project team is now working on importing the thermodynamic data from the old database, and the new tool is expected to be made available to users in mid-2018. A one-day course on thermodynamic data collection and assessment was organised by the NEA and took place in Barcelona, Spain in September 2017. Preparations for Phase 6 are currently underway. TDB-6 will have a new participant (The Central Organisation for Radioactive Waste [COVRA] from the Netherlands). The Agreement is expected to be signed by all participants in 2018.





Legal Affairs

The goal of the NEA in this sector is to help create the sound national and international legal regimes required for the peaceful uses of nuclear energy, including as regards nuclear safety, international trade in nuclear materials and equipment, public engagement, issues of liability and compensation for nuclear damage, and to serve as a leading centre for nuclear law information and education. The staff provides support to the Nuclear Law Committee (NLC) and its working parties in this area.

Highlights

- On 18-20 October 2017, the NLC and the Nuclear Regulatory Authority of the Slovak Republic co-organised the Third International Workshop on the Indemnification of Damage in the Event of a Nuclear Accident, in Bratislava, bringing together more than 170 participants from 24 NEA member countries and 8 non-member countries.
- Two of the three new NLC working parties established in 2016 – the Working Party on Nuclear Liability and Transport (WPNLT) and the Working Party on the Legal Aspects of Nuclear Safety (WPLANS) – held their first and second meetings, respectively.
- One issue of the *Nuclear Law Bulletin* was published, with articles on the licensing of new nuclear reactors, the development of international nuclear law and on nuclear third party liability.
- Professionals and experts from more than 40 countries attended the 17th session of the International School of Nuclear Law (ISNL) from late August to early September; and the 6th session of the International Nuclear Law Essentials (INLE) in February.
- One national report on the regulatory and institutional framework governing nuclear activities in OECD and NEA member countries was updated online in co-operation with the relevant national delegation.

Development and harmonisation of nuclear legislation

Ensuring adequate and equitable compensation for third party damage caused by a nuclear incident continued to attract the highest level of attention among member countries. Those countries that are party to the Paris Convention on Third Party Liability in the Field of Nuclear Energy (the Paris Convention) and the Brussels Convention Supplementary to the Paris Convention (the Brussels Supplementary Convention) continued their efforts to have the 2004 protocols amending those conventions enter into force. The 2004 protocol to amend the Paris Convention has not yet entered into force as a result of a decision by the Council of the European Union (2004/294/EC) requiring that EU member states that are contracting parties to the Paris Convention (with the exception of Denmark and Slovenia), deposit their instruments of ratification of the Protocol simultaneously. The protocol to amend the Brussels Supplementary Convention, on the other hand, requires ratification by all its contracting parties. Italy is the last EU member state to finalise its national legislative process, which will allow the 2004 protocols to enter into force.

At the NLC meeting held in June 2017, presentations on national developments in nuclear law were given by member countries (Canada, Switzerland and the United Kingdom) and non-member countries (China and Lithuania). The International Atomic Energy Agency (IAEA) and the European Commission (EC) reported on matters of special interest under their respective auspices, and the NLC examined several issues regarding the interpretation and implementation of the Paris Convention. Committee members were also updated on the activities of working parties, i.e. the Working Party on Deep Geological Repositories and Nuclear Liability (WPDGR), the WPNLT and the WPLANS. The issue of nuclear liability as applicable to small modular reactors (SMRs) was also addressed, with presentations from the NEA Division of Nuclear Technology Development and Economics, and the French, Russian and US Delegations. Finally, the committee continued to address the implementation of the Aarhus and Espoo Conventions as related to nuclear activities. The EC representative provided an overview of the second implementation report on the Strategic Environmental Assessment Directive (SEAD).

In June 2017, the WPLANS held its second meeting, where members decided to focus the initial work of the working party on analysing legal frameworks for the long-term, extended or continued operation of nuclear power and/or research reactors established by NEA member countries. A survey on this topic was distributed to the NLC and to WPLANS, with responses expected by the end of 2017. The information provided will be compiled into a reference document.

The WPNLT held its first meeting in 2017, where members discussed the programme of work. The NEA Expert Group on Pre-Disposal Management of Radioactive Waste (EGPMRW) and the World Nuclear Transport Institute reported on their activities so that the WPNLT could consider further co-operation in the future. The group also discussed the opportunity to enquire about national legislations and rules applicable to nuclear transport and transit so that the NEA

The sixth session of INLE was held on 20-24 February 2017.

can then prepare a publicly available document to provide practical information on the administrative aspects of dealing with nuclear liability when preparing the transport of nuclear substances. Finally, the availability of insurance to cover damage caused by radioactive sources was also addressed.

The NEA continued to contribute to the work of the IAEA International Expert Group on Nuclear Liability (INLEX), the International Nuclear Law Association and the World Nuclear Association, as well as to nuclear law educational programmes, such as the Winter Course on Nuclear Law organised in New Delhi, India, by the Nuclear Law Association India and TERI University.

Third international workshop on nuclear liability

On 18-20 October 2017, the NEA and the Nuclear Regulatory Authority of the Slovak Republic co-organised the Third International Workshop on the Indemnification of Damage in the Event of a Nuclear Accident. The workshop, held in Bratislava, Slovak Republic, brought together more than 170 participants from 24 NEA member countries and 8 non-member countries, representing a variety of organisations, including government agencies, regulatory authorities, operators, suppliers, nuclear insurance pools and law firms. It aimed to explore the practical application of international nuclear liability instruments and the potential consequences with regard to non-convention states in the event of a nuclear accident causing transboundary damage. Participants discussed approaches to determining the damage to be compensated, demonstrating the causal link between the damage and the nuclear accident, identifying the liable entity, handling claims, resolving disputes and ensuring adequate financial compensation for victims.

Nuclear law publications programme

The *Nuclear Law Bulletin* (NLB) is a unique international publication for both professionals and academics in the field of nuclear law, providing comprehensive information on nuclear law developments. It features topical articles written by renowned legal experts, covers legislative developments worldwide and reports on relevant case law, international agreements and the activities of intergovernmental organisations. The 99th issue of the NLB was published in 2017, with articles addressing the licensing of new nuclear reactors; the development of international nuclear law; and nuclear third party liability. All issues of the NLB are available free online at www.oecd-nea.org/law/nlb.

Country profiles on the regulatory and institutional framework for nuclear activities in member countries are available at www.oecd-nea.org/law/legislation. The NEA continues its concerted efforts to update this online repository of information and is grateful for the support of OECD and NEA member countries. In 2017, an update was posted for Japan. The NEA Office of Legal Counsel is actively working with more than ten other countries to update their respective profiles.

Nuclear law education programmes

The sixth session of International Nuclear Law Essentials (INLE), an intensive, one-week programme on the international nuclear law framework and on major issues affecting the peaceful uses of nuclear energy, was held on 20-24 February 2017. It brought together a diverse international group of professionals from 13 countries for a series of master lectures by 23 speakers, including NEA Director-General William D. Magwood, IV and Commissioner Stephen G. Burns of the United States Nuclear Regulatory Commission, on topics related to nuclear safety, security, non-proliferation and liability. For more information on the INLE, see www.oecd-nea.org/law/inle.

The 17th session of the International School of Nuclear Law (ISNL), a unique academic programme organised by the NEA and the University of Montpellier, was held from 21 August to 1 September 2017. Over the past 17 sessions, the ISNL has provided a high-quality educational experience to more than 950 participants from around the world. The 2017 session attracted 64 participants from 40 countries – selected from 170 applicants – and included participants sponsored by the IAEA. The programme brings together leading experts in nuclear safety, security, liability, non-proliferation and safeguards to provide an in-depth exploration of the legal aspects related to the use and oversight of nuclear energy. ISNL participants are able to apply for a university diploma in international nuclear law recognised by the University of Montpellier. Further information can be obtained at www.oecd-nea.org/law/isnl.

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Information and Communications

The goal of the NEA in this sector is to provide member governments and other major stakeholders with information resulting from NEA activities and to enhance awareness and understanding of the scientific, technical, economic and legal aspects of nuclear activities as well as awareness of the NEA itself.

Highlights

- The Agency produced 24 publications and 48 technical reports in 2017. Overall dissemination and downloads remained very strong.
- Twenty-four press and news releases were issued in 2017, including on the NEA Workshop on Stakeholder Involvement in Nuclear Decision Making, the accession of Argentina and Romania to the NEA and the first NEA International Mentoring Workshop in Science and Engineering, held in Chiba, Japan.
- Online networking platforms were used extensively throughout the year to communicate the Agency's latest publications, news and events.
- The Agency has continued to increase its visibility through participation of NEA management in major international fora and events in member countries and elsewhere.

The NEA is an intergovernmental agency specialised in studying the scientific, technical and economic aspects of nuclear energy. It strives to provide high-quality, factual information in a timely manner to its member countries as well as to other interested parties wishing to learn about nuclear energy's multiple aspects and the results of the Agency's work.

Relations with the media

Relations with the media in 2017 covered a wide variety of topics and questions concerning the development and use of nuclear power. Twenty-four press and news releases were issued, for example notifying the media of the NEA Workshop on Stakeholder Involvement in Nuclear Decision Making, of the accession of Argentina and Romania to the NEA, the signature of the Memorandum of Understanding (MOU) between the Electric Power Research Institute, Inc. (EPRI) and the NEA, the first NEA International Mentoring Workshop in Science and Engineering, the signature of the MOU between the World Association of Nuclear Operators (WANO) and the NEA, and of the IAEA International Ministerial Conference on Nuclear Power in the 21st Century organised in co-operation with the NEA.

Over the course of the year, the NEA and the NEA Director-General were cited in numerous news articles in specialised publications and the international press, including *World Nuclear News, The Economist, Nuclear Energy Insider, Deutsche Welle, CBS News, BBC* and *Les Echos*. The NEA Director-General was also interviewed by CNBC and appeared on the television show *Sustainable Energy* in an episode on nuclear energy.

Publications

In 2017, the Agency produced 24 publications, all of which are available free on the NEA website at www.oecd-nea.org/pub. A list of these publications is provided on page 65.

A total of 48 NEA technical reports were also issued under the unclassified "R" series, directly downloadable from the substantive areas' web pages.

The most accessed online reports during the course of the year included *Projected Costs of Generating Electricity – 2015 Edition; Uranium 2016: Resources, Production and Demand; Costs of Decommissioning Nuclear Power Plants; Nuclear Energy Data 2016;* and *Small Modular Reactors: Nuclear Energy Market Potential for Near-term Deployment.*

The Agency's specialised journal, *NEA News,* keeps NEA correspondents and other interested professionals abreast of significant findings and advances in the Agency's programme of work. It provides feature articles on the latest developments in the nuclear energy field, as well as updates on NEA work, news briefs and information about NEA publications and forthcoming events.

In 2017, *NEA News* covered topics such as legacy management, NEA support to Fukushima Daiichi decommissioning strategy planning, the future of medical isotope supply, advanced reactors and future energy market needs, and a new NEA methodology for presenting national inventories of spent fuel and radioactive waste. *NEA News* is available free on the Agency's website at www.oecd-nea.org/nea-news.

Online communication

The NEA's online presence and use of new media technologies play a key role in communicating the work and accomplishments of the Agency. Website traffic remained steady in 2017, with the following areas attracting the most views: the NEA Data Bank's Java-based Nuclear Data Information System (JANIS), the Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library and the News section.

Online networking platforms have helped strengthen communication of NEA activities. The Agency maintains a regular presence on Facebook and LinkedIn, and can be

The first NEA International Mentoring Workshop in Science and Engineering, held in Chiba, Japan.

followed on Twitter @OECD_NEA. In 2017, the NEA continued to increase the frequency of its posts and engagement on all three platforms. The Agency's social media profile continued to grow in 2017 with a 23.1% increase in the number of followers on Twitter, a 20.4% increase on LinkedIn and a 13% increase on Facebook.

The Agency also integrated video into its digital communications strategy and revived its YouTube profile. Two long-form and seven short-form videos were created and disseminated on YouTube and Facebook, helping increase the visibility of NEA results, publications and events. Topics covered in 2017 included the signature of the MOU between WANO and the NEA, *NEA News 35.1* and the first NEA International Mentoring Workshop in Science and Engineering held in Chiba, Japan.

Subscriptions to the NEA Monthly News Bulletin have remained constant with approximately 20 000 subscribers. Distributed free of charge, the bulletin includes monthly updates on NEA work, activities and newly released reports. Online subscriptions can be made at www.oecd-nea.org/bulletin. Current and archive issues can also be viewed at www.oecd-nea.org/general/mnb.

Online interaction with NEA delegates continued to expand in 2017. Most NEA committees and their working groups rely extensively on electronic communication such as password-protected extranet pages, e-mail discussion lists or online collaborative work spaces. The Delegates' Area of the NEA website also continues to offer an important service for many NEA committees and working groups. This section of the website provides authorised users with official NEA documents, information on forthcoming NEA meetings, contact details for other committee members, as well as access to the presentations and background notes prepared for the Steering Committee policy debates.

Public affairs and visibility in international fora

NEA Director-General William D. Magwood, IV spoke in a variety of fora and countries in 2017 to communicate key messages about nuclear energy and the work of the NEA. These fora included the 32nd Korea Atomic Power Annual Conference in Korea in April, the International Congress on Advances in Nuclear Power Plants (ICAPP) in Japan in April, the Second World Nuclear Energy Development Forum in China in April, the American Nuclear Society (ANS) Annual Meeting in the United States in June, ATOMEXPO 2017 International Forum in Russia in June, the International Workshop on Decommissioning of Nuclear Power Plants in Japan in June, the Second International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station in Japan in July, the Fourth International Symposium on Safety Improvement and Stakeholder Confidence in Radioactive Waste Management (SaRaM) in Korea in September, the World Nuclear Association Symposium 2017 in the United Kingdom in September. He also gave lectures and held discussions with students at a number of higher education institutions, including Balseiro Institute, Handong Global University, Jorge A. Sabato Institute, Mumbai University and the University of Piteşti.

During 2017, the NEA co-sponsored and organised information stands at several international events where the NEA Director-General or NEA experts intervened. These included:

- Workshop on Current and Emerging Methods for Optimising Safety and Efficiency in Nuclear Decommissioning, Sarpsborg, Norway, 7-9 February;
- Certificate Course on "Nuclear Energy and Law", New Delhi, India, 6-11 March;
- 2017 RICOMET Conference on the Social and Ethical Aspects of Decision-making in Radiological Risk Situations, Vienna, Austria, 27-29 June;
- Sixth Asia-Pacific Symposium on Radiochemistry (APSORC-17), Jeju, Korea, 17-22 September;
- International Nuclear Fuel Cycle Conference (GLOBAL 2017), Seoul, Korea, 24-29 September;
- Fourth International Symposium on the System of Radiological Protection (ICRP) in collaboration with the Second European Radiological Protection Research Week (ERPW), Paris, France, 10-12 October;
- International Ministerial Conference on Nuclear Power in the 21st Century, Abu Dhabi, United Arab Emirates, 30 October-1 November;
- 10th International Symposium on the Release of Radioactive Material from Regulatory Control: Provisions for Clearance and Exemption, Berlin, Germany, 7-9 November;
- Second Workshop on the Regulatory Supervision of Legacy Sites: From Recognition to Resolution – The Process, Lillehammer, Norway, 21-23 November.

Vacant post	**Chief of Cabinet, Head of the Central Secretariat, External Relations and Public Affairs**

Organisational Structure of the NEA

The Nuclear Energy Agency (NEA) is a semi-autonomous body of the Organisation for Economic Co-operation and Development. OECD member countries wishing to participate in the activities of the Agency must make a formal request to join. The NEA currently has 33 member countries:

Argentina	Luxembourg
Australia	Mexico
Austria	Netherlands
Belgium	Norway
Canada	Poland
Czech Republic	Portugal
Denmark	Romania
Finland	Russia
France	Slovak Republic
Germany	Slovenia
Greece	Spain
Hungary	Sweden
Iceland	Switzerland
Ireland	Turkey
Italy	United Kingdom
Japan	United States
Korea	

The NEA is governed by the **Steering Committee for Nuclear Energy**. This committee is primarily made up of senior officials from national atomic energy authorities and associated ministries. It oversees and shapes the work of the Agency to ensure its responsiveness to member countries' needs, notably in establishing the biennial programmes of work and budgets. It approves the mandates of the seven standing technical committees and one management board (see page 63).

In 2017, the members of the **Bureau of the Steering Committee** for Nuclear Energy were:

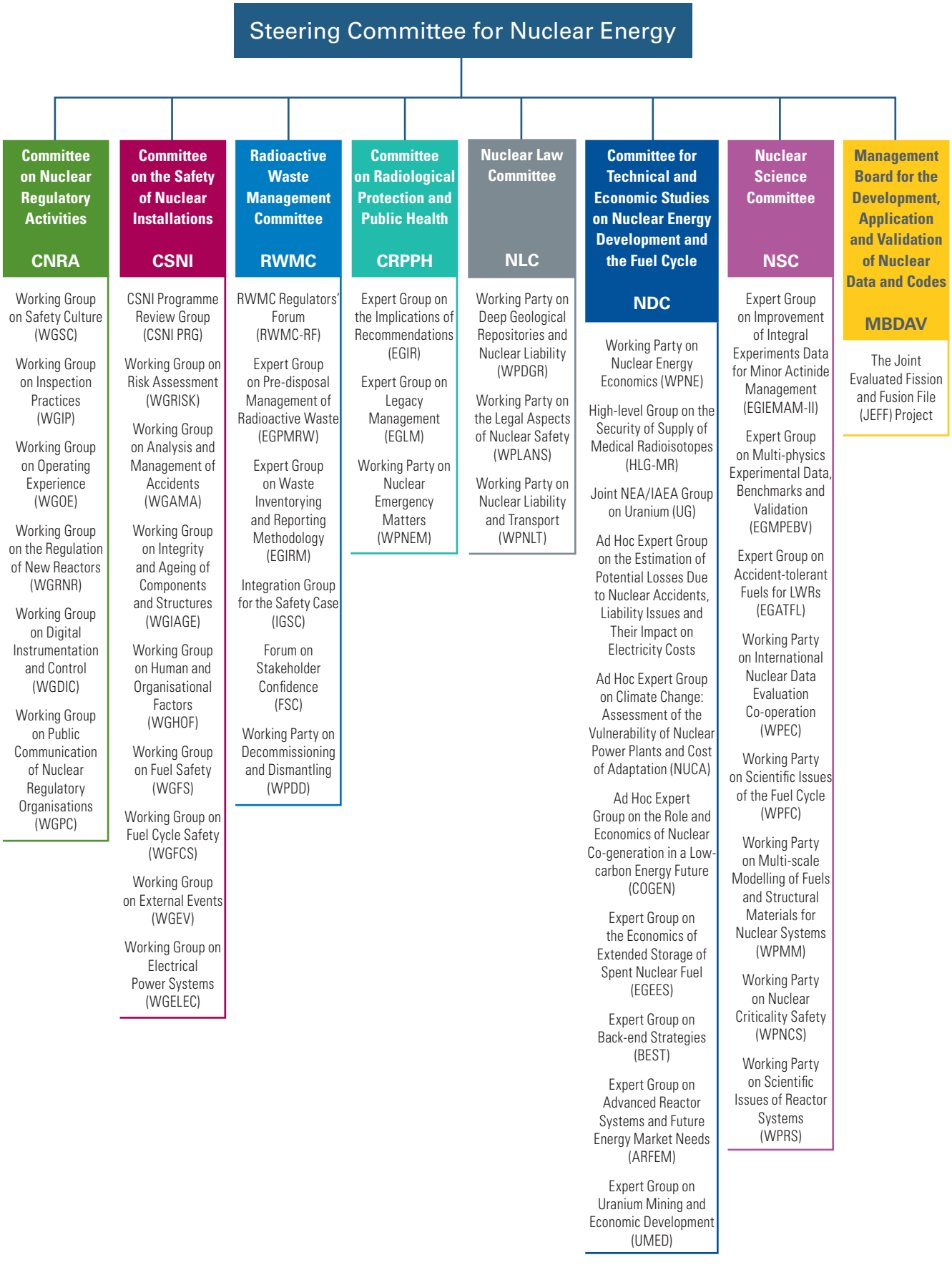
- Dr Marta ŽIAKOVÁ (Slovak Republic), Chair
- Mr Jan BENS (Belgium), Vice-Chair
- Mr Richard STRATFORD (United States), Vice-Chair
- Dr Hiroshi YAMAGATA (Japan), Vice-Chair
- Dr Wonpil BAEK (Korea), Vice-Chair
- Mrs Anne LAZAR-SURY (France) Vice-Chair

The **standing technical committees and the management board of the Data Bank** are composed of member country experts and technical specialists. These NEA bodies constitute a unique feature and important strength of the NEA, providing flexibility for adapting to new issues and helping to achieve consensus rapidly. Their main areas of work are listed in the chart on the next page.

The Steering Committee for Nuclear Energy and the Agency's seven standing technical committees and one management board are serviced by the **NEA Secretariat**, composed in 2017 of 111 professional and support staff from 19 countries. Professional staff are often specialists from national administrations and research institutes, bringing their experience to the Agency for two to five years on average.

Participation in the work of the Agency by non-member countries is an established practice. Experts from selected **partner countries**, including China and India, take part in NEA activities on an invitee or participant basis.

OECD Boulogne building.


Steering Committee for Nuclear Energy
Committee on Nuclear Regulatory Activities
CNRA
Working Group on Safety Culture (WGSC)
Working Group on Inspection Practices (WGIP)
Working Group on Operating Experience (WGOE)
Working Group on the Regulation of New Reactors (WGRNR)
Working Group on Digital Instrumentation and Control (WGDIC)
Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC)
Committee on the Safety of Nuclear Installations
CSNI
CSNI Programme Review Group (CSNI PRG)
Working Group on Risk Assessment (WGRISK)
Working Group on Analysis and Management of Accidents (WGAMA)
Working Group on Integrity and Ageing of Components and Structures (WGIAGE)
Working Group on Human and Organisational Factors (WGHOF)
Working Group on Fuel Safety (WGFS)
Working Group on Fuel Cycle Safety (WGFCS)
Working Group on External Events (WGEV)
Working Group on Electrical Power Systems (WGELEC)
Radioactive Waste Management Committee
RWMC
RWMC Regulators' Forum (RWMC-RF)
Expert Group on Pre-disposal Management of Radioactive Waste (EGPMRW)
Expert Group on Waste Inventorying and Reporting Methodology (EGIRM)
Integration Group for the Safety Case (IGSC)
Forum on Stakeholder Confidence (FSC)
Working Party on Decommissioning and Dismantling (WPDD)
Committee on Radiological Protection and Public Health
CRPPH
Expert Group on the Implications of Recommendations (EGIR)
Expert Group on Legacy Management (EGLM)
Working Party on Nuclear Emergency Matters (WPNEM)
Nuclear Law Committee
NLC
Working Party on Deep Geological Repositories and Nuclear Liability (WPDGR)
Working Party on the Legal Aspects of Nuclear Safety (WPLANS)
Working Party on Nuclear Liability and Transport (WPNLT)
Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle
NDC
Working Party on Nuclear Energy Economics (WPNE)
High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR)
Joint NEA/IAEA Group on Uranium (UG)
Ad Hoc Expert Group on the Estimation of Potential Losses Due to Nuclear Accidents, Liability Issues and Their Impact on Electricity Costs
Ad Hoc Expert Group on Climate Change: Assessment of the Vulnerability of Nuclear Power Plants and Cost of Adaptation (NUCA)
Ad Hoc Expert Group on the Role and Economics of Nuclear Co-generation in a Low-carbon Energy Future (COGEN)
Expert Group on the Economics of Extended Storage of Spent Nuclear Fuel (EGEES)
Expert Group on Back-end Strategies (BEST)
Expert Group on Advanced Reactor Systems and Future Energy Market Needs (ARFEM)
Expert Group on Uranium Mining and Economic Development (UMED)
Nuclear Science Committee
NSC
Expert Group on Improvement of Integral Experiments Data for Minor Actinide Management (EGIEMAM-II)
Expert Group on Multi-physics Experimental Data, Benchmarks and Validation (EGMPEBV)
Expert Group on Accident-tolerant Fuels for LWRs (EGATFL)
Working Party on International Nuclear Data Evaluation Co-operation (WPEC)
Working Party on Scientific Issues of the Fuel Cycle (WPFC)
Working Party on Multi-scale Modelling of Fuels and Structural Materials for Nuclear Systems (WPMM)
Working Party on Nuclear Criticality Safety (WPNCS)
Working Party on Scientific Issues of Reactor Systems (WPRS)
Management Board for the Development, Application and Validation of Nuclear Data and Codes
MBDAV
The Joint Evaluated Fission and Fusion File (JEFF) Project

NEA MANAGEMENT STRUCTURE IN 2017

William D. Magwood, IV
NEA Director-General

Daniel Iracane
Deputy Director-General and Chief Nuclear Officer

Masahiko Fujihara
Deputy Director-General for Legal Affairs and Strategic Resources

Ximena Vásquez-Maignan
Head of the Office of Legal Counsel

Ricardo Lopez
(until September 2017)
Head of the Office of Administration

Vacant post

Chief of Cabinet, Head of the Central Secretariat, External Relations and Public Affairs

Ho Nieh
Head of the Division of Nuclear Safety Technology and Regulation

Yeonhee Hah
Head of the Division of Radiological Protection and Human Aspects of Nuclear Safety

Gloria Kwong
(as from 10 June 2017)
Acting Head of the Division of Radioactive Waste Management

Tatiana Ivanova
Head of the Division of Nuclear Science

Jim Gulliford
Head of the Data Bank

Henri Paillère
Acting Head of the Division of Nuclear Development

All NEA publications are available free of charge on the NEA website.

General Interest

Annual Report 2016

NEA No. 7349.
68 pages.

Rapport annuel 2016

AEN n° 7350.
72 pages.

NEA News, No. 34.2

NEA No. 7292.
28 pages.

NEA News, No. 35.1

NEA No. 7347.
32 pages.

Nuclear Energy Agency

NEA No. 7398.
28 pages.

Also available in French.

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

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.

Nuclear Energy Data 2017/Données sur l'énergie nucléaire 2017

NEA No. 7365. 100 pages.

Available online at: http://oe.cd/2aK

Nuclear Energy Data is the Nuclear Energy Agency's annual compilation of statistics and country reports documenting nuclear power status in NEA member countries and in the OECD area. Information provided by governments includes statistics on total electricity produced by all sources and by nuclear power, fuel cycle capacities and requirements, and projections to 2035, where available. Country reports summarise energy policies, updates of the status in nuclear energy programmes and fuel cycle developments. In 2016, nuclear power continued to supply significant amounts of low-carbon baseload electricity, despite strong competition from low-cost fossil fuels and subsidised renewable energy sources. Three new units were connected to the grid in 2016, in Korea, Russia and the United States. In Japan, an additional three reactors returned to operation in 2016, bringing the total to five under the new regulatory regime. Three reactors were officially shut down in 2016 – one in Japan, one in Russia and one in the United States. Governments committed to having nuclear power in the energy mix advanced plans for developing or increasing nuclear generating capacity, with the preparation of new build projects making progress in Finland, Hungary, Turkey and the United Kingdom. Further details on these and other developments are provided in the publication's numerous tables, graphs and country reports.

NEA Workshop on Stakeholder Involvement in Nuclear Decision Making

Summary Report

NEA No. 7302. 83 pages.

Available online at: http://oe.cd/2aJ

See the video at: https://youtu.be/h4pb471lO6U

Because nuclear issues are embedded in broader societal issues such as the environment, energy, risk management, health policy and sustainability, they can often generate considerable interest and concern. Actors involved in the nuclear energy sector, including regulators, governments and licensees, share the goal of reaching accepted, sustainable decisions and to ensure that the decision-making process is transparent. Stakeholder involvement in decision making is today seen as an essential means for improving decisions and for optimising their implementation.

In this context, the Nuclear Energy Agency (NEA) organised a Workshop on Stakeholder Involvement in Nuclear Decision Making in January 2017, acknowledging that different countries and sectors may face similar challenges and that sharing experiences and approaches could be useful. The workshop was an opportunity to bring together experts with first-hand knowledge and experience in areas related to nuclear law, regulatory practices, radiological protection, nuclear waste management, the deployment of new nuclear facilities, extended operation of nuclear facilities, deployment of other energy technologies and infrastructures, and social and traditional media.

This summary report attempts to capture the collective wisdom generated over three days of interaction. It highlights some commonalities and differences in views and approaches, and identifies particular lessons that can be applied to improve the strategy and practice of involving stakeholders in decision making. Overall, the learning gained from this workshop can benefit governments and citizens alike.

Nuclear safety and regulation

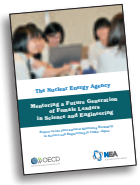
State-of-the-Art Report on Molten Corium Concrete Interaction and Ex-Vessel Molten Core Coolability

NEA No. 7392. 365 pages.

Available online at: http://oe.cd/2eT

Activities carried out over the last three decades in relation to core-concrete interactions and melt coolability, as well as related containment failure modes, have significantly increased the level of understanding in this area. In a severe accident with little or no cooling of the reactor core, the residual decay heat in the fuel can cause the core materials to melt. One of the challenges in such cases is to determine the consequences of molten core materials causing a failure of the reactor pressure vessel. Molten corium will interact, for example, with structural concrete below the vessel. The reaction between corium and concrete, commonly referred to as MCCI (molten core concrete interaction), can be extensive and can release combustible gases. The cooling behaviour of ex-vessel melts through sprays or flooding is also complex. This report summarises the current state of the art on MCCI and melt coolability, and thus should be useful to specialists seeking to predict the consequences of severe accidents, to model developers for severe-accident computer codes and to designers of mitigation measures.

Radiological Protection and Human Aspects of Nuclear Safety



Mentoring a Future Generation of Female Leaders in Science and Engineering

12 pages.

Radioactive waste management

Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities

NEA No. 7344. 64 pages.

Available online at: http://oe.cd/2aL

The cost estimation process of decommissioning nuclear facilities has continued to evolve in recent years, with a general trend towards demonstrating greater levels of detail in the estimate and more explicit consideration of uncertainties, the latter of which may have an impact on decommissioning project costs. The 2012 report on the *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations,* a joint recommendation by the Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA) and the European Commission, proposes a standardised structure of cost items for decommissioning projects that can be used either directly for the production of cost estimates or for mapping of cost items for benchmarking purposes. The ISDC, however, provides only limited guidance on the treatment of uncertainty when preparing cost estimates. *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities,* prepared jointly by the NEA and IAEA, is intended to complement the ISDC, assisting cost estimators and reviewers in systematically addressing uncertainties in decommissioning cost estimates. Based on experiences gained in participating countries and projects, the report describes how uncertainty and risks can be analysed and incorporated in decommissioning cost estimates, while presenting the outcomes in a transparent manner.

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.

National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste

Extended Methodology for the Common Presentation of Data

NEA No. 7371. 70 pages.

Available online at: http://oe.cd/2aM

Radioactive waste inventory data are an important element in the development of a national radioactive waste management programme since these data affect the design and selection of the ultimate disposal methods. Inventory data are generally presented as an amount of radioactive waste under various waste classes, according to the waste classification scheme developed and adopted by the country or national programme in question. Various waste classification schemes have evolved in most countries, and these schemes classify radioactive waste according to its origin, to criteria related to the protection of workers or to the physical, chemical and radiological properties of the waste and the planned disposal method(s).

The diversity in classification schemes across countries has restricted the possibility of comparing waste inventories and led to difficulties in interpreting waste management practices, both nationally and internationally. To help improve this situation, the Nuclear Energy Agency developed a methodology that ensures consistency of national radioactive waste and spent fuel inventory data when presenting them in a common scheme in direct connection with accepted management strategy and disposal routes. This report is a follow-up to the 2016 report that introduced the methodology and presenting scheme for spent fuel, and it now extends this methodology and presenting scheme to all types of radioactive waste and corresponding management strategies.

Radiological Characterisation from a Waste and Materials End-State Perspective

Practices and Experience

NEA No. 7373. 96 pages.

Available online at: http://oe.cd/2aN

Radiological characterisation is a key enabling activity for the planning and implementation of nuclear facility decommissioning. Effective characterisation allows the extent, location and nature of contamination to be determined and provides crucial information for facility dismantling, the management of material and waste arisings, the protection of workers, the public and the environment, and associated cost estimations.

This report will be useful for characterisation practitioners who carry out tactical planning, preparation, optimisation and implementation of characterisation to support the decommissioning of nuclear facilities and the management of associated materials and waste. It compiles recent experience from NEA member countries in radiological characterisation, including from international experts, international case studies, an international conference, and international standards and guidance. Using this comprehensive evidence base, the report identifies relevant good practice and provides practical advice covering all stages of the characterisation process.

Recycling and Reuse of Materials Arising from the Decommissioning of Nuclear Facilities

NEA No. 7310. 68 pages.

Available online at: http://oe.cd/2aO

Large quantities of materials arising from the decommissioning of nuclear facilities are non-radioactive per se. An additional, significant share of materials is of very low-level or low-level radioactivity and can, after having undergone treatment and a clearance process, be recycled and reused in a restricted or unrestricted way. Recycle and reuse options today provide valuable solutions to minimise radioactive waste from decommissioning and at the same time maximise the recovery of valuable materials. The NEA Co-operative Programme on Decommissioning (CPD) prepared this overview on the various approaches being undertaken by international and national organisations for the management of slightly contaminated material resulting from activities in the nuclear sector.

The report draws on CPD member organisations' experiences and practices related to recycling and reuse, which were gathered through an international survey. It provides information on improvements and changes in technologies, methodologies and regulations since the 1996 report on this subject, with the conclusions and recommendations taking into account 20 years of additional experience that will be useful for current and future practitioners. Case studies are provided to illustrate significant points of interest, for example in relation to scrap metals, concrete and soil.

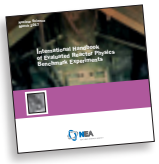
Sourcebook of International Activities Related to the Development of Safety Cases for Deep Geological Repositories

NEA No. 7341. 64 pages.

Available online at: http://oe.cd/2aP

All national radioactive waste management authorities recognise today that a robust safety case is essential in developing disposal facilities for radioactive waste. To improve the robustness of the safety case for the development of a deep geological repository, a wide variety of activities have been carried out by national programmes and international organisations over the past years. The Nuclear Energy Agency, since first introducing the modern concept of the "safety case", has continued to monitor major developments in safety case activities at the international level. This Sourcebook summarises the activities being undertaken by the Nuclear Energy Agency, the European Commission and the International Atomic Energy Agency concerning the safety case for the operational and post-closure phases of geological repositories for radioactive waste that ranges from low-level to high-level waste and for spent fuel. In doing so, it highlights important differences in focus among the three organisations.

Nuclear science and the Data Bank



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.

SFCOMPO 2.0: International Database of Spent Nuclear Fuel Isotopic Assay Data

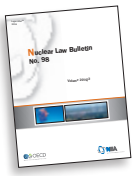
NEA No. 7391. DVD.

SFCOMPO 2.0 is the NEA database of experimental assay measurements. Measurements are isotopic concentrations from destructive radiochemical analyses of spent nuclear fuel (SNF) samples, supplemented with design information for the fuel rod and fuel assembly from which each sample was taken, as well as with relevant information on operating conditions and design characteristics of the host reactors. SFCOMPO 2.0 contains data from 750 SNF samples coming from 44 reactors representing 8 different international reactor designs. SFCOMPO 2.0 was released online in June 2017.

SFCOMPO 2.0 has been developed by the NEA in close collaboration with Oak Ridge National Laboratory (ORNL). The data in SFCOMPO 2.0 has undergone an independent and iterative review process by the Expert Group on Assay Data of Spent Nuclear Fuel (EGADSNF), under the NEA Working Party on Nuclear Criticality Safety (WPNCS). The data have been reviewed for consistency with the experimental reports but have not been formally evaluated. Assay data evaluations are a multidisciplinary effort involving reactor specialists, modelling and simulation experts, and radiochemistry experts. Any errors in measurements, omissions or inconsistencies in the original reported data may be reproduced in the database. Therefore, it is important that any user of the data for code validation consider and assess the potential data deficiencies. The evaluation of assay data will provide a more complete assessment and may result in the development of benchmark specifications and measurement data in cases of high quality experiments.

SFCOMPO 2.0 contains only openly accessible, published experimental assay data. An online Java application of SFCOMPO 2.0 is available at: www.oecd-nea.org/sfcompo.

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".

Nuclear Law Bulletin, Volume No. 99

NEA No. 7366. 120 pages.

Available online at: http://oe.cd/2aQ

Feature articles in this issue include: "Reformed and reforming: Adapting the licensing process to meet new challenges"; "Reflections on the development of international nuclear law"; and "Facing the challenge of nuclear mass tort processing".

Publications of Secretariat-serviced bodies

Generation IV International Forum (GIF) Annual Report 2016

GIF report. 162 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.

Multinational Design Evaluation Programme (MDEP) Annual Report: April 2016-April 2017

MDEP report. 58 pages.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 35 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Korea, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 33 countries: Argentina, Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Korea, Romania, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission and the International Atomic Energy Agency also take part in the work of the Agency.

The mission of the NEA is:

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

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

Also available in French under the title:

AEN – RAPPORT ANNUEL – 2017

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NEA publications and information

The full **catalogue of publications** is available online at www.oecd-nea.org/pub.

In addition to basic information on the Agency and its work programme, the **NEA website** offers free downloads of hundreds of technical and policy-oriented reports.

An **NEA monthly electronic bulletin** is distributed free of charge to subscribers, providing updates of new results, events and publications. Sign up at www.oecd-nea.org/bulletin.

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