2017 – No. 34.2

# NEA News

## In this issue:



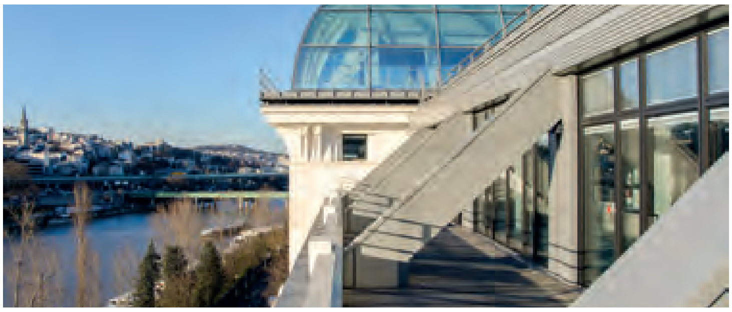
OECD
BETTER POLICIES FOR BETTER LIVES

NEA
NUCLEAR ENERGY AGENCY

NEA News
Volume No. 34.2 2017

# Contents





OECD Boulogne building.

# The coming crisis in nuclear skills and education

In the early 1990s, nuclear engineering programmes in universities across the United States began to collapse. Whereas at the beginning of the decade, there were nearly 2 000 nuclear engineering students studying in US colleges and universities, the perception that there was no future career in nuclear technology led to a drop in enrolments to less than 800 by 1998. At the same time, entire programmes were closing and university research reactors were being shut down at a rate of almost one each year.

A governmental decision was made to reverse this trend. Impactful investments in university research, scholarships and fellowships, and infrastructure — along with vocal support for this field of study from senior government officials and members of Congress — had an immediate impact. Enrolments grew quickly and later accelerated as industry began hiring aggressively. Today, there are around 5 000 nuclear engineering students in US schools, many focused on medical applications, non-proliferation, fusion and other areas — including, of course, advanced nuclear energy technologies.

The nuclear specialists emerging from these education programmes arrived at just the right time, as governmental agencies, industry and scientific organisations rushed to prepare for retirements in the ranks of experienced nuclear engineers. The foresight to support nuclear education in the late 1990s averted what might have been a crisis in human resources by 2010.

However today, as we review the situation globally, the potential for a crisis over the next decade in the availability of trained nuclear specialists seems extraordinarily high. In many NEA countries, training of nuclear engineers and scientists is on a steadily declining path. Once highly lauded programmes have been significantly diminished or already eliminated. In some fields, such as nuclear chemistry — which is essential in the application of radioactive materials to support advanced medical applications and explore advanced treatments for nuclear waste — few programmes exist anywhere. No matter what energy policies are chosen by NEA member countries, the long-term nature of nuclear power will require many nuclear specialists.

The field of health physics, which is essential for the safe implementation of any activity involving radiological materials and process, including addressing nuclear waste and legacy facilities, highlights the risks now facing us. A survey last year of members of the NEA Committee on Radiological Protection and Public Health (CRPPH) found that the number of universities offering health physics degrees or courses in NEA member countries had dropped by more than a third over the last decade. When CRPPH members were asked "Do you feel that your organisation is in a strong position to hire a sufficient number of radiological protection experts over the next 10 years," the answer was a resounding "no".

The NEA has begun reviewing ways it can help its members address these challenges. The CRPPH is considering the establishment of an NEA training course to educate young health physicists on the intentions of the principle concepts of the radiological protection system. We are also engaging with the United Nations International Atomic Energy Agency to jointly organise courses for nuclear leaders. Other possible activities are also being evaluated.

Most prominently, the NEA hopes to soon launch the NEA Nuclear Education, Skills and Technology framework, known as "NEST." NEST would enable member countries, including those planning new nuclear plants and those planning to forgo use of nuclear energy, to co-operate in the development of a new generation of nuclear science and technology specialists. Our plan is to establish multinational, multidisciplinary projects in a range of topics aimed at the development of practical solutions to real-world problems.

NEA efforts, as helpful as they may be, cannot on their own avert the looming crisis in skills. Each country will need to assess the specialists needed for whatever policies they plan to implement and ensure that they will have access to the trained experts needed to bring these policies to reality.

William D. Magwood, IV,
NEA Director-General

# The NEA Nuclear Innovation 2050 Initiative

by F. Rayment and M. Deffrennes

Dr Fiona Rayment (fiona.e.rayment@nnl.co.uk) is Director of Fuel Cycle Solutions at the National Nuclear Laboratory in the United Kingdom and Chair of the NI2050 Advisory Panel. Dr Marc Deffrennes (marc.deffrennes@oecd.org) is a Nuclear Energy Analyst in the NEA Division of Nuclear Development.

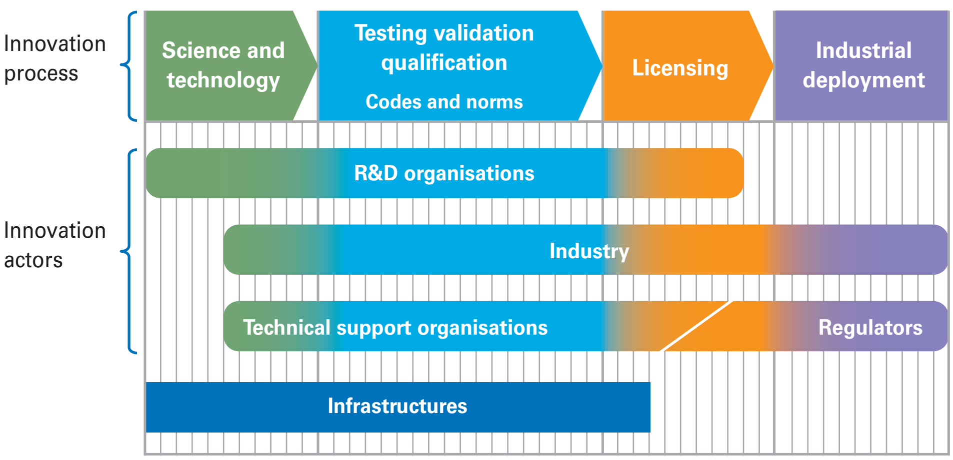
The NEA launched its Nuclear Innovation 2050 (NI2050) Initiative with the aim of identifying research and development (R&D) strategies and associated priorities to achieve commercial readiness of innovative, sustainable nuclear fission technologies in a fast and cost-effective way. As defined at the beginning of the process, these R&D strategies would be elaborated with NEA stakeholders at large, in particular involving nearly all NEA committees, nuclear research organisations, industry, regulators and technical safety organisations.

Recent work by the NEA, including the joint NEA/IEA *Technology Roadmap: Nuclear Energy,* published in 2015, highlights the important role that nuclear fission technology can play in achieving a low-carbon future. The report notes that an economics-driven scenario to limit global rises in temperature to the widely accepted 2° Celsius target, which guides international discussions regarding limits on carbon emissions, would require global nuclear electricity generation capacity to increase by 2.3 times by 2050. For this to happen, transferring the outcomes of science towards industrial applications, while accelerating the time to market for innovative technologies, and reducing the associated investments and licensing risks, are all necessary conditions. Meeting the even more ambitious goal of climate experts to go "well-beyond" the 2°C target and eliminate carbon emissions from energy production by 2100 will almost certainly require additional technological breakthroughs and a wider contribution of nuclear energy beyond electricity generation.

The NI2050 Initiative can be seen as an NEA incubator for the selection and development of large-scale R&D programmes of action (and associated infrastructures), aiming primarily at accelerating the readiness of innovative technologies and helping them reach competitive deployment in time to contribute to the low-carbon energy objectives recalled above. Such programmes of action, once developed to the proper level of maturity, will then be proposed to NEA stakeholders for them to discuss the ways and means of practical implementation, including in terms of legal and financial frameworks.

Figure 1 below illustrates this function of NI2050 as an enabler for effective technology development and deployment, bridging the diverse stakeholder communities involved.

**Figure 1: Innovation from science to market deployment**

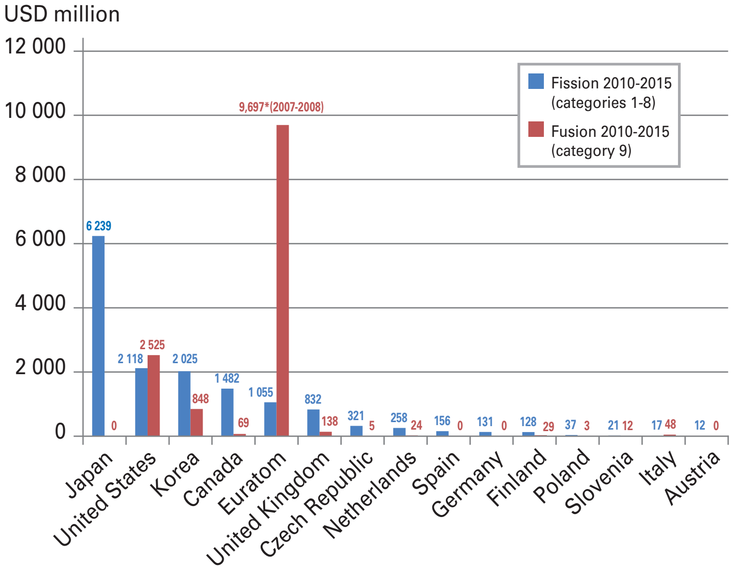


In the course of the past year, information on actual and projected R&D programmes and budgets within NEA member countries and the European Commission have been collected via a survey. Most members have now returned their responses to the questionnaire and work has begun to analyse the content. Figure 2 summarises the total cumulative budget figures for nuclear R&D as communicated by members for the period 2010-2015.

In order to help select and further develop a set of large R&D programmes of action, to be later proposed to stakeholders for implementation, the NI2050 Advisory Panel has recently revisited the main challenges and opportunities for nuclear fission in a low-carbon energy future. These challenges and opportunities are strongly interlinked and can be summarised as follows:

- **Safety and waste management are two primary topics for nuclear energy and for public confidence.** Safety is subject to continuous improvement, and future nuclear systems are being designed to make off-site radioactive releases negligible for any condition of a plant, making evacuation unnecessary. For radioactive waste, progress should be made to reduce the volumes and lifetimes of high-level waste, and to facilitate the acceptance of geological disposal as the best solution.
- **Nuclear needs to be competitive with other energy sources.** Energy markets are still very much under development. It is hard to predict how energy prices will evolve. Therefore, all efforts have to be made to reduce costs at all stages, from design, construction and operation to decommissioning. Simplification of design, advanced manufacturing and construction processes, effective supply chains, reduced maintenance, minimisation of waste production and integration of decommissioning from the early stage of design are all areas where R&D should be of help. Harmonisation is also an important contributor to cost reduction, including on the licensing side.
- **Nuclear energy needs to be integrated into low-carbon energy mixes.** The energy mix of the future will contain more intermittent renewable sources. Flexibility will therefore be necessary, allowing diverse sources to complement each other while ensuring the reliability of supply. Going beyond the generation of electricity and providing heat or hydrogen will offer an opportunity for nuclear energy to further contribute to the decarbonisation of economies.
- **Nuclear power needs to make the best use of resources.** There is no shortage of uranium for the present time, nor will there be for the coming decades. However, if recourse to nuclear energy increases towards the middle of the century and beyond, it makes sense to enable its effective use. In addition to ensuring that existing fuels are more efficient, moving towards fast neutron reactors and the associated closed fuel cycle will enable enhanced resource efficiencies.
- **The nuclear sector needs to integrate innovative enabling technologies.** For diverse reasons, the field of nuclear energy has tended to be conservative when it comes to implementing new technologies. In the future, new innovative technologies will need to be pursued. A few examples are modularisation and factory production, advanced materials and IT or big data. For these to be effective, it is critical to engage with the safety authorities in a timely fashion to ensure that innovative technologies are effectively integrated in terms of licensing.
- **The nuclear sector must rely on competent people.** The development of a next generation of competent people is critical for the future development of nuclear energy. One way to ensure the necessary, skilled workforce for the future is to engage young scientists in attractive and innovative nuclear research projects. The NEA is actively participating in such efforts through its NEA Nuclear Education, Skills and Technology (NEST) project (see *NEA News* 34.1).

**Figure 2: Total fission and fusion budget 2010-2015**



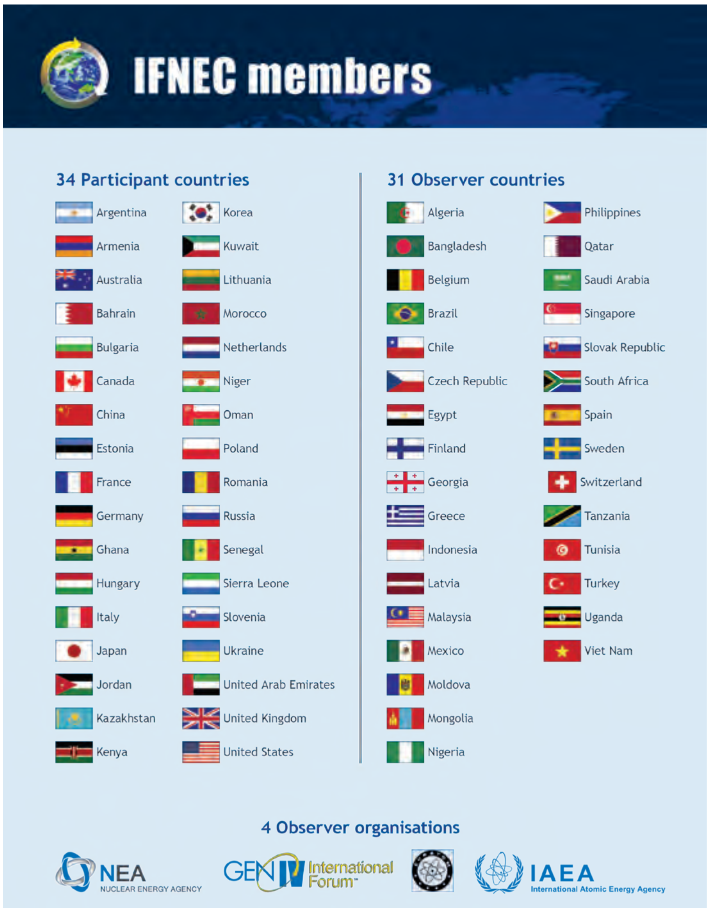

The next steps of the NI2050 Initiative, building on the challenges and opportunities discussed above, will be to select and develop a set of large R&D programmes of action, in line with the NI2050 objective of accelerating innovation and market deployment. A set of criteria will be developed to support this selection process, keeping in mind that the first set of criteria will not be exhaustive. Selected programmes, when developed at the right level of maturity within the NEA NI2050 Initiative and with recourse to the proper expertise, will be proposed for implementation to stakeholders, in particular through co-operative frameworks.

The Nuclear Innovation 2050 Initiative has evolved over the last year to become an NEA incubator for the selection and development of a number of large nuclear fission R&D programmes (and infrastructures) that can support the role of nuclear energy in a low-carbon future, mainly by accelerating innovation and the market deployment of technologies. One year after its launch, during which basic information has been collected and a number of Advisory Panel and Expert meetings have been held to fine-tune the objectives and scope, the initiative has reached the stage where more concrete outcomes might now be expected, in particular in terms of programmes of action to be proposed for co-operative implementation.

# The International Framework for Nuclear Energy Cooperation (IFNEC)

by A. Duncan

Ms Aleshia Duncan (aleshia.duncan@oecd.org) is Policy Advisor to the International Framework for Nuclear Energy Cooperation (IFNEC).




The International Framework for Nuclear Energy Cooperation (IFNEC) brings together 34 participant countries, 31 observer countries and 4 observer organisations, according to its Statement of Mission, "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".

IFNEC has grown in size over its six years of existence, welcoming new countries and international organisations and expanding the depth and breadth of its work in order to accommodate its diverse membership. It was created in 2010 from an existing partnership of countries called the Global Nuclear Energy Partnership (GNEP). The Nuclear Energy Agency (NEA) is the most recent observer organisation to join IFNEC, having been officially recognised as a member in October 2014. The NEA became the Technical Secretariat to IFNEC in 2015, and is funded solely by voluntary contributions.

## IFNEC structure

The guiding principle of IFNEC is respect for all its members, which means that all IFNEC participant countries that have endorsed the IFNEC Statement of Mission have equal status in IFNEC and that policy decisions are made by consensus. IFNEC is directed by an Executive Committee, advised by a Steering Group and currently has three working groups – the Infrastructure Development Working Group (IDWG), the Reliable Nuclear Fuel Services Working Group (RNFSWG) and the newly formed Ad Hoc Nuclear Suppliers and Customer Countries Engagement Working Group.

The Executive Committee convenes annually and rotates its meeting location among IFNEC participant countries. Members of the Executive Committee are ministerial officials designated by each participant country. The annual host country also serves as the Chair of the Executive Committee meeting, which has thus far been hosted and chaired by Jordan (2010), Poland (2011), Morocco (2012), the United Arab Emirates (2013), Korea (2014), Romania (2015) and Argentina (2016).

The Steering Group consists of representatives from all IFNEC participant countries, observer countries and observer organisations. It serves as the highest permanent-level, policymaking body, which implements actions on behalf of the Executive Committee and conveys guidance and support to the IFNEC working groups. The Steering Group is led by the Chair (currently from the United States) and supported by three Vice Chairs (from China, France and Japan). The Steering Group Chair is responsible for co-ordinating with IFNEC members to set direction, develop and implement policies, lead activities involving special areas of interest such as finance and small modular reactors, and ensure that IFNEC Technical Secretariat support is provided.

The IDWG supports the development of the infrastructure needed to ensure that 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. The RNFSWG supports the co-operation of member countries in efforts that enhance reliable, commercially based fuel services which provide options for developing nuclear energy while reducing the risk of nuclear proliferation. It has focused on the back end of the fuel cycle and has been exploring issues associated with spent fuel management and disposition. Continued efforts include furthering the potential for shared, multinational solutions to the back-end challenges many member countries continue to face today. The RNFSWG has also examined a dual track approach and recently published a report on *Practical Considerations to Begin Resolving the Final Spent Fuel Disposal Pathway for Countries with Small Nuclear Programs*. The report is available on the IFNEC website.

The NEA, as the Technical Secretariat, co-ordinates all communication, meeting planning, record management, publication development, website administration and support for the Executive Committee, Steering Group and working groups. In 2016, the NEA Technical Secretariat completed the migration of the IFNEC website, transferred the historical files, hosted IFNEC meetings in May 2016, conducted a survey of IFNEC members, planned and provided resources for meetings hosted in Argentina in October 2016 and managed the production and editorial process for IFNEC communication documents and technical reports.

The International conference "*Nuclear Energy's Role in the 21st Century: Addressing the Challenge of Financing*", OECD Conference Centre, May 2016.

## A focus on finance

IFNEC has sought to contribute to important global nuclear energy matters, including a multi-year, stakeholder-wide focus on financial challenges in relation to nuclear energy projects, ranging from deployment of nuclear energy to decommissioning. Work in this area has culminated in the publication of reports on various finance models and approaches.

During the past six years, the IFNEC Steering Group has hosted special finance sessions and conferences in London, Abu Dhabi, Bucharest and Paris. IFNEC has brought together global financial experts and leadership from multilateral development banks, export credit agencies and national lending institutions to discuss the challenges of financing nuclear projects. These financial experts have participated in a signature feature of IFNEC: hypothetical moderated scenarios with energy planning authorities, regulators and utilities to walk through the necessary components of financing projects, explore alternative financing options and highlight the role of the energy planning authority in implementing national policies so as to provide the political and national support necessary to pursue nuclear project financing. All conference proceedings from this multi-year effort are publicly available on the IFNEC website.

The Nuclear Finance Conference on 11-12 May 2016, in Paris, France was co-sponsored by the NEA. The benefit of co-sponsoring the conference with the NEA was the obvious synergy of working with an international organisation that is globally recognised for its technical expertise and extensive published data in the area of nuclear economics. The conference convened more than 150 leading stakeholders ranging from energy planning authorities, regulators and export credit agencies to vendors, utilities, bankers, rating agencies and insurers with the objective of identifying key barriers and developing approaches and solutions that can be effectively implemented.

OECD Secretary-General Angel Gurría provided the opening keynote address. The co-hosts of the conference, NEA Director-General William D. Magwood, IV and IFNEC Steering Group Chair Edward G. McGinnis, cited the agreement of the countries at the 21st Conference of the Parties (COP21) of the UN Framework Convention on Climate Change (UNFCCC) to reduce carbon emissions, coupled with energy security and longterm stable energy supply goals as critical for continued discussion on the challenge of financing nuclear projects. The conference proceedings, *Nuclear Energy's Role in the 21st Century: Addressing the Challenge of Financing*, were recently published and made publicly available on both the IFNEC and NEA websites.

A Latin American Nuclear Energy Stakeholders Conference was also held on 25-26 October 2016, in Buenos Aires, Argentina. The conference was hosted by the Ministry of Energy and Mining, the Ministry of Foreign Affairs and the National Atomic Energy Commission (CNEA). Keynote speeches were given by the Minister of Energy and Mining, Juan José Aranguren and NEA Director-General William D. Magwood, IV. Undersecretary for Nuclear Energy Julian Gadano announced during his opening remarks that Argentina hoped to soon join the NEA. An interactive and dynamic programme provided the opportunity for more than 220 participants from a broad array of government and industry stakeholders to share information, understand the challenges facing the region with respect to the safe, secure and sustainable use of nuclear energy, and identify solutions to such challenges.

In addition to the Latin American Conference, the government of Argentina hosted the IFNEC Steering Group meeting and chaired the Executive Committee meeting on 26-27 October 2016. The Argentina government demonstrated its support from the highest level of government by having the President's Cabinet Chief, Marcos Peña, deliver the welcome remarks. During the Executive Committee meeting, a proposal for the Ad Hoc Nuclear Supplier and Customer Engagement Working Group was approved, with Argentina and Japan volunteering to serve as Co-chairs.

As decided during the Steering Group and Working Group meetings in May 2016, IFNEC leadership will henceforth meet annually in Paris, France. The next IFNEC leadership meetings are scheduled for the week of 26 June 2017.

For more information about IFNEC or the NEA Technical Secretariat, or to view IFNEC publications, please visit www.ifnec.org or www.oecd-nea.org.

# NEA collaborative activities related to accident-tolerant fuels

by S. Massara and A. Breest

Dr Simone Massara (simone.massara@oecd.org) is a Nuclear Scientist in the NEA Division of Nuclear Science; Dr Axel Breest (axel.breest@oecd.org) is Nuclear Safety Research Co-ordinator in the NEA Division of Nuclear Safety Technology and Regulation.


Halden reactor hall showing the rotating floor plate above the cavity containing the reactor vessel, Norway.

The broad spectrum of NEA collaborative activities underpinning nuclear materials research spans from modelling and simulation, including advanced multiscale and multiphysics methods, to the development of a database for current and advanced nuclear fuels. The NEA is also supporting collaborative efforts towards the development of advanced materials, such as fuels for partitioning and transmutation purposes and accident-tolerant fuels (ATFs). ATFs cover a broad range of materials potentially envisaged for the core of generation II light water reactors (LWRs) currently in operation, as well as for generation III reactors under construction. ATFs usually imply for example materials for the fuel sub-assembly (fuel, cladding and boiling water reactor [BWR] channel box) and for control rod devices.

R&D on ATF candidate materials began prior to the Fukushima Daiichi nuclear power plant accident in March 2011. During the international debate that followed the accident, the development of advanced fuel designs with a substantially enhanced performance under severe accidents was identified as an important measure that would significantly improve the safety of LWRs. As a result, new momentum arose to expand national and international R&D programmes related to ATFs.

In order to complement national R&D efforts devoted to ATFs, the NEA responded with two medium-term actions under its Nuclear Science Committee (NSC) and its Committee on the Safety of Nuclear Installations (CSNI). Two international workshops on ATFs were organised in 2012 and 2013, followed by the establishment of an expert group in 2014. On the experimental side, irradiations of ATF candidate materials are scheduled for 2017 within the framework of the NEA Halden Reactor Project (HRP). The following sections examine in more detail the work of this expert group and of ATF-related irradiations within the Halden Reactor Project.

## The Expert Group on Accident-tolerant Fuels for LWRs

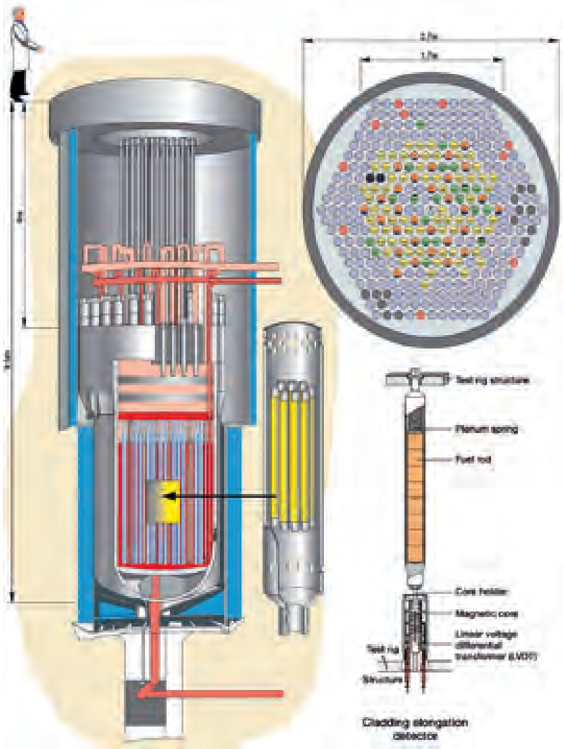
In 2014, the NEA Nuclear Science Committee established the Expert Group on Accident-tolerant Fuels for LWRs, which acts primarily as a forum for scientific and technical information exchange on advanced LWR fuels with enhanced accident tolerance. Ideally, new designs will provide enhanced tolerance to extended station blackout conditions with loss of active cooling, while maintaining or improving the fuel performance and safety characteristics during normal operations and for other design-basis accidents (DBAs) or beyond-design-basis-accident (BDBA) scenarios. The desired characteristics of these enhanced materials and designs include:

- improved reaction kinetics with steam;
- a reduced hydrogen generation rate;
- improved fuel and cladding thermo-mechanical properties to retain coolable and controllable geometry for an extended period without cooling;
- enhanced fission product retention.

The expert group currently includes members from 34 organisations – representing R&D organisations, nuclear operators, fuel vendors, academia, technical support organisations and research and test reactors from 14 NEA member countries (Belgium, the Czech Republic, France, Germany, Japan, Korea, the Netherlands, Norway, Russia, Spain, Switzerland, Sweden, the United Kingdom and the United States). Observers from the International Atomic Energy Agency (IAEA) and representatives from the People's Republic of China are regularly invited to meetings.

To accomplish its broad programme of work and to cover a variety of technical issues – which include, *inter alia*, material science as applied to fuel and cladding materials, core design, 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.

Source: Institute for Energy Technology, Norway.




severe accident analyses, fuel cycle issues, economics and licensing issues – three NEA task forces were established to implement the programme of work on systems assessment, cladding and core materials, and fuel concepts. These task forces are in the process of drafting two technical reports to outline the international, state-of-the-art knowledge on fundamental properties and behaviour under normal operations and accident conditions (DBAs and BDBAs) for advanced core materials and components with enhanced accident tolerance. These reports will also identify major knowledge gaps that need to be addressed in order to bring the most promising ATF candidates to commercial readiness by the 2020s; provide a definition of evaluation metrics that will be used to characterise the performance of ATF candidate materials; agree upon a definition of technology readiness levels (TRL) used to characterise the development level of ATF candidate materials; make a proposal of illustrative scenarios to compare the performance of ATF candidate materials in BDBA conditions; and undertake a review of the status of modelling and simulation codes (fuel performance and system level) applicable to ATFs.

In order to minimise overlap and avoid duplication between NEA and IAEA activities, close links are maintained with the IAEA, and particularly with the IAEA "Coordinated Research Project on Analysis of Options and Experimental Examination of Fuels for Water Cooled Reactors with Increased Accident Tolerance" (ACTOF), which was initiated in 2015 for a period of three years.

A large spectrum of cladding materials, non-fuel components and fuel designs will be addressed in NEA reports to identify knowledge gaps, carry out a review of experimental facilities available for qualification purposes, and possibly orient further actions needed for ATF candidate materials, including:

- cladding materials: coated and improved Zr-based alloys, SiC and SiC/SiC composites, non-Zr-based metallic claddings, refractory metals;
- non-fuel components, such as advanced control rod systems and advanced channel boxes for BWRs;
- fuel designs: improved $UO_2$ (doped either with Cr, Mo, BeO or SiC, or oxide/metallic microcell), high-density fuel (i.e. nitride and/or silicide) and fully ceramic micro-encapsulated fuel derived from the fuel technology developed for the (very) high-temperature gas reactor (VHTR).

## Experimental programme of the NEA Halden Reactor Project

The NEA Halden Reactor Project (HRP) is an internationally sponsored project organised under the auspices of the NEA and operated by the Institute for Energy Technology (IFE) in Norway. The project is the oldest ongoing joint project at the NEA, having begun 58 years ago. Today, the HRP includes members from 20 countries and covers three main topics: i) nuclear fuels, ii) nuclear materials, and iii) human factors and digital systems.

For nuclear fuels, numerous, separate research projects are performed with a focus on fuel safety and operational margins. All the projects take the form of highly instrumented irradiation testing carried out in the Halden boiling water reactor (HBWR), and are followed by post-irradiation examinations.

A new long-term fuel irradiation experiment is currently in the planning stages as part of the HRP joint research programme. It will focus on improved performance fuels, including those with increased tolerance to accident conditions. The main objective is to study the thermo-mechanical and fission gas release behaviour of four different fuels proposed as candidates for ATF concepts. Irradiation will initially focus on fuel volume change, such as densification and swelling during the early stages of irradiation, while at the same time monitoring fuel rod pressure. The focus will later turn to fission gas release behaviour.

Each fuel rod will be equipped with a fuel thermocouple, a fuel stack elongation detector and a rod pressure sensor. The irradiation is planned to start in 2017 and to last for four to five years with a target burn-up of ~40 MWd/kg oxide. The power history will entail an initial period at moderate power followed by later periods with power increase so as to promote fission gas release. The fuel will be irradiated directly in the HBWR moderator at 235°C and 34 bar pressure conditions.

To evaluate the potential benefits of promising, accident-tolerant fuel claddings, a new experiment will be carried out within the HRP joint research programme to study the behaviour of several candidate claddings compared to a reference of Zircaloy-4. The overall objective of the experiment is to demonstrate that the in-reactor behaviour of ATF claddings is at least as good as Zr-based claddings in use today under prototypic pressurised water reactor (PWR) operation conditions, based on the rate of oxide thickness increase and on dimensional behaviour.

The irradiation test, due to begin at the end of 2016 (see Box 1 on page 10), consists of six test rods installed in a pressure flask connected to a PWR loop system with a coolant temperature of 300-320°C and 155 bar pressure. The water chemistry is 2-3 ppm Li with boron addition aimed at maintaining a pH300 of ~7.2. Five of the six fuel rods each consist of four segments of ~120 mm in length (with ~100 mm active fuel stack height plus end pellets) interconnected with 50 mm plug sections, and the unsegmented rod is ~630 mm in length (with ~600 mm active stack height plus end pellets).

**Box 1: The Halden Reactor Project test matrix for fuel includes the following technologies**

- one rod with UN fuel with low Si content (<1 000 ppm weight);
- one rod with UN-$U_3Si_5$ fuel with Si content of 10-15% light atoms;
- one rod with metallic microcell $UO_2$ fuel with up to 5 vol% Mo (or Mo alloy);
- one rod with ceramic microcell $UO_2$ fuel with ~2 vol% $SiO_2$-based oxide mixture;
- one rod with three variants of UN (high-purity, carbon-rich, oxygen-rich);
- one reference fuel rod.

All six rods will be fuelled with ~10wt% enriched $UO_2$ pellets (see Box 2), which will be slightly oversized to give an initial pellet-clad gap of ~50 µm so as to promote early onset of pellet-cladding mechanical interaction. Rod powers will be 20-25 kW/m with a fast neutron flux (>0.1 MeV) of the order of ~$2x10^{13}$ n/cm$^2$/s. The irradiation is planned to last for four to five years with a target burn-up of ~40 MWd/kg oxide.

The test rig will be unloaded each year for an interim inspection, which will include visual inspections (indications of loss of coating integrity), eddy current/proximity probe measurements (for defect detection and oxide thickness), profilometry measurements (for segment/rod length and diameter change), a consideration of whether to remove/replace segments in case of planned, early destructive post-irradiation examinations, or to remove/replace segments in case of unexpected poor behaviour.

At the end of the irradiation, post-irradiation examinations will be performed, adding to the above list of inspection with neutron radiography, ceramography/metallography, high-temperature steam oxidation tests and mechanical testing, as well as additional microstructural investigations at HRP-participating hotlabs.

The NEA will continue to support collaborative activities on accident-tolerant fuels both through its Expert Group on Accident-tolerant Fuels for LWRs and through the activities of the NEA Halden Reactor Project.

The authors of this article would like to acknowledge for their considerable contributions to the aforementioned work: K. Pasamehmetoglu (Idaho National Laboratory, United States), Chair of the Expert Group on Accident-tolerant Fuels for LWRs (EGATFL); S. Bragg-Sitton (Idaho National Laboratory, United States), Chair of EGATFL Task Force 1: Systems Assessment; M. Moatti (EDF, France), Chair of EGATFL Task Force 2: Cladding and Core Materials; M. Kurata (Japan Atomic Energy Agency), Chair of EGATFL Task Force 3: Fuel Designs; and M. A. McGrath, Project Manager, NEA Halden Reactor Project, Norway.

**Box 2: The test matrix for Halden Reactor Project candidate cladding**

- **Rod-1: Cr-coated, Zr-based cladding**
  The French Alternative Energies and Atomic Energy Commission (CEA), in collaboration with Areva-NP and EDF, is developing an optimised Cr-coating, and the test includes one fuel rod made from two segments of ~5 µm thick Cr-coated Zry-4 and two segments of ~15 µm thick Cr-coated Zry-4.
- **Rod-2: Surface modified and coated Zr-based cladding**
  The Korea Atomic Energy Research Institute (KAERI) is developing an optimised CrAl and Cr/FeCrAl coating with and without an oxide dispersion strengthened (ODS) treatment. The ODS treatment consists of laser beam scanning (LBS) of a $Y_2O_3$ powder spread on a Zry-4 tube forming an ODS-alloyed layer 20% of wall thickness. The test includes one fuel rod made from two segments of ~50 µm thick CrAl-coated Zry-4, one with ODS and the other without, and two segments of ~100 µm thick Cr/FeCrAl-coated Zry-4, one with ODS and the other without.
- **Rod-3: Cr or Mo-coated Zr-based cladding**
  The Westinghouse Electric Company is continuing to investigate applying Cr- or Mo-based coatings to optimised Zirlo cladding, and the test includes one fuel rod made from two coated segments from the Westinghouse Electric Company (the other two segments are FeCrAl).
- **Rod-4: Optimised FeCrAl alloy cladding**
  The Oak Ridge National Laboratory (ORNL) is developing a FeCrAl ferritic alloy with 5-7 wt% Al, and the test includes one fuel rod (rod 3) with two segments made from FeCrAl (the other two segments are Cr- or Mo-coated optimised Zirlo), as well as an unsegmented fuel rod made with full test rod length FeCrAl cladding of ~350 µm thickness, instrumented with a cladding elongation detector to monitor pellet-cladding mechanical interaction behaviour online during the irradiation.
- **Rod-5: Mo alloy-based cladding**
  The Electric Power Research Institute (EPRI) is developing a composite metal cladding with a Mo alloy tube for structural strength and an outer tube of Zr-2.6Nb for aqueous corrosion and steam oxidation resistance. The inner and outer tubes are hot isostatic pressed together for an interdiffusional bond. The test includes one fuel rod made from two segments of Mo/Zr-Nb composite cladding and two segments of the same composite cladding, but with an Nb film in between the two tubes to investigate if this prevents the formation of Mo-Zr intermetallic phases.
- **Rod-6: Reference Zry-4 cladding**

## Further information

NEA Expert Group on Accident-tolerant Fuels for LWRs: www.oecd-nea.org/science/egatfl.

NEA Halden Reactor Project: www.oecd-nea.org/jointproj/halden.html.

# Costing for decommissioning: Continuing NEA engagement

by M. Gillogly, I. Weber and M. Siemann

Ms Mari Gillogly (mari.gillogly@oecd.org) is Policy Analyst and Ms Inge Weber (inge.weber@oecd.org) is Radioactive Waste Management Specialist in the NEA Division of Radiological Protection and Radioactive Waste Management. Dr Michael Siemann (michael.siemann@oecd.org) is Head of the NEA Division of Radiological Protection and Radioactive Waste Management.


Decommissioning cost estimation has been discussed at length in the context of NEA work over the years and has led to the publication of several reports including the *International Structure for Decommissioning Costing* (ISDC) *of Nuclear Installations* (NEA, 2012) and *Costs of Decommissioning Nuclear Power Plants* (NEA, 2016). Feature articles on the costs of decommissioning have also been published in *NEA News*, including the recent *Nuclear Power Plant Decommissioning Costs in Perspective* (*NEA News* No. 34.1). A policy debate on the Financing of Decommissioning was held at the 2016 April meeting of the NEA Steering Committee for Nuclear Energy, at which time participants acknowledged the limited amount of experience worldwide with fully decommissioned nuclear power plant projects. The background document for this debate was transformed into a publication entitled *Financing the Decommissioning of Nuclear Facilities* (NEA, 2016).

In order to continue exploring this topic, the NEA organised a two-day International Conference on Financing of Decommissioning (ICFD-2016) held in Stockholm, Sweden on 20-21 September 2016. The conference was jointly organised by the NEA and Sweden's Radiation Safety Authority (SSM), and it welcomed over 100 participants from 18 countries. Participants were able to share and discuss their experiences with the aim of better understanding funding mechanisms, cost estimation approaches and risk management strategies in a range of NEA member countries.

Two keynote speeches launched the conference, offering insight into decommissioning financing in the current economic situation from an investment perspective, and into a "stress test" methodology for funds developed in Germany. The German example underlines a reality that has already been highlighted in the NEA decommissioning cost study (NEA, 2016): that funding mechanisms, cost estimation and risk management approaches are different in all countries. The heterogeneity of national systems for decommissioning financing can be explained by differing national contexts, where most systems are well-developed, operational and individualised, but where each of these fits into a given country's national legislative and commercial landscape. More often than not, the entire national system and its mechanisms, rather than the specific detailed features, must be considered in determining the overall effectiveness of such arrangements. The conference conclusion thus appropriately underlined that there is no best or worst method or system, and that experiences from a variety of countries need to be considered in light of their potential relevance in other contexts.

In terms of funding mechanisms, it should also be noted that different systems for guarantees and for the verification of funds have been established in NEA member countries, and that responsible organisations periodically review the various mechanisms in place, as well as how well these are functioning according to specific requirements and expectations. Commonalities can nonetheless be identified when examining the relevant characteristics which help to identify and choose the appropriate funding mechanism, especially in terms of how well these might respond to changing and challenging market conditions, or to unexpected or uncertain situations that may arise (early shutdowns, shifts in regulatory requirements over time, or unidentified final waste disposal routes). The conclusions of the International Conference on Financing of Decommissioning (ICFD-2016) emphasised that more attention should be given to these factors when reviewing the ongoing suitability of funding mechanisms.

Some progress has already been made in providing international guidance on good practices for the comprehensiveness, quality, consistency and comparability of cost estimations for decommissioning nuclear facilities. Weaknesses remain, however, especially in terms of understanding the relationship between estimates and

SOGIN

Segmenting large plant items during the dismantling of the cooling towers for residual heat removal, Caorso nuclear power plant, Italy.

Enresa, Spain

Dismantling of elements from the primary pump, José Cabrera nuclear power plant, Spain.

actual costs, as well as in dealing with issues of limited relevance or with unreliable cost data. A general reluctance to share data also continues, with barriers sometimes set up to prevent data sharing. Looking ahead, more experience will be gained through continued use of the International Structure for Decommissioning Costing; and more actual cost data can and should become available as additional projects are undertaken. Improvements are expected in relation to the treatment of uncertainties in cost estimations, notably through forthcoming guidance from a joint NEA/IAEA project. Adequate benchmarking will also contribute to the development of validation methods for cost estimation approaches.

A number of key factors were identified at the conference in relation to risk management for decommissioning financing, all of which could improve project cost control for nuclear power plant decommissioning. First, good project management and oversight is of utmost importance. A speaker from the United States gave the example of shared risks and benefits when contracts were provided to subcontractors; a representative from the European Court of Auditors recommended monitoring operations more closely throughout the lifecycle of a plant; and a speaker from Spain insisted on the value of considering project management costs within the total cost, as in the case of the José Cabrera nuclear power plant (NPP). Sound knowledge of the NPP was also considered a prerequisite for preventing costs from increasing dramatically over time, which could include understanding the site's initial state, soil and environmental situation, contamination within buildings or water sources. And finally, it was noted that cost increases are often greater for earlier-than-planned definitive shutdowns, and that funding mechanisms need to include the possibility of such an event.

After taking into account costing, funding and financing risks, a number of overarching conclusions were drawn at the end of the conference, particularly the importance of having viable options for management, which includes the disposal of radioactive waste from decommissioning. Lack of available options for radioactive waste, as well as the possibility to remove spent fuel from the facility to be decommissioned, are two of the primary constraints involved in decommissioning, but they also give rise to major uncertainties when attempting to determine overall financial requirements.

Discussions are already taking place in existing international fora on this subject, but it must be reiterated that radioactive waste management issues – the "back end" of the fuel cycle – should be a focus of decommissioning considerations at the beginning of facility planning and development. Reliable decommissioning cost estimation can only be based on an intensive information exchange between experts at the international level, and such estimates need to be validated against actual decommissioning cost experience. This practice-sharing in cost estimation and benchmarking in turn enables continued decommissioning project improvements, while allowing for broader discussions on some of the more sensitive parameters for financing schemes (namely, the stability and predictability of rates-of-return on decommissioning funds and the date of the final shutdown of a given NPP).

Growing interest in co-operation on all decommissioning topics has broadened the role of international organisations in offering opportunities for international experience exchange and information sharing. At the Stockholm workshop, the activities of the NEA, the IAEA and the European Commission (EC), as well as other joint activities, were recognised as vital for the international exchange of lessons learnt and for experience sharing. The limited number of experts in this field has also underlined the critical nature of better co-ordination and of clearly separating activities among international organisations, with specific definitions of scope.

The NEA and IAEA will continue to disseminate reports and organise discussions on this subject so as to work towards expanding the knowledge base for decommissioning estimates and address risks and uncertainties in the financing of decommissioning. Two forthcoming reports will bring this discussion to a wider audience: the joint NEA/IAEA report *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities* and the IAEA report on *Decommissioning Risk Management*.

As recommended by conference participants, the NEA will continue to sharpen the focus and scope of its joint activities on analysing structure, adequacy and funding (including the availability of funding when the funds become necessary) for the financing of decommissioning, radioactive waste disposal and spent fuel management.

# 10th national workshop of the NEA Forum on Stakeholder Confidence

by K. Martin

Ms Kamishan Martin (kamishan.martin@oecd.org) is a Nuclear Safety Specialist in the Division of Human Aspects of Nuclear Safety.

Participants at the annual FSC meeting in Bern, Switzerland, September 2016.

Management of radioactive waste presents a number of challenges, including processing, storage of different levels of waste, transport of waste and the ultimate disposal of waste. Such a complex process may take decades to complete, and today's decision makers will not necessarily be around to ensure that future generations understand how decisions were made or how to maintain the associated safety in radioactive waste management, emphasising the need for a close relationship between policymakers who decide what is to be done with such waste and representatives of local communities, as well as younger generations who will be tasked with sustaining the waste management programme's decisions over the long term.

Since 2000, the Nuclear Energy Agency has held and facilitated open dialogues in the NEA Forum on Stakeholder Confidence (FSC), where member countries analyse, document and develop recommendations for developing waste management programmes. The FSC fosters learning about dialogues with those who have a role to play or an interest in the process of making decisions about radioactive waste management and about ways to develop shared confidence, informed consent and acceptance of radioactive waste management solutions. Participants include government policy and regulatory officials, research and development specialists, implementers and industry representatives, all of whom exchange information and experiences on embedding waste management programmes into a socio-political, decision-making context.

Eighteen NEA member countries with radioactive waste management programmes participate actively in the FSC, including Belgium, Canada, the Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Korea, Norway, Poland, Russia, Spain, Sweden, Switzerland, the United Kingdom and the United States. FSC members' exchange experiences and information on open governance. Their commitment helps to promote a cultural change in their organisations and home countries. Some stakeholders are fearful that radioactive waste management programmes may compromise their safety, and this may lead to a lack of confidence in the decision-making process. Historically, the workshops have proven to be constructive in fostering national dialogue and helping frame the issues that stakeholders would like to see addressed. The neutral platform of the FSC makes it possible to:

- gather all stakeholders from the host country under a single roof;
- help new actors, or those who are not members of an established organisation, to participate in the process;
- help initiate a new phase in an existing process of reflection and exchange;

10th national workshop of the FSC
Bern, Switzerland.


The Mont Terri Rock Laboratory,
Switzerland.

- give local stakeholders the possibility to meet international delegates and to share experiences;
- record the views of different kinds of stakeholders.

In September 2016, the FSC held its 10th national workshop in Bern, Switzerland immediately following the annual meeting. The workshop was hosted by the Swiss Federal Office of Energy (SFOE) and focused on two challenges: the societal and intergenerational knowledge gap, and the sustainability and stability of decisions.

Determining sites for deep geological repositories in Switzerland is a politically controversial topic that has been discussed on many occasions, without yet reaching a conclusion. The selection procedure for Switzerland is today outlined in the "Sectoral Plan for Deep Geological Repositories", which provides both conceptual and implementation aspects. The plan stipulates the different forms of participation, with a major focus on integrating the regional population through regional conferences that have three main tasks:

- to discuss socio-economic, environmental and ecological impacts, the development of scenarios for sustainable regional development, proposals to support measures and projects aimed at minimising potentially negative socio-economic and environmental impacts or increasing positive effects, as well as the basis for monitoring such impacts.
- to discuss proposals for the layout, location of, and access to, the surface infrastructure;
- to accumulate expertise, preserve knowledge and form opinions.

Site selection takes place in three stages that will last over 20 years. Geological information will be gathered gradually, leading to a reduction in the number of prospective sites, with safety being the main criterion in site selection.

The 10th national workshop in Switzerland brought together 84 attendees, including international FSC members, Swiss stakeholders, government officials, regulators, implementers, regional siting representatives, members of the public and youth ranging from 16 to 25 years of age. Opening remarks were delivered by the NEA Director-General William D. Magwood, IV, and Swiss Federal Councillor Doris Leuthard. The workshop format included a series of presentations on the major themes of the workshop and on the Swiss site selection process for a deep geological repository followed by roundtable discussions in smaller breakout sessions to discuss presentations. During roundtable discussions, participants were asked to reflect upon the material presented. To stimulate discussion, moderators provided theoretical questions on the workshop themes, which included:

- societal and intergenerational knowledge gaps;
- intergenerational involvement;
- transparency of the decision-making process;
- sustainable decisions for all stakeholders having a voice in the decision-making process;
- flexibility of decisions and decision-making processes, as well as the reversibility of decisions made in relation to the management of radioactive waste over the long term.

The workshop offered an opportunity to reinforce and create ties among stakeholders, who were also able to visit a national research facility, the Mont Terri Rock Laboratory.

Through such initiatives, the FSC contributes to a new approach to decision making on the management of radioactive waste. Workshops provide the occasion and method for mutual learning and for implementing dialogue, with themes taken up in a spirit of openness and service to member countries. FSC workshops and visits have proven to be constructive in fostering national dialogue and helping frame issues that stakeholders would like to address.

# International Conference on Nuclear Data for Science and Technology

by F. Michel-Sendis , O. Cabellos and J. Dyrda

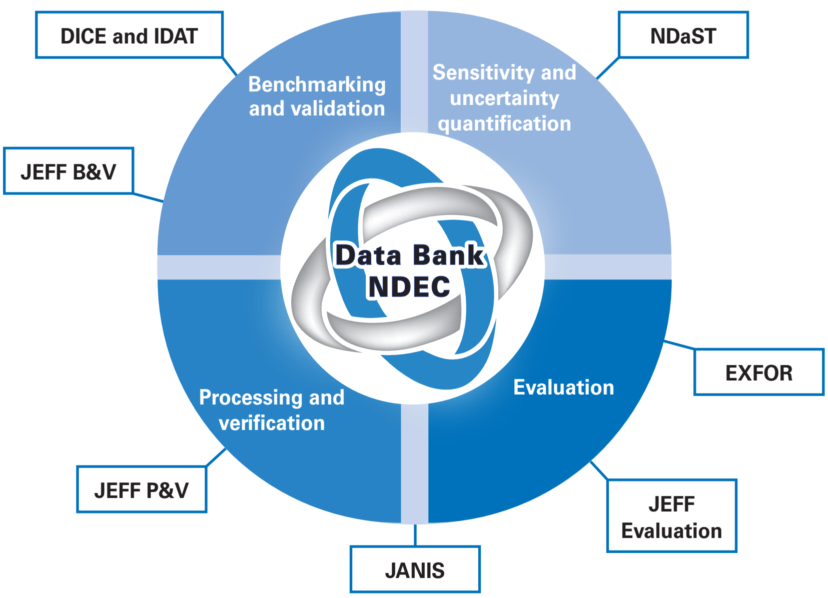
Dr Franco Michel-Sendis (franco.michel-sendis@oecd.org) and Dr Oscar Cabellos (oscar.cabellos@oecd.org) are Nuclear Data Scientists in the NEA Data Bank. Dr James Dyrda (james.dyrda@oecd.org) is a Nuclear Scientist in the NEA Nuclear Science Division.

The International Conference on Nuclear Data for Science and Technology (ND-2016), organised by the European Commission (EC) in co-operation with the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) in Bruges, Belgium on 11-16 September 2016, offered over 500 participants from 41 countries the opportunity to present nuclear data measurements, nuclear theories and models, data evaluation and validation, integral experiments and uncertainty quantification for different areas of application. The conference is instrumental in the advancement of nuclear data in the interest of both science and technology, and the NEA Data Bank took the opportunity to present its activities to participants, underlining in particular its role in supporting the nuclear data necessary for the demands of the future. NEA Director-General William D. Magwood, IV gave an introductory keynote address and joined the Q&A panel at the opening plenary session. The conference was an important opportunity for NEA staff to highlight significant progress, not only in specific NEA co-ordinated projects but also in open access support, which includes software tools and databases for users in NEA member countries.

## NEA nuclear data tools and databases

The challenge for any nuclear data evaluation is to periodically release a revised, fully consistent and complete library, with all required data and covariances, ensuring it is robust and reliable for a variety of applications. Within an evaluation effort, benchmarking activities play an important role in validating proposed libraries. The Joint Evaluated Fission and Fusion (JEFF) Project is an example of a library that relies on NEA tools and databases for a coherent and efficient benchmarking process. These tools and databases have been used in particular to assist the JEFF Project in its production and selection of JEFF-3.3 file candidates. NEA staff offered a brief summary of these tools (as shown in Figure 1 below) at the ND-2016.

**Figure 1: NEA Data Bank tools and databases**



Robert Eastman, Shutterstock

Twisting tunnel of digital binary computer code.

NEA representatives also made presentations on other projects, software and databases managed by the NEA Data Bank, including on:

- The Java-based Nuclear Information Software (JANIS), which has been developed by the NEA Data Bank to facilitate the visualisation and manipulation of nuclear data, gives access to all major Evaluated Nuclear Data libraries. It also provides access to experimental nuclear data (Experimental Nuclear Reaction Data – EXFOR) and their bibliographical references (Computer Index of Nuclear Reaction Data – CINDA).
- The Database for the International Criticality Safety Benchmark Evaluation Project (DICE), which contains 567 evaluations representing 4 913 critical, near-critical or subcritical configurations in a standardised format that allows for criticality safety analyses. This database is routinely used to validate calculation tools and cross-section libraries. DICE also provides the user with access to sensitivity coefficients (percent changes of k-effective as a result of elementary changes to basic nuclear data) for the major nuclides and reactions.
- The Nuclear Data Sensitivity Tool (NDaST), which is a Java-based software, designed to perform calculations on nuclear data sensitivity files for benchmark cases. These calculations are either an estimation of the impact of nuclear data perturbations to the computed case results, and/or the uncertainty in the computed results due to evaluated nuclear covariance data. NDaST can access JANIS data and benchmark cases from the International Reactor Physics Evaluation (IRPhE) database in addition to the criticality benchmarks from the International Criticality Safety Benchmark Evaluation Project (ICSBEP).
- The Nuclear Data Evaluation Cycle (NDEC), currently under construction at the NEA Data Bank, is a systematised, workflow platform for handling and diagnosing the quality of nuclear data evaluations under the different steps involved in the production of nuclear data libraries. These steps are the verification, processing, differential validation and integral benchmarking of evaluated nuclear data files.
- The new Spent Fuel Isotopic Composition (SFCOMPO-2.0) database of spent fuel assay data, developed by the NEA in strong collaboration with the Oak Ridge National Laboratory, was also presented. Assay data are radio-chemically determined nuclide densities of spent fuel samples complemented by corresponding reactor design data, operational data and irradiation conditions of the samples. Today, SFCOMPO-2.0 contains experimental data from over 730 samples of over 40 reactors representing 8 different reactor types. SFCOMPO-2.0 is available as a Java application, downloadable from the NEA website.

At the close of the conference, the Head of the NEA Data Bank, Jim Gulliford, gave a presentation on Nuclear Data Knowledge Management, focusing on international co-operation and NEA activities. One trend at the conference this year was the increasing attendance of Chinese experts, and continued growth in the technical capability of China with regard to nuclear data, as exemplified through the presentation on the release of their Chinese Evaluated Nuclear Data Library (CENDL). In order to further facilitate this enhanced engagement with the international community, it was confirmed by the organisers that the 2019 event would be hosted by China.

### Further information

See International Conference on Nuclear Data for Science and Technology at www.nd2016.eu.

# Nuclear safety, nuclear science, radioactive waste management, radiological protection

NEA joint projects and information exchange programmes enable interested countries, on a cost-sharing basis, to pursue research or the sharing of data with respect to particular areas or issues in the nuclear energy field. The projects are carried out under the auspices, and with the support, of the NEA.

At present, 17 joint projects are being conducted or completed in relation to nuclear safety, one in the area of nuclear science (advanced fuels), two in support of radioactive waste management and one in the field of radiological protection. These projects complement the NEA programme of work and contribute to achieving excellence in each area of research.*

| Project | Participants | Budget | Objectives |
|---|---|---|---|
| **Advanced Thermal-hydraulic Test Loop for Accident Simulation (ATLAS) Project**<br>Contact: nils.sandberg@oecd.org<br>Current mandate: April 2014-March 2017 | Belgium, China, Finland, France, Germany, Hungary, India, Japan, Korea, Russia, Spain, Sweden, Switzerland, United Arab Emirates and United States. | EUR 2.5 million | • Provide experimental data for resolving key light water reactor (LWR) thermal-hydraulics safety issues related to multiple, high-risk failures, notably those highlighted by the Fukushima Daiichi nuclear power plant (NPP) accident.<br>• Focus in particular on the validation of simulation models and methods for complex phenomena of high safety relevance to thermal-hydraulic transients in design-basis accidents and design extension conditions. |
| **Behaviour of Iodine Project (BIP)**<br>Contact: axel.breest@oecd.org<br>Current mandate: January 2016-December 2018 | Belgium, Canada, Finland, France, Germany, Japan, Korea, Spain, Sweden, United Kingdom and United States. | EUR 1 million | • Obtain a more detailed and mechanistic understanding of iodine adsorption/desorption on containment surfaces by means of new experiments with well characterised containment paints and paint constituents, and novel instrumentation (spectroscopic methods).<br>• Obtain a more detailed and mechanistic understanding of organic iodide formation by means of new experiments with well characterised containment paints and paint constituents, and novel instrumentation (chromatographic methods).<br>• Develop a common understanding of how to extrapolate with confidence from small-scale studies to reactor-scale conditions. |
| **Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant (BSAF)**<br>Contact: kentaro.funaki@oecd.org<br>Current mandate: April 2015-March 2018 | Canada, China, Finland, France, Germany, Japan, Korea, Russia, Spain, Switzerland and United States. | EUR 270 K | • Analyse the accident progression of the Fukushima Daiichi NPP accident using the common information database.<br>• Improve the understanding of the severe accident (SA) phenomena which occurred during the accident, through comparison with participants' analysis results and with measured plant data.<br>• Contribute the above results to the improvement of methods and models of the SA codes applied in each participating organisation in order to reduce uncertainties in SA analysis and to validate the SA analysis codes by using data measured through the decommmissioning process.<br>• Contribute results of the analysis on accident progression, the status in the reactor pressure vessels (RPVs) and the primary containment vessels (PCVs), and the status of debris distribution to a future debris removal plan. |

* At the time of publication, a new joint project was under preparation in the area of nuclear science: "Thermodynamic Characterisation of Fuel Debris and Fission Products Based on Scenario Analysis of Severe Accident Progression at Fukushima Daiichi Nuclear Power Station" or the "TCOFF Project".

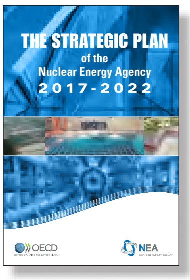
| Project | Participants | Budget | Objectives |
|---|---|---|---|
| **Cable Ageing Data and Knowledge (CADAK) Project**<br>Contact: ollivilhelm.nevander@oecd.org<br>Current mandate: January 2015-December 2017 | Canada, Germany, Slovak Republic, Switzerland and United States. | EUR 50 K/year | • Establish the technical basis for assessing the qualified life of electrical cables in light of the uncertainties identified following the initial (early) qualification testing. This research will investigate the adequacy of the margins and their ability to address the uncertainties.<br>• Enter for a number of member countries cable data and information in the system, e.g. technical standards being applied in the qualification of cables and inspection methods being used regularly.<br>• Estimate the remaining qualified lifetime of cables used in NPPs. The cable condition-monitoring techniques shared by the participants within CADAK will become an up-to-date encyclopaedic source to monitor and predict the performance of numerous unique applications of cables. |
| **Cabri International Project (CIP)**<br>Contact: martin.kissane@oecd.org<br>Current mandate: March 2015-March 2018 | Czech Republic, Finland, France, Germany, Japan, Korea, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and United States. | ≈EUR 74 million | • Extend the database for high burn-up fuel performance in reactivity-induced accident (RIA) conditions.<br>• Perform relevant tests under coolant conditions representative of pressurised water reactors (PWRs).<br>• Extend the database to include tests done in the Nuclear Safety Research Reactor (Japan) on boiling water reactor (BWR) and PWR fuel. |
| **Component Operational Experience, Degradation and Ageing Programme (CODAP)**<br>Contact: ollivilhelm.nevander@oecd.org<br>Current mandate: February 2015-December 2017 | Canada, Chinese Taipei, Czech Republic, France, Germany, Japan, Korea, Slovak Republic, Spain, Switzerland and United States. | EUR 75 K/year | • Collect information on passive metallic component degradation and failures of the primary system, RPV internals, main process and standby safety systems, and support systems (i.e. ASME Code Class 1, 2 and 3 or equivalent), as well as non-safety-related (non-code) components with significant operational impact.<br>• Establish a knowledge base for general information on component and degradation mechanisms such as applicable regulations, codes and standards, bibliography and references, R&D programmes and pro-active actions, information on key parameters, models, thresholds and kinetics, fitness for service criteria, and information on mitigation, monitoring, surveillance, diagnostics, repair and replacement.<br>• Develop topical reports on degradation mechanisms in close co-ordination with the CSNI Working Group on Integrity and Ageing of Components and Structures (WGIAGE). |
| **Co-operative Programme on Decommissioning (CPD)**<br>Contact: inge.weber@oecd.org<br>Current mandate: January 2014-December 2018 | Belgium, Canada, Chinese Taipei, Denmark, European Commission, France, Germany, Italy, Japan, Korea, Russia, Slovak Republic, Spain, Sweden, United Kingdom and United States. | ≈EUR 80 K/year | • Exchange scientific and technical information among decommissioning projects nuclear facility, based on biannual meetings of the Technical Advisory Group, to ensure that the safest, most environmentally friendly and economical options for decommissioning are employed. |
| **Fire Incidents Records Exchange (FIRE) Project**<br>Contact: ollivilhelm.nevander@oecd.org<br>Current mandate: January 2016-December 2019 | Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Korea, Netherlands, Spain, Sweden, Switzerland and United States. | EUR 70 K/year | • Collect fire event experience (via international exchange) in the appropriate format and in a quality-assured and consistent database.<br>• Collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention.<br>• Generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences.<br>• Establish a mechanism for the efficient feedback of experience gained in connection with fire, including the development of defences against their occurrence, such as indicators for risk informed and performance based inspections.<br>• Record the characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies. |

| Project | Participants | Budget | Objectives |
|---|---|---|---|
| **Fire Propagation in Elementary, Multi-room Scenarios (PRISME) Project**<br>Contact: andrew.white@oecd.org<br>Previous mandate: July 2011-December 2016<br>New mandate under discussion | Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden and United Kingdom. | EUR 7 million | • Answer questions concerning smoke, fire and heat propagation inside a plant, by means of experiments tailored for code validation purposes for fire modelling computer codes.<br>• Undertake experiments related to smoke and hot gas propagation, through a horizontal opening between two superimposed compartments.<br>• Provide information on heat transfer to cables and on cable damage.<br>• Provide information on the effectiveness of fire extinguishing systems. |
| **Halden Reactor Project**<br>Contact: axel.breest@oecd.org<br>Current mandate: January 2015-December 2017 | Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Japan, Kazakhstan, Korea, Norway, Russia, Slovak Republic, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom and United States. | ≈ EUR 55 million | Generate key information for safety and licensing assessments and aim at providing:<br>• extended fuel utilisation: basic data on how the fuel performs, both under normal operation and transient conditions, with emphasis on extended fuel utilisation in commercial reactors;<br>• degradation of core materials: knowledge of plant materials behaviour under the combined deteriorating effects of water chemistry and nuclear environment, also relevant for plant lifetime assessments;<br>• man-machine systems: advances in computerised surveillance systems, virtual reality, digital information, human factors and man-machine interaction in support of control room upgradings. |
| **High Energy Arcing Fault Events (HEAF) Project**<br>Contact: ollivilhelm.nevander@oecd.org<br>Previous mandate: July 2012-December 2016<br>New mandate under discussion | Canada, France, Germany, Japan, Korea, Spain and United States. | Costs covered by the US NRC and in-kind contributions | Perform experiments to obtain scientific fire data on the high energy arcing faults phenomena known to occur in nuclear power plants through carefully designed experiments:<br>• use data from the experiments and past events to develop a mechanistic model to account for the failure modes and consequence portions of HEAFs;<br>• improve the state of knowledge and provide better characterisation of HEAFs in fire probabilistic risk assessment (PRA) and US National Fire Protection Association NFPA 805 license amendment request applications;<br>• examine the initial impact of the arc to primary equipment and the subsequent damage created by the initiation of an arc (e.g. secondary fires).<br>• use international collaboration to expand on the pool of available test data and acquire authorship involvement in the development of a new US NUREG that consequently has international standing and applicability. |
| **Hydrogen Mitigation Experiments for Reactor Safety (HYMERES) Project**<br>Contact: axel.breest@oecd.org<br>Previous mandate: January 2013-December 2016<br>New mandate under discussion | Canada, China, Czech Republic, Finland, France, Germany, India, Japan, Korea, Russia, Spain, Sweden and Switzerland. | EUR 4 million | Improve the understanding of hydrogen risk phenomenology in containment in order to enhance modelling in support of safety assessments that will be performed for current and new NPPs. With respect to previous projects related to hydrogen risk, HYMERES introduces three new elements:<br>• tests adressing the interaction of safety components;<br>• realistic flow conditions;<br>• reviews of system behaviour for selected cases. |
| **Information System on Occupational Exposure (ISOE)**<br>Contact: olvido.guzman@oecd.org<br>Current mandate: January 2016-December 2019 | Armenia, Belarus, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Korea, Lithuania, Mexico, Netherlands, Pakistan, Romania, Russia, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Ukraine, United Arab Emirates, United Kingdom and United States. | EUR 396 100 | • Collect, analyse and exchange occupational exposure data and occupational exposure management experience at NPPs.<br>• Provide broad and regularly updated information on methods to improve the protection of workers and on occupational exposure in NPPs.<br>• Provide a mechanism for dissemination of information on these issues, including evaluation and analysis of the data assembled and experience exchanged, as a contribution to the optimisation of radiological protection. |

| Project | Participants | Budget | Objectives |
|---|---|---|---|
| **International Common-cause Failure Data Exchange (ICDE) Project**<br>Contact: axel.breest@oecd.org<br>Current mandate: January 2015-December 2018 | Canada, Czech Republic, Finland, France, Germany, Japan, Korea, Spain, Sweden, Switzerland and United States. | EUR 120 K/ year | • Provide a framework for multinational co-operation.<br>• Collect and analyse common-cause failure (CCF) events over the long term so as to better understand such events, their causes and their prevention.<br>• Generate qualitative insights into the root causes of CCF events which can then be used to derive approaches or mechanisms for their prevention or mitigation of their consequences.<br>• Establish a mechanism for the efficient feedback of experience gained in connection with CCF phenomena, including the development of defences against their occurrence, such as indicators for risk-based inspections.<br>• Generate quantitative insights and record event attributes to facilitate the quantification of CCF frequencies in member countries. Use the ICDE data to estimate CCF parameters. |
| **Loss of Forced Coolant (LOFC) Project**<br>Contact: andrew.white@oecd.org<br>Current mandate: March 2011-March 2019 | Czech Republic, France, Germany, Hungary, Japan, Korea and United States. | EUR 3 million | Perform integral tests in the high-temperature engineering test reactor (HTTR) in order to:<br>• provide experimental data to clarify the anticipated transient without scram (ATWS) in the case of an LOFC with occurrence of reactor re-criticality;<br>• provide experimental data to validate the key assumptions in computer codes predicting the behaviour of reactor kinetics, core physics and thermal-hydraulics related to protective measures for safety;<br>• provide experimental data to verify the capabilities of these codes regarding the simulation of phenomena coupled between reactor core physics and thermal-hydraulics. |
| **Primary Coolant Loop Test Facility (PKL) Project**<br>Contact: nils.sandberg@oecd.org<br>Previous mandate: April 2012-April 2016<br>New mandate under discussion | Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Korea, Spain, Sweden, Switzerland, United Kingdom and United States. | EUR 3.9 million | • Investigate safety issues relevant for current PWR plants as well as for new PWR design concepts.<br>• Focus on complex heat transfer mechanisms in the steam generators and boron precipitation processes under postulated accident situations. |
| **Source Term Evaluation and Mitigation (STEM) Project**<br>Contact: axel.breest@oecd.org<br>Current mandate: January 2016-December 2019 | Canada, Czech Republic, Finland, France, Germany, Japan, United Kingdom and United States. | EUR 2.5 million | Improve the general evaluation of the source term, and in particular:<br>• perform experiments to study the stability of aerosol particles under radiation and the long-term gas/deposits equilibrium in a containment;<br>• conduct a literature survey on the effect of paint ageing;<br>• perform experiments to study ruthenium transport in pipes. |
| **Studsvik Cladding Integrity Project (SCIP)**<br>Contact: axel.breest@oecd.org<br>Current mandate: July 2014-June 2019 | Czech Republic, Finland, France, Germany, Japan, Korea, Norway, Russia, Spain, Sweden, Switzerland, United Kingdom and United States. | ≈EUR 12 million | • Generate high-quality experimental data to improve the understanding of the dominant failure mechanisms for water reactor fuels and devise means for reducing fuel failures.<br>• Achieve results of general applicability (i.e. not restricted to a particular fuel design, fabrication specification or operating condition).<br>• Achieve experimental efficiency through the judicious use of a combination of experimental and theoretical techniques and approaches. |
| **Thermochemical Database (TDB) Project**<br>Contact: maria-eleni.ragoussi@oecd.org<br>Current mandate: April 2014-March 2018 | Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, United Kingdom and United States. | EUR 1.5 million | Produce a database that:<br>• contains data for elements of interest in radioactive waste disposal systems;<br>• documents why and how the data were selected;<br>• gives recommendations based on original experimental data, rather than on compilations and estimates;<br>• documents the sources of experimental data used;<br>• is internally consistent;<br>• addresses all solids and aqueous species of the elements of interest for nuclear waste storage performance assessment calculations. |

| Project | Participants | Budget | Objectives |
|---|---|---|---|
| **Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project**<br>Contact: simone.massara@oecd.org<br>Current mandate: January 2013-December 2017 | Canada, France, Japan, Korea, Netherlands, United Kingdom and United States. | ≈ EUR 470 K | Make available a comprehensive, internationally recognised thermodynamic database and associated phase diagrams on nuclear fuel materials for the existing and future generation of nuclear reactors. Specific technical objectives this project intends to achieve are:<br>• predict the solid, liquid and/or gas phases formed during fuel/cladding chemical interaction under normal and accident conditions;<br>• improve the control of the experimental conditions during the fabrication of the fuel materials at high temperature;<br>• predict the evolution of the chemical composition of fuel under irradiation versus temperature and burn-up. |
| **Thermal-hydraulics, Hydrogen, Aerosols, Iodine (THAI) Project**<br>Contact: martin.kissane@oecd.org<br>Current mandate: February 2016-July 2019 | Belgium, Canada, Czech Republic, Finland, France, Germany, Hungary, Japan, Korea, Luxembourg, Netherlands, Slovak Republic, Sweden and United Kingdom. | ≈ EUR 4.7 million | Address remaining questions and examine experimental data relevant to nuclear reactor containments under severe accident conditions concerning:<br>• release of fission products from a water pool;<br>• resuspension of fission products;<br>• hydrogen combustion;<br>• passive autocatalytic recombiner (PAR) operation in counter-current flow conditions. |

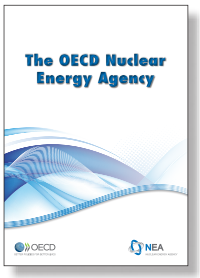
# General Interest




### The Strategic Plan of the Nuclear Energy Agency 2017-2022

*NEA No. 7295. 60 pages.*

*Available online at: www.oecd-nea.org/general/about/strategic-plan2017-2022.pdf*

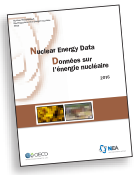



### The OECD Nuclear Energy Agency

*8 pages. Brochure.*

*Also available in French and Chinese.*

## Nuclear development and the fuel cycle

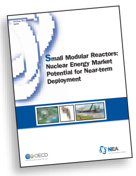


### Energy Data 2016/ *Données sur l'énergie nucléaire 2016*

*NEA No. 7300. 108 pages.*

*Available online at: www.oecd-nea.org/ndd/pubs/2016/7300-ned-2016.pdf*

*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 installed generating capacity, total electricity produced by all sources and by nuclear power, nuclear energy policies and fuel cycle developments, as well as projections of nuclear generating capacity and electricity production to 2035, where available. Total electricity generation at nuclear power plants and the share of electricity production from nuclear power plants increased slightly in 2015, by 0.2% and 0.1%, respectively. Two new units were connected to the grid in 2015, in Russia and Korea; two reactors returned to operation in Japan under the new regulatory regime; and seven reactors were officially shut down – five in Japan, one in Germany and one in the United Kingdom. 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 progressing in Finland, Hungary, Turkey and the United Kingdom.



### Small Modular Reactors

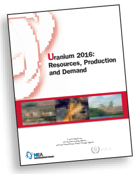
Nuclear Energy Market Potential for Near-term Deployment

*NEA No. 7213. 72 pages.*

*Available online at: www.oecd-nea.org/ndd/pubs/2016/7213-smrs.pdf*

Recent interest in small modular reactors (SMRs) is being driven by a desire to reduce the total capital costs associated with nuclear power plants and to provide power to small grid systems. According to estimates available today, if all the competitive advantages of SMRs were realised, including serial production, optimised supply chains and smaller financing costs, SMRs could be expected to have lower absolute and specific (per-kWe) construction costs than large reactors. Although the economic parameters of SMRs are not yet fully determined, a potential market exists for this technology, particularly in energy mixes with large shares of renewables.

This report assesses the size of the market for SMRs that are currently being developed and that have the potential to broaden the ways of deploying nuclear power in different parts of the world. The study focuses on light water SMRs that are expected to be constructed in the coming decades and that strongly rely on serial, factory-based production of reactor modules. In a high-case scenario, up to 21 GWe of SMRs could be added globally by 2035, representing approximately 3% of total installed nuclear capacity.



### Uranium 2016: Resources, Production and Demand

*NEA No. 7301. 548 pages.*

*Available online at: www.oecd-nea.org/ndd/pubs/2016/7301-uranium-2016.pdf*

Uranium is the raw material used to produce fuel for long-lived nuclear power facilities, necessary for the generation of significant amounts of baseload low-carbon electricity for decades to come. Although a valuable commodity, declining market prices for uranium in recent years, driven by uncertainties concerning evolutions in the use of nuclear power, have led to the postponement of mine development plans in a number of countries and to some questions being raised about future uranium supply. This 26th edition of the "Red Book", a recognised world reference on uranium jointly prepared by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), provides analyses and information from 49 producing and consuming countries in order to address these and other questions. The present edition provides the most recent review of world uranium market fundamentals and presents data on global uranium exploration, resources, production and reactor-related requirements. It offers updated information on established uranium production centres and mine development plans, as well as projections of nuclear generating capacity and reactor-related requirements through 2035, in order to address long-term uranium supply and demand issues.

## Radioactive waste management

### Financing the Decommissioning of Nuclear Facilities

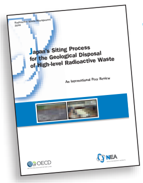
*NEA No. 7326. 21 pages.*

*Available online at: www.oecd-nea.org/rwm/pubs/2016/7326-fin-decom-nf.pdf*

Decommissioning of both commercial and R&D nuclear facilities is expected to increase significantly in the coming years, and the largest of such industrial decommissioning projects could command considerable budgets. It is important to understand the costs of decommissioning projects in order to develop realistic cost estimates as early as possible based on preliminary decommissioning plans, but also to develop funding mechanisms to ensure that future decommissioning expenses can be adequately covered. Sound financial provisions need to be accumulated early on to reduce the potential risk for residual, unfunded liabilities and the burden on future generations, while ensuring environmental protection.

Decommissioning planning can be subject to considerable uncertainties, particularly in relation to potential changes in financial markets, in energy policies or in the conditions and requirements for decommissioning individual nuclear installations, and such uncertainties need to be reflected in regularly updated cost estimates.

This booklet offers a useful overview of the relevant aspects of financing the decommissioning of nuclear facilities. It provides information on cost estimation for decommissioning, as well as details about funding mechanisms and the management of funds based on current practice in NEA member countries.



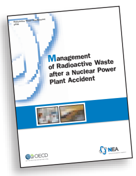
### Japan's Siting Process for the Geological Disposal of High-level Radioactive Waste

An International Peer Review

*NEA No. 7331. 46 pages.*

*Available online at: www.oecd-nea.org/rwm/pubs/2016/7331-japan-peer-review-gdrw.pdf*

The Nuclear Energy Agency carried out an independent peer review of Japan's siting process and criteria for the geological disposal of high-level radioactive waste in May 2016. The review concluded that Japan's site screening process is generally in accordance with international practices. As the goal of the siting process is to locate a site – that is both appropriate and accepted by the community – to host a geological disposal facility for high-level radioactive waste, the international review team emphasises in this report the importance of maintaining an open dialogue and interaction between the regulator, the implementer and the public. Dialogue should begin in the early phases and continue throughout the siting process. The international review team also underlines the importance of taking into account feasibility aspects when selecting a site for preliminary investigations, but suggests that it would be inappropriate to set detailed scientific criteria for nationwide screening at this stage. The team has provided extensive advisory remarks in the report as opportunities for improvement, including the recommendation to use clear and consistent terminology in defining the site screening criteria as it is a critical factor in a successful siting process.



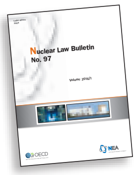
### Management of Radioactive Waste after a Nuclear Power Plant Accident

*NEA No. 7305. 225 pages.*

*Available online at: www.oecd-nea.org/rwm/pubs/2016/7305-mgmt-rwm-npp-2016.pdf*

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

## Nuclear law



### Nuclear Law Bulletin, Volumes No. 96 and No. 97

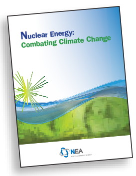
*NEA No. 7311. 120 pages.*

*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 these two issues include "Nuclear Third Party Liability in Germany"; "Towards Nuclear Disarmament: State of Affairs in the International Legal Framework"; "Treaty implementation applied to conventions on nuclear safety" and "Crisis, criticism, change: Regulatory reform in the wake of nuclear accidents".

## Also available

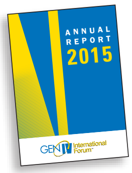


### Nuclear Energy: Combating Climate Change

*(brochure)*

*NEA No. 7208. 9 pages.*

## Publications of Secretariat-serviced bodies



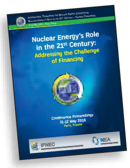
### Generation IV International Forum (GIF) Annual Report 2014

*GIF report. 124 pages.*

This ninth edition of the *Generation IV International Forum (GIF) Annual Report* highlights the main achievements of the Forum in 2015. On 26 February 2015, the Framework Agreement for International Collaboration on Research and Development of Generation IV Nuclear Energy Systems was extended for another ten years, thereby paving the way for continued collaboration among participating countries. GIF organised the 3rd Symposium in Makuhari Messe, Japan in May 2015 to present progress made in the development of the six generation IV systems: the gas-cooled fast reactor, the sodium-cooled fast reactor, the supercritical-water-cooled reactor, the very-high-temperature reactor, the lead-cooled fast reactor and the molten salt reactor. The report gives a detailed description of progress made in the 11 existing project arrangements. It also describes the development of safety design criteria and guidelines for the sodium-cooled fast reactor, in addition to the outcome of GIF engagement with regulators on safety approaches for generation IV systems.

### Multinational Design Evaluation Programme (MDEP) Annual Report: April 2014-April 2015

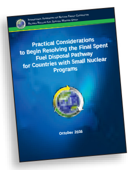
*MDEP report. 56 pages.*



### Nuclear Energy's Role in the 21st Century: Addressing the Challenge of Financing

*IFNEC report. 69 pages.*

In May 2016, the International Framework for Nuclear Energy Cooperation (IFNEC) held a conference in cooperation with the Nuclear Energy Agency (NEA) on "Nuclear Energy's Role in the 21st Century: Addressing the Challenge of Financing". This conference brought together over 150 stakeholders from more than 30 countries, including government representatives and members of the nuclear and finance communities, as well as experts from the NEA and the OECD. Conference participants discussed the primary challenges faced by the markets, including how to secure financing for new nuclear projects, as well as approaches and solutions to such challenges. Through multiple expert presentations, moderated sessions and scenario discussions, participants acquired a better understanding of the unique challenges, approaches and techniques involved in financing new nuclear power plants. A CD containing the conference proceedings and presentations is included in the report.



### Practical Considerations to Begin Resolving the Final Spent Fuel Disposal Pathway for Countries with Small Nuclear Programs

*IFNEC report. 11 pages.*

The American Nuclear Society (ANS) offers print and digital advertising opportunities to help promote your nuclear-related products and services, conferences and events, employment opportunities, or academic courses to our more than 11,000 readers worldwide.

## PRINT ADVERTISING OPPORTUNITIES

### Nuclear News

The monthly membership magazine of the American Nuclear Society, published since 1959, is recognized worldwide as the flagship trade publication covering the entire nuclear field.

### Radwaste SOLUTIONS

This specialty magazine provides dedicated editorial coverage of the decommissioning and waste management segments of the nuclear industry.

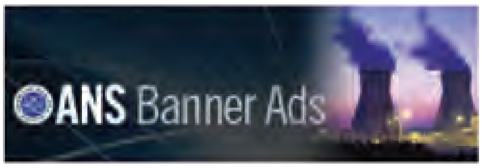
## ONLINE ADVERTISING OPPORTUNITIES

### ANS Career Center

Post open positions or search resumes within the premier online forum linking utilities, vendors, government agencies, and academic institutions with qualified nuclear candidates.

### ANS News

The American Nuclear Society's bimonthly membership newsletter covering the people, activities, and events of the Society.




Banners are displayed and rotated throughout the entire ANS website (more than 110,000 total web pages).


HTML e-mail broadcast to the entire ANS membership each month, highlighting timely membership, meetings, and outreach activities.


The daily blog site of ANS and your link to the nuclear social media network.


Post documents on issues, strategies, trends and products relevant to the nuclear industry.

Since ANS accepted its first advertisement in 1960, more than 1600 companies have purchased over 38,000 pages of ad space. For more information contact us:

www.ans.org/advertise · +1-708-579-8289 · advertising@ans.org

ANS

NEA
NUCLEAR ENERGY AGENCY

The Nuclear Energy Agency (NEA) is an intergovernmental agency established in 1958.
Its primary objective 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. It is a non-partisan, unbiased source of information, data and analyses, drawing on one of the best international networks of technical experts.

Visit our website at:
**www.oecd-nea.org**

You can also visit us on Facebook at: www.facebook.com/OECDNuclearEnergyAgency
and follow us on Twitter @OECD_NEA

NEA News is published twice yearly. The opinions expressed herein are those of the contributors and do not necessarily reflect the views of the Agency or of its member countries.
The material in NEA News may be freely used provided the source is acknowledged.

All correspondence should be addressed to:
The Editor, NEA News – OECD/NEA – 2, rue André-Pascal – 75775 Paris Cedex 16, France
Tel.: +33 (0)1 45 24 10 12 – Fax: +33 (0)1 45 24 11 10

*Cover page photo credits: High voltage line (F. Vuillaume, NEA); Halden reactor (Thor Energy); Graphic (Thinkstock); Dismantling of elements from the primary pump, José Cabrera nuclear power plant, Spain (Enresa).*

OECD/NEA Publishing, 2 rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE

**Nuclear Energy Agency (NEA)**
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt, France
Tel.: +33 (0)1 45 24 10 15
nea@oecd-nea.org www.oecd-nea.org

NEA No. 7292