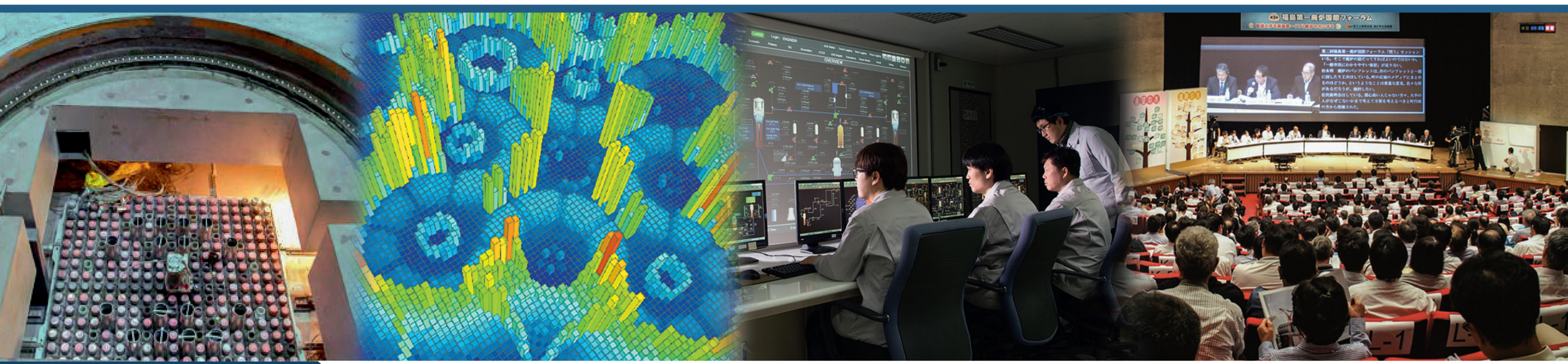
NEA News

2018 – No. 36.2



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NEA News
Volume No. 36.2 2018

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From left to right: William D. Magwood, IV, Director-General, Nuclear Energy Agency (NEA), Viorel Ştefan, Vice Prime Minister of Romania, Mr Ludger Schuknecht, Deputy Secretary-General, Organisation for Economic Co-operation and Development (OECD) and Horia Grama, State Secretary, and President of the Nuclear Agency and for Radioactive Waste at the opening of the Regional Ministerial Meeting on Nuclear Energy, Technology and Radioactive Waste Management, Bucharest, Romania, October 2018.

Global concerns, local actions

As the NEA strives for more effective ways to serve its members and to support policymakers as they prepare society for the challenges of the future, it is clear that existing models and approaches to formulating and implementing energy and technology policies must be scrutinised. The old approach of important decisions being made by experts and officials and later explained to the public is no longer widely accepted by society.

Involving the public and other stakeholders in key decisions is not straightforward. Just posting information on the Internet is no longer sufficient. But what is the best approach for officials bring stakeholders into complex decisions? The considerations around decisions involving esoteric technical concepts are difficult to communicate to general audiences; this is certainly the case with matters involving nuclear technology. This question will be central to the upcoming NEA Workshop on Stakeholder Involvement: Risk Communication, which will be held in September 2019.

These matters are not simply exercises of public communications, but are today a central aspect of technology policy and even the scientific enterprise itself. These complexities are highlighted in the guest editorial presented in this edition of NEA News by Bernard Boullis, Advisor to France's High Commissioner for Atomic Energy. In examining the interface between science and policymaking – in this case, in the long-term management of radioactive waste – Boullis poses some important questions about the scientific community's duty to engage with both the public and policymakers.

The complexity of these matters is magnified by the different cultures, legal traditions, and needs of different parts of the world. While the NEA is an intergovernmental agency with a global focus, we recognise that the universality of physics does not translate to a universality of policy processes, decision-making, and public engagement. It was therefore an important step forward for energy ministers and senior officials from 10 countries to gather in Bucharest, Romania at the end of October 2018 to explore the benefits of enhanced regional cooperation. In a meeting co-organised by the NEA and the Romanian government, the unique characteristics of the region and the common challenges faced by the participating countries made for a rich exchange. Areas such as the design of electricity markets, the financing of nuclear projects, safety culture, and human resource development all emerged as key, common areas of interest.

A vital example of how important issues may have local aspects is the area of safety culture. As highlighted in this edition of NEA News, NEA Country-Specific Safety Culture Forums, the first of which was held in Sweden with co-operation of the Swedish Radiation Safety Authority and the World Association of Nuclear Operators (WANO), shed important light on how national culture relates to safety culture.

Recognising and addressing regional and national differences will become an increasingly important aspect of the work of the NEA, but as ever, the mission of the NEA is centered about the common issues that bring the global community together. Among these, the necessity of strong nuclear safety and the vital need for innovation are among the most important. These imperatives come together in the global interest in accident-tolerant fuels (ATFs), and discussed in this this edition of NEA News, with development programmes ongoing in many institutions. Advanced fuels, which has been a key area of consideration in the course of the Nuclear Innovation 2050, hold the promise for higher levels of safety during abnormal events and improved economics and performance during normal operations.

As we proceed into 2019, the NEA will continue to seek balance and synergies between global commonalities and regional considerations in order to bring the greatest value to our members.

William D. Magwood, IV,
NEA Director-General

Perspectives on nuclear data activities at the Data Bank: Enhancing the validation function

by F. Michel-Sendis, L. Fiorito, M. Fleming

Mr Franco Michel-Sendis (franco.michel-sendis@oecd-nea.org) is Head of the Nuclear Data Services, Mr Luca Fiorito (luca.fiorito@oecd-nea.org) is Junior Scientist and Mr Michael Fleming (michael.fleming@oecd-nea.org) is Nuclear Data Physicist in the NEA Data Bank.

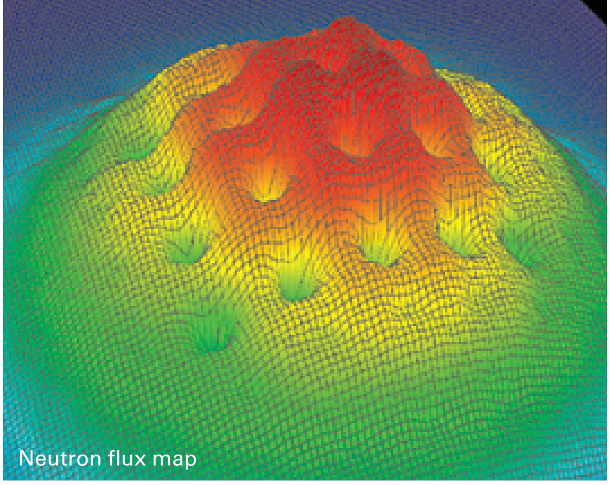
Twisting tunnel of digital binary computer code.

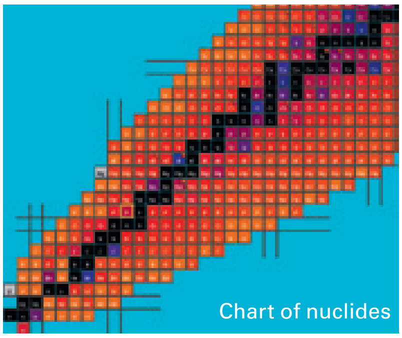
Since its creation in 1978[1], one of the core missions of the NEA Data Bank is to support the production of high quality nuclear data for the international scientific and technical community. In 2015, the Data Bank's own governing board was renamed the Management Board for the Development Application and Validation of Nuclear Data and Codes (MBDAV), emphasising the importance that the NEA gives to the validation of codes and data. Historically, the Data Bank's nuclear data activities have been concentrated on two main axes: the compilation of experimental nuclear reaction data for the international Experimental Nuclear Reaction Data (EXFOR) database, and the co-ordination of the Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library, active since 1982.

What is nuclear data?

By the generic term "nuclear data", we understand the description, in electronic files, of the physical properties of single nuclei and of their interactions with particles, radiation, other nuclei or a crystalline structure. Nuclear data is therefore a rather large technical field. Even in nuclear reaction cross-section data only, interaction probabilities values are given for energy ranges that may easily span ten orders of magnitude, for different reactions and different incident particles. The measurement, compilation and evaluation of nuclear data is an extremely time and resource intensive effort that builds on collective knowledge meticulously generated by generations of scientists in different experimental and research facilities around the globe. The Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library project was established as a collaboration of Data Bank countries to function as a recipient and a curator of this knowledge, and as such has been releasing periodic updates of nuclear data libraries, some of which have been adopted by the European industry (JEF-2.2[2], JEFF-3.1.1) and integrated into their own code systems.

As nuclear data is fundamental in the design of any nuclear technology, several countries have their own national nuclear data evaluation programmes to cater for their R&D needs and technology choices. We can mention, in particular, the American library ENDF (Evaluated Nuclear Data File), the Russian libraries BROND (Russian Evaluated Neutron Data Library) and RUSFOND (Russian National Library





of Evaluated Neutron Data), the Chinese library CENDL (Chinese Evaluated Neutron Data Library), or the Japanese library JENDL (Japanese Evaluated Nuclear Data Library).

Why do different nuclear data libraries exist?

Nuclear data files (also called "evaluations") are prepared through a complex evaluation process, the objective of which is to provide a "best fit" of experimentally measured data with theoretical models, and, sometimes, adjusting it to better reproduce integral values that are given by experiment. It represents, at the time it is made, our best attempt at accurately describing a given physical process. New nuclear data evaluations may be prompted by specific nuclear data needs that had not been previously addressed (for instance, extending the evaluation to a larger energy range). In general, evaluations may be revised over the years as new measurements are taken or superseded and theoretical frameworks refined, along with novel computational methods coming into play. As long as the resulting outcome agrees with the experiment, different scientific approaches that result in different nuclear data representations may coexist as different files or libraries. In order to efficiently compare these different data evaluations, a robust nuclear data visualisation software is necessary. To meet this particular need, the NEA has developed and maintained, since the early 2000s, a Nuclear Data visualisation tool called JANIS, which today is a reference tool used daily by scientists around the world (see figure 1).

Nuclear data is shared across evaluation projects

Evaluated neutron data files are assemblies of various types of data[3], each type representing, for example, the value of the reaction cross-section as a function of the incident particle energy, the number of eventually emitted particles as the outcome of that reaction, their energy and angular distribution, and the uncertainties and correlations that may exist for these quantities. For the sake of simplicity, we use the term "data segment" to refer to this diversity of data that may exist within one file. For each isotopic evaluation file, these data segments may, in practice, come from other data evaluation projects in the world; it is very common that different nuclear data libraries share data with one another (today all nuclear data libraries, like JEFF, are public and available online).

Figure 1: JANIS-4 rendering of the total neutron cross-section data N-15, displaying the latest evaluated libraries (JEFF-3.3, ENDF/B-VIII, JENDL-4.0u and the relevant EXFOR experimental points)

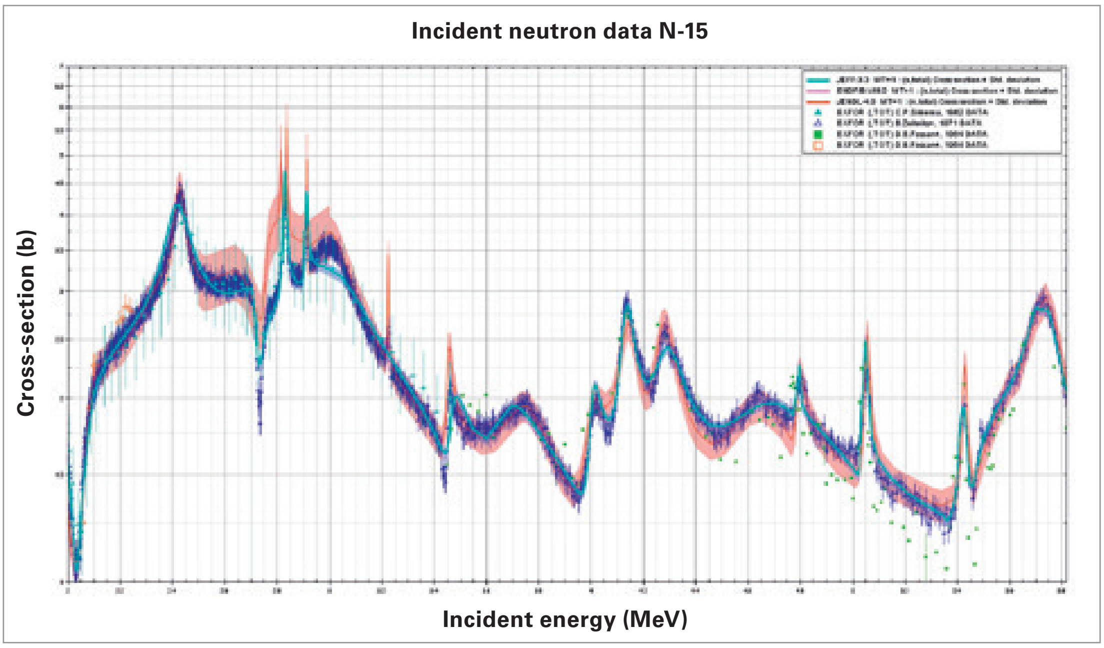
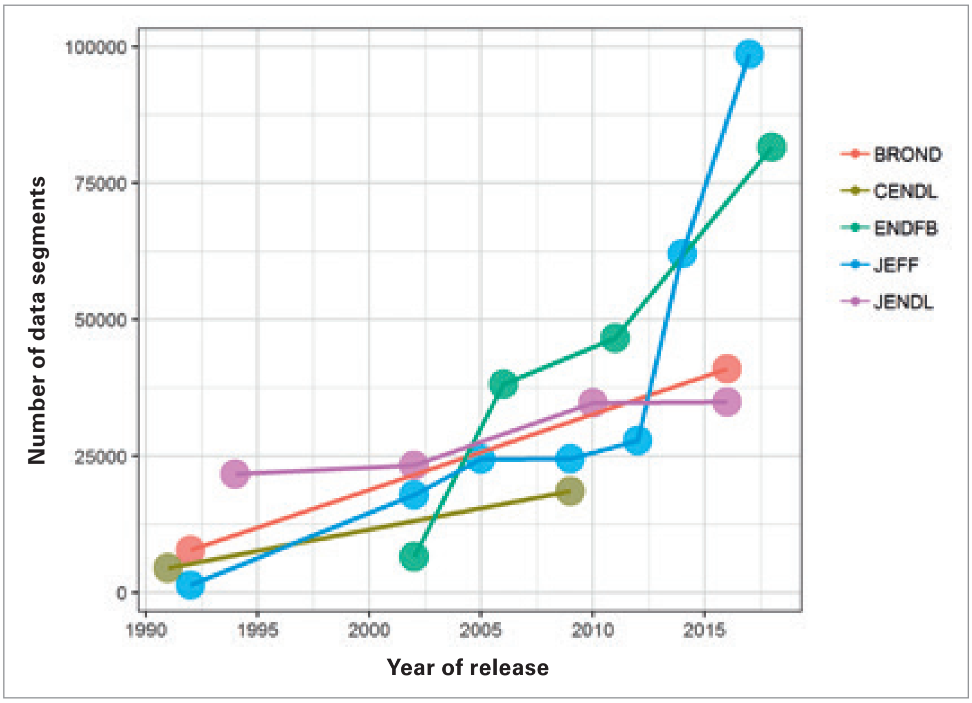
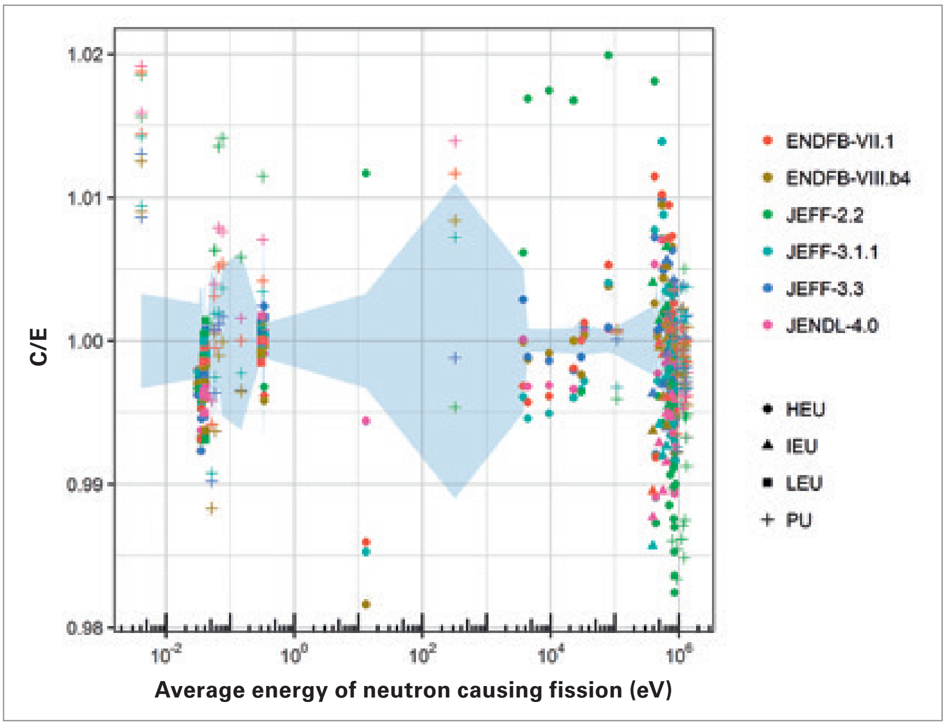


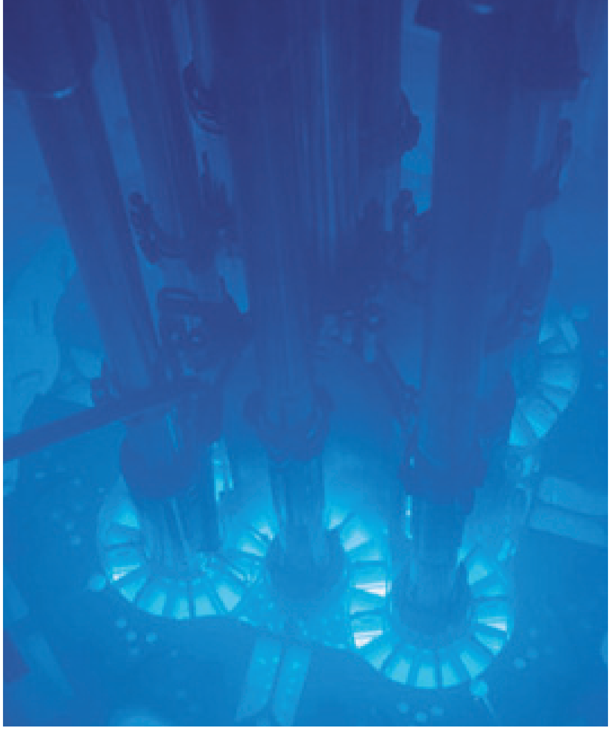
Figure 2: Total number of data segments described in the major nuclear data libraries over their different versions (release numbers above the data points), as a function of the release year



Source : DB/NDS – NDEC.

Figure 3: C/E ratio of 97 critical benchmark experiments from the ICSBEP, representing a selection of low-enriched (LEU), intermediate-enriched (IEU) or highly-enriched (HEU) uranium systems and plutonium (PU) systems for a different set of nuclear data libraries (grey area represents the experimental uncertainty)

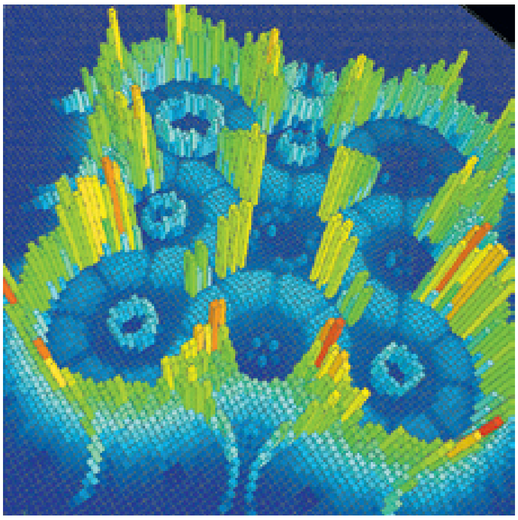




The core of the Advanced Test Reactor (ATR).

Courtesy of Idaho National Engineering and Environmental Laboratory (INEEL)

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



In the past decade, nuclear data libraries have increasingly moved towards the adoption of evaluated data based on various nuclear reaction model codes, in particular for isotopes and reactions for which there is no experimental microscopic data, leading to a significant increase in the total amount of information that evaluated libraries now contain. Figure 2 illustrates the amount of data segments that have been effectively described in the major nuclear data libraries over the past 30 years. For neutron data only, the latest JEFF-3.3 library (2017) contains 70 times more data than the earlier JEF-2.2 (1992). In order to be able to provide efficient verification processes for these data, it is clear that systematic processes must be put into place.

NDEC: Verification and testing of evaluated nuclear data

In recent years, significant efforts have been directed in the Data Bank towards the development of systematic quality assurance (QA) processes that automatise the verification and processing[1] of evaluated neutron data files for continuous-energy Monte Carlo applications. In 2018, a web-based application NDEC (Nuclear Data Evaluation Cycle) – a task manager for the execution of modular checking and processing code sequences – was developed. NDEC prepares the data for visualisation with JANIS and produces, among its various output files, correctly processed and tested ACE-formatted files that may be used in Monte Carlo particle transport codes, paving the way for these to be used in integral benchmarking[5] calculations.

Integral benchmarking of nuclear data libraries

The integral benchmarking of nuclear data is an application-dependent endeavour requiring properly modelled, quality-assured integral experiments. For benchmarking criticality safety aspects, integral experiment benchmark evaluations from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) are routinely used to test the capacity of a nuclear data library to accurately reproduce, in a transport calculation, the neutron multiplication factor of a system. NDEC provides a consistent processing sequence across different nuclear data libraries for this benchmarking phase, easing the comparison of their performance in the simulation of critical experiments. This step took place at the Nuclear Data Services of the Data Bank during the preparatory phase of the JEFF-3.3 neutron library, where the use of NDEC allowed for a significant reduction in the testing cycle time of the library, thus revealing errors or large discrepancies at a much earlier stage of development, and making it possible to correct these errors. Figure 3 gives a comparison of critical performance for different libraries for a suite of 97 ICSBEP evaluations, highlighting the ICSBEP category of the fissile material, as a function of the average neutron energy causing fission, a metric that characterises the experiment. Over the years and with the different nuclear data releases, the accuracy of our simulations of these types of experiments has significantly improved. It is clear, however, that for the validation of general purpose nuclear data libraries, the good performance that is demonstrated in criticality aspects must also be verified in other application domains. In this context, sensitivity and uncertainty analyses provide a unique path for building our understanding of which integral experiments are representative of other applications of interest, and for selecting relevant integral benchmarking validation suites. It is this topic of "extended benchmarking" that constitutes, in our view, an opportunity in which the Data Bank is uniquely placed to carry out its data validation mandate, in strong collaboration with other NEA-managed activities, in particular those of the Nuclear Science Committee (NSC).

Horizontal work with the NEA Nuclear Science Division

Through the NSC and, in particular, the Working Party on Scientific Issues of Reactors Systems (WPRS) and the Working Party on Nuclear Criticality Safety (WPNCS), the NEA co-ordinates several integral benchmark evaluations databases for code and nuclear data validation that have today become international references, such as the aforementioned ICSBEP and the International Reactor Physics Experiment Evaluation Project (IRPhEP). In particular, the Nuclear Data Services of the Data Bank will continue to ensure the co-ordination of specific evaluated nuclear data development and validation activities through its support of the Working Party on International Nuclear Data Evaluation Co-operation (WPEC) of the NSC. It is through this cross-cutting collaboration that scientific consensus is built on the verification and validation protocols that are desired by the international nuclear data community, and it is by being at the core of these exchanges that the Data Bank is best placed to implement those that are seen as most necessary, in particular those that involve the integral experiment databases co-ordinated by the NEA.

Conclusion

Developing and systematising verification sequences such as NDEC is only a first step towards the establishment of more complete QA processes for nuclear data libraries at the Data Bank, which necessarily include a consistent comparison of nuclear data performance in a wide range of integral experiments. In general, we recognise a trend in which the added value of the nuclear data evaluation process lies not only in the final output of a frozen list of electronic files (the term "nuclear data library" itself is representative of this static view), but more and more resides in complex knowledge management systems – or databases – where the evaluation process itself is systematised, transparent, documented and ideally linked to testing and validation: a process that is – as basic QA criteria requires – reproducible.

The Nuclear Data Services of the Data Bank, where the JEFF project is hosted and co-ordinated, is in the unique position of servicing an international evaluated nuclear data library project. In September 2018, MBDAV approved the new mandate of the JEFF Co-ordination Group for the 2018-2021 period, for which the deliverables are:

- the definition of a system for generation of a complete nuclear data library, combining the best available scientific and technical knowhow in a reproducible process;
- the specifications for the quality assurance system that is desired for the new library;
- the definition of an enlarged suite of benchmarks covering the physics interests of the community.

In this ambitious new phase, the Nuclear Data Services of the Data Bank will have a key role in the centralisation of processes and in the implementation of efficient ways of working remotely and collaboratively, providing access to the most pertinent knowledge. We believe the first steps in those directions have been made.

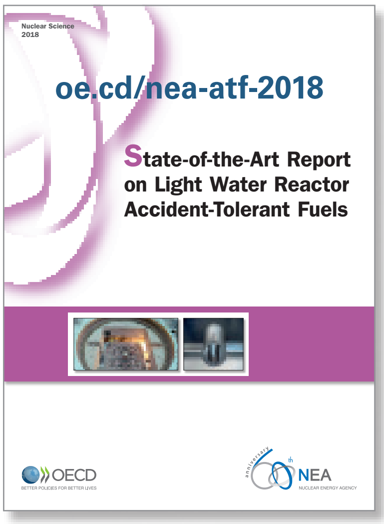
Notes

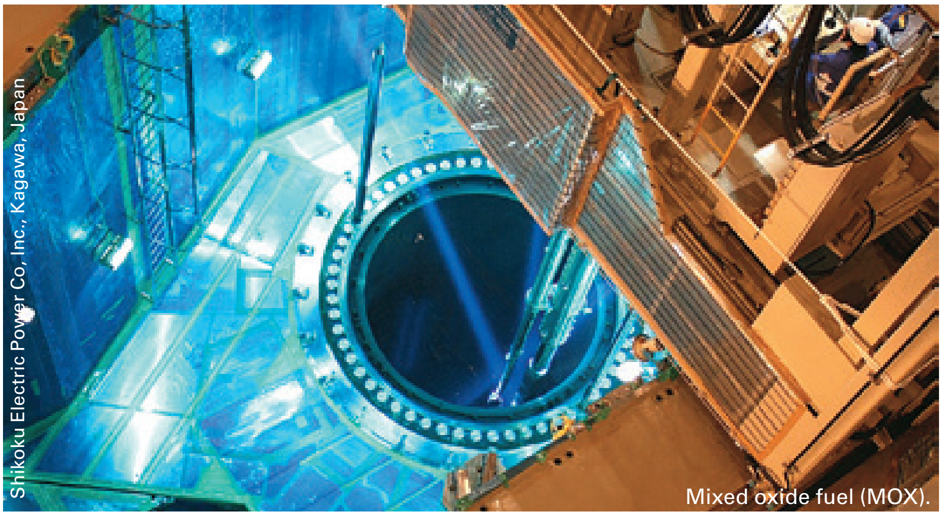
1. The Data Bank was formed out of the merging of two functions that pre-existed as parts of the European Nuclear Energy Agency (ENEA): the Neutron Data Compilation Centre (CCDN) that was based in Saclay, France, and the Computer Program Library (CPL) that was located in Ispra, Italy.
2. In the late 1990s, the Joint Evaluated File (JEF) project was renamed the Joint Evaluated Fission and Fusion (JEFF) file project.
3. This would be represented by individual sections referred to as MF and MT in today's universal nuclear data format "ENDF-6", a format developed in the US in the 1990s and adopted by all nuclear data libraries in the world.
4. By "nuclear data processing", we refer to the reconstruction of the data to suit the specifics of the application conditions.
5. By "benchmarking", we mean the calculation-to-experiment comparison of integral or macroscopic quantities (such as k_{eff}, the neutron multiplication factor of a system) given by a simulation code and a given nuclear data library.

An NEA State-of-the-Art Report on Accident-Tolerant Fuels [1]

by K. Pasamehmetoglu, S. Bragg-Sitton, M. Moatti, M. Kurata and D. Costa

Dr Kemal Pasamehmetoglu (INL) (kemal.pasamehmetoglu@inl.gov) Versatile Test Reactor Executive Director and Chair of the NSC Expert Group on Accident Tolerant Fuel for LWRs, Dr Shannon Bragg-Sitton (INL) (shannon.bragg-sitton@inl.gov) is Deputy National Technical Director for the Advanced Fuels Campaign (AFC) in the DOE Fuel Cycle Technologies Program, Dr Marie Moatti (EDF) (marie.moatti@edf.fr) is Senior Executive Advisor on Nuclear Fuel Safety & Economics, Dr Masaki Kurata (JAEA, CLADS) (kurata.masaki@jaea.go.jp) is Division Leader, Fuel Debris and Core Status valuation Division and Dr Davide Costa (davide.costa@oecd-nea.org) is Nuclear Scientist in the Division of Nuclear Science.





Mixed oxide fuel (MOX).

The safe, reliable and economic operation of the world's nuclear power reactor fleet is a top priority for the nuclear industry. Continual improvement of technology, including advanced materials and nuclear fuels, is central to the industry's success.

The current nuclear power industry is based on mature technology and has an excellent safety and operational record. All light water reactors (LWRs) around the world are using fuel systems comprised of uranium oxide (UO_2) encased within a zirconium-based alloy cladding. Some reactors use uranium-plutonium oxide fuels, which are also known as mixed oxide (MOX) fuels. The oxide fuel-Zircaloy system has been optimised over many decades and performs very well under normal operations and anticipated transients. However, because of the highly exothermic nature of zirconium-steam reactions, under some low probability accidents – when core cooling is temporarily lost and part of the reactor core is uncovered – it may lead to an excess generation of heat and hydrogen, resulting in damage to the core.

After the 2011 Great East Japan Earthquake and Tsunami, and the subsequent damage to the Fukushima Daiichi power plant, enhancing the accident tolerance of LWRs became a topic of serious discussion; in particular, global interest has expanded in exploring fuels with enhanced performance during such rare events, with accident-tolerant fuel (ATF) development programmes starting in many research institutions and industry teams. While there is broad consensus that a new fuel system alone is insufficient to mitigate accident consequences, fuel in combination with other systems may provide some relief in responding to such rare events, while providing additional benefits during more frequent events and/or normal operations. The goal of ATF development is therefore to identify alternative fuel system technologies that will further enhance the safety, competitiveness and economics of commercial nuclear power.

In this context, the NEA organised two international workshops in 2012 and 2013 to gauge the interest of its member countries in the development of LWR fuels with enhanced accident tolerance. Because of the wide-ranging interest, the Expert Group on Accident-tolerant Fuels for Light Water Reactors (EGATFL) was subsequently established in 2014. A total of 35 institutions from 14 member countries – Belgium, the Czech Republic, France, Germany, Japan, Korea, the Netherlands, Norway, Russia, Spain, Sweden, Switzerland, the United Kingdom and the United States – as well as invited technical experts from China, took part in the activities of the group.

1. *State-of-the-Art Report on Light Water Reactor Accident-Tolerant Fuels,* on which this article is based, is available for download from the NEA website.

The expert group was divided into three task forces, which addressed the following issues respectively:

- evaluation metrics and systems assessment;
- cladding and core materials options;
- fuel options.

The task forces, comprised of experts from the participating institutions, worked between 2014 and 2017, with semi-annual integration meetings. The efforts of the three task forces were co-ordinated to produce the *State-of-the-Art Report* (SOAR) *on Light Water Reactor Accident-Tolerant Fuels* – reflecting the consensus reached by the participating organisations. The report illustrates an overview of the state of the art for various technologies currently being pursued by many organisations. The purpose is not to favour or dismiss any given concept. The report is intended as a guide for decision makers, national programmes and industrial stakeholders who may use the information in the report to decide on their own set of priorities and choose the most appropriate technology based on their specific strategy, business case and deployment schedules, which vary from state to state, as well as from company to company. The content is organised into five parts:

- Part I: Evaluation metrics and illustrative scenarios;
- Part II: Cladding and core materials;
- Part III: Advanced fuel designs;
- Part IV: Technology readiness level evaluation;
- Part V: Cross-cutting issues between fuel and cladding designs.

As mentioned above, three task forces tackled different issues. Task Force I prepared a framework for the evaluation of the ATFs, in particular:

- defining the desired properties, behaviours and performances of ATF systems (claddings and fuels);
- introducing appropriate metrics to evaluate ATF performances against the oxide fuel-zircaloy system and to compare the different designs;
- describing standard tests to investigate key features and ATF behaviours;
- describing illustrative accident scenarios that may be adopted to assess – through severe accident analysis codes – the potential performance enhancement of ATFs relative to the current standard fuel system in accident conditions;
- defining the technology readiness levels (TRLs) applicable to ATFs;
- providing a survey of the available modelling and simulation tools (fuel performance and severe accident analysis codes) and experimental facilities available to support the development of the various ATF concepts.

Based on the evaluation metrics established by Task Force I and presented in Part I of the report, attribute guides were defined for each cladding and fuel technology in order to provide a comprehensive evaluation scheme covering the following topics:

- fabrication/manufacturability;
- normal operation and anticipated operation occurrences;
- behaviour in accident conditions (design-basis accidents, design extension conditions);
- fuel cycle-related issues (fuel storage, transport, disposal, reprocessing).

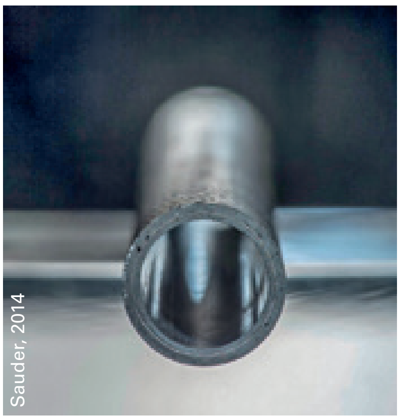
The attribute guides are the backbone of EGATFL work and were used to assess the gap between the present R&D status on ATF designs and the requirements to be met for commercial deployment in LWRs.

Based on the information collected in the attribute guides, the second and third task forces (Task Force II and III) focused, respectively, on the cladding and fuel options, to provide a thorough review of the available ATFs, and expressed a shared position on the state-of-the-art knowledge on the various options in terms of properties, available experimental data, available modelling results and ongoing R&D activities. An evaluation of the current TRLs for each option was also provided based on a consensus amongst the participating experts.

Task Force II contributed five chapters (Part II of the report) on different claddings and some non-fuel components such as advanced channel boxes and control rods. Representatives from academia, national laboratories, fuel suppliers, regulators, experimental facilities, and nuclear operators contributed to these chapters (see Table 1).

Four types of cladding designs, as well as SiC/SiC channel boxes and accident-tolerant control rods, were reviewed following the defined attributes:

Segment of SiC/SiC fuel cladding including a metal liner.



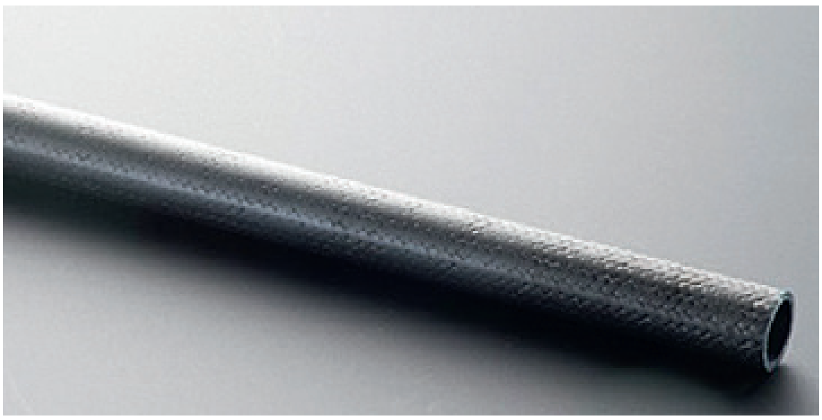


Table 1: Organisations that participated in the Task Force II review

Cladding designs				Core components	
SiC and SiC/SiC composites	Coated & improved Zr-alloys	Advanced steels	Refractory metals	SiC/SiC Channel boxes	ATCR
KAERI Muroran FJP* KIT ORNL PSI Westinghouse	UIUC FJP* KAERI IFE KIT	ORNL GE NFD	EPRI CGN	Toshiba EPRI	CRIEPI AREVA

* French Joint Programme (CEA-AREVA-EDF).

- coated and improved zirconium alloys, including different types of coatings: metallic (Cr, Cr-Al, multi-layer including FeCrAl), ceramic (nitrides, including multi-layer concepts, MAX phases) and oxide dispersed strengthened (ODS) surface treatments;
- advanced steels (FeCrAl);
- lined molybdenum alloy (Mo-alloy) cladding;
- SiC/SiC cladding;
- core materials such as accident-tolerant control rods (ATCRs) and SiC/SiC channel boxes.

Task Force III followed a similar approach, compiling four chapters (Part III of the report) on various candidate fuel designs (doped UO_2, high-thermal conductivity fuel, high-density fuel, encapsulated fuel). Similar to Task Force II, several contributors from different organisations (see Table 2) participated in the review.

The review of the advanced fuel concepts is divided into four groups:

- oxide doped UO_2;
- high-thermal conductivity fuels;
- high-density fuels;
- encapsulated fuel.

In Part IV of the report, the EGATFL contributors jointly provided an evaluation of the technology readiness level for different fuel-cladding and non-fuel component candidate designs. According to the definition of TRLs provided in this report, coated and improved Zircaloy concepts and advanced steels concepts for ATF cladding accomplished the proof-of-concept stage (up to TRL 3 on a scale ranging from 1 to 9), and the R&D for the proof-of-principle stage (above TRL 3) has begun. The R&D activity to achieve the TRL 3 level is ongoing for refractory metal and SiC-based concepts. The R&D level

Table 2: Organisations that participated in the Task Force III review

Improved UO_2			
Doped UO2		High-thermal conductivity UO_2	
		Metallic additive	Ceramic additive
Cr_2O_3 doped UO_2 Al_2O_3-Cr_2O_3 doped UO_2	Ceramic microcell UO_2	CERamic METal (CERMET), Mo-modified UO_2 Metallic microcell UO_2	BeO-modified UO_2 SiC/diamond modified UO_2
FJP* Westinghouse	KAERI	FJP* KAERI	CGN University of Florida

* French Joint Programme (CEA-AREVA-EDF).

High-density fuel				Encapsulated fuel
Silicide	Nitride	Carbide**	Metal**	
NRG Westinghouse	FJP*	TF3	TF3	CGN KAERI ORNL

* French Joint Programme (CEA-AREVA-EDF).
** Carbide and metal fuels were treated as reference concepts in TF3.

Transient Reactor Test Facility (TREAT).

for the reviewed non-fuel core components achieved TRL 3. As for the fuel design concepts, doped UO_2 are already in the proof-of-performance stage (above TRL 6); although data need to be accumulated for accident conditions. Metallic and BeO additive concepts for high-thermal conductivity fuel have achieved the proof-of-concept stage (up to TRL 3). The R&D of other advanced fuel concepts, including advanced additives, high-density fuels and encapsulated fuels, is still in the proof-of-concept stage.

Based on the collected state-of-the-art information, the last part of the report (Part V) presents a joint assessment of the compatibility between fuels and cladding designs with respect to different classes of properties (e.g. chemical, mechanical, neutronics, thermal). This evaluation suggests that, whatever the cladding, data are missing for high-density fuel designs – especially with regard to chemical and mechanical properties. Neutronics is recognised as being a potential issue for FeCrAl and refractory metal cladding, requiring a more challenging design (without compromising the concept itself), except when these claddings are combined with high-density uranium silicide, uranium carbide and metal fuels. Low ductility of SiC/SiC cladding is recognised as being a potential challenge for this cladding concept, whichever the fuel design; more data on the pellet cladding mechanical interaction need to be collected.

Even though the EGATFL report is a technical report, it is organised in such a way that readers with different technical backgrounds can access its content through a structure that provides different levels of information adapted to their needs:

- Part I provides some of the keys needed to access the technical analysis through the introduction of the metrics upon which the attribute guides are based. It is also useful for policy makers as it provides a thorough description of the TRL scale, together with a review of the available R&D tools to address scientific and engineering issues related to ATFs (e.g. test facilities, fuel performance codes, system codes, severe accident analysis codes).
- Readers interested in an overview of the current status of technologies described in the report can refer to Part IV, which contains an assessment of the industrial maturity of each design, irrespective of its likely performance.
- Based on the information presented in Parts I and IV, stakeholders from both industry and government can acquire insights into the current developmental stages of ATFs and the capability of existing infrastructures to face the challenges that innovative fuels represent for R&D organisations, the nuclear industry and for regulatory bodies. When examined in the context of country-specific perspectives, and complemented with the advice of technical experts, this material can assist policy makers to sketch out the national R&D strategies that would need to be implemented to pursue the development of future nuclear fuels.
- Parts II and III allow the reader to delve into more technical detail regarding ATFs, by providing a consistent and complete – although synthetic – description of the technical details collected in the attribute guides.
- Finally, fuel specialists will be able to access the raw evaluations emerging from this expert group's efforts in appendices, where the completed attribute guides are provided for the cladding and core materials (Appendix A), and for the advanced fuel designs (Appendix B).

The report reflects the situation for ATFs as of the beginning of January 2018 when the EGATFL approved the report during its final meeting.

References

NEA (2018) *State-of-the-Art Report on Light Water Reactor Accident-Tolerant Fuels,* OECD Publishing, Paris. View the webinar and download the report at oe.cd/nea-atf-webinar-2018.

Country-Specific Safety Culture Forum: Sweden

By P. Bourassa, K. Martin and Y. Hah

Ms Pascale Bourassa (pascale.bourassa@oecd-nea.org) is Deputy Head for Human Aspects of Nuclear Safety, Ms Kamishan Martin (kamishan.martin@oecd-nea.org) is Nuclear Safety Specialist in the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety and Ms Yeonhee Hah (yeonhee.hah@oecd-nea.org) is Head of the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety.

Stockhom, Sweden.

Nuclear power is a highly technical undertaking. Designing, building and operating nuclear plants requires highly experienced and highly qualified specialists in a wide range of engineering and scientific fields. However, the technical aspects cannot be the only area of focus to ensure safety; attention to the safety culture of the work environment is also necessary. Organisations need to consider how people interact and communicate with each other, when are issues raised and how are they addressed, what priority is given to safety – especially when they seem to be competing priorities.

The relationship of national culture to nuclear safety culture has become an increasing area of focus in recent years. Operators from many countries might be able to work together to identify and address an issue associated with nuclear fuel operating under certain conditions and compare experiences but how do they address areas of human behaviour and determine the best approaches in their country? Physics always works across borders, but the same cannot always be said of issues of safety culture within organisations[1]. Yet for many years it was assumed that this was the case.

However, practical experience has shown that there are important differences in how people work together and communicate in different countries. The national context in which people live does not stop at the gate of a nuclear plant. Hence, it is important that the nuclear community take the time to uncover these national influences, realise their potential impacts on safety and develop a path towards sustaining a healthy safety culture.

With this in mind, NEA Director-General William D. Magwood, IV created the Country-Specific Safety Culture Forum (CSSCF) in co-operation with Peter Prozesky, CEO of the World Association of Nuclear Operators (WANO). The aim is to bring awareness and understanding of how a national context relates to safety culture, and how operators and regulators could think about these effects in their day-to-day activities. Each forum consists of a process of reflection and dialogue to collect information on the national attributes and of finding ways to work within this context in order to sustain a healthy safety culture.

The goal of the forum is not to make any judgements about the national context, but rather to raise awareness; the goal is not to make comparisons with other cultures, but rather to identify how to leverage strengths and work with potential challenges. No national culture is preferable to another, but as safety culture is optimised in any setting, an understanding and reflection of the relevant national context can make training and the absorption of nuclear safety culture principles more effective.

The forum

The NEA publication, *The Safety Culture of an Effective Nuclear Regulatory Body,* recognised the influence of the national culture: "It is important that characteristics of national culture ... not be viewed as an impediment to safety culture but rather as characteristics and cultural strengths to be aware of and to be used and fostered in developing safety culture" (NEA, 2016).

The CSSCF, designed by the NEA and WANO, tailored by the host country's nuclear regulatory organisation and led by the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety, offers a safe and open

1 *Country-Specific Safety Culture Forum: Sweden,* on which this article is based, is available for download from the NEA website.

Safety helmets.

Central control room of a nuclear power plant.

environment for various actors within the country's nuclear community to reflect on the national context and its impact on safety.

Over the course of two days, participants interact through role play, dialogues and plenaries. In mixed groups – with people from different nuclear organisations and in various levels and positions – they discuss what national attributes resonate with them and how these may influence safety. They challenge each other on the behaviours, the actions and the decisions that are acted out in front of them (and by them) during a mock technical scenario that goes awry. Then they explore possible approaches and paths forward that could enable them to work with those attributes that may impede a healthy safety culture and also how to ensure they apply any strengths that could enhance safety. There is no judgement of the national context throughout the exercise – it is deliberately designed to raise awareness of the influences of the national context and create an environment in which it is possible to openly discuss how to work with it.

The forum's results are captured in a report meant to serve as a springboard for further dialogue within the participating organisations and anyone interested in better understanding how their national context may influence their behaviours and actions. As the CSSCF is an activity available to all NEA member countries, the intention is to build a catalogue of country reports over the coming years.

The outcomes of the CSSCF are thus trifold: immediate raised awareness for the participants; medium-term when the reports are integrated into organisational learning; and long-term with a catalogue of reports available to enhance the awareness and increase global collective knowledge.

The CSSCF will hopefully help regulators and operators to improve their training programmes and make further improvements to their nuclear safety cultures. The report can be used to further the dialogue within each organisation and will be an aid for designing effective training programmes. A learning organisation that strives to continuously improve safe operations regularly reflects on its organisational behaviours and their underlying core values and deeply rooted assumptions. The hope is that this first CSSCF is only the beginning of a process that will continue in Sweden and that will also be of interest to other member countries, ultimately inspiring them to start their own journey towards better understanding their national context and its relation to safety culture.

Inaugural event with Sweden

In January 2018, the Swedish Radiation Safety Authority (SSM) hosted the first ever CSSCF to pilot the concept. The event took place in Stockholm, Sweden and involved over 60 participants from the Swedish nuclear community, including staff from the SSM. Prior to the event itself, the SSM, WANO and NEA staff worked closely together to conduct a snapshot study of typical Swedish attributes and how they manifest themselves in organisational behaviours. The data was collected through focus groups comprised of workers and interviews with managers to include with a representative sample of the forum's participating organisations. The objective was to use the collected information to develop the scenarios used in the role-playing during the forum and to inform the resulting report.

As a result of the CSSCF, six national attributes surfaced as the most influential on safety culture. These attributes were considered in the context of the following five organisational behaviours identified throughout the snapshot study and the two-day forum: employeeship, leadership, management, decision making, accountability, feedback and learning.

The report on CSSCF: Sweden

In September 2018, the NEA held a webinar to launch the report on the outcomes of the CSSCF: Sweden. A one-hour panel discussion was led by NEA Director-General Magwood and included WANO Leadership Manager Ian Moss and SSM Deputy Director-General Fredrik Hassel. NEA Director-General Magwood noted that, "No national culture is preferable to another but as safety culture is optimised in any setting, an understanding and reflection of the relevant national context can make training and absorption of nuclear safety culture principles more effective." The panel also welcomed a nuclear power plant forum participant, Vattenfall Vice-president Ann Berg. As a result of the CSSCF, she indicated that her organisation will use the report to further the dialogue and training on safety culture.

Also in September 2018, the SSM hosted a side event during the International Atomic Energy Agency (IAEA) General Conference in Vienna, Austria. Close to 60 participants attended the event to hear Director-General Magwood, Fredrik Hassel and WANO Paris Centre Director Ingemar Engkvist discuss the CSSCF and why it is so important to be aware of the national attributes that most influence safety culture as well as how to deliberately work within that context to ensure a healthy safety culture for safe operations of nuclear installations worldwide.

During the IAEA side event, both the United Kingdom's Office for Nuclear Regulation and Switzerland's Swiss Federal Nuclear Safety Inspectorate indicated that they would host a CSSCF in their respective countries.

Science and Radioactive Waste Management [1]

by B. Boullis

Bernard Boullis, Advisor to the High Commissioner for Atomic Energy, France.

European Commission representation, boulevard Saint-Germain, Paris.

The management of radioactive waste is a very important issue that some see as the Achilles' heel of nuclear energy, while for others it is just an easy target.

It is a highly scientific and technical issue, but there is much more to it than that. And it is often difficult, even for a scientist, to remain grounded in science on such a divisive topic, without revealing personal convictions or taking sides. But that is what is required to make a proper contribution, by assessing what I consider to be the major scientific issues in this area.

Science has already provided so much for what we call the back end of the cycle, with some considerable achievements.

The issues relating to the management of radioactive waste have served as a stimulus to the scientific community, leading to advances in areas well outside the nuclear field. I am thinking of work in separation chemistry to develop reprocessing procedures, and of studies on material behaviour over the very long term with the development of approaches for dealing with such periods (thousands of years or more), by speeding up the phenomena that we wish to see, or by analysing historical analogues.

Thanks to this work, the 400 000 or so tonnes of spent fuel unloaded from nuclear reactors around the world over the past fifty years are now managed under conditions that are as safe as possible, even if the practical arrangements vary significantly from one country to the next.

That said, several factors have limited the implementation of solutions:

- The general public does not have the same perception of the situation as technical experts, and that is putting it mildly. This is one of the main reasons why it has not been possible to date to fully deploy the options available. The geological disposal of the most highly radioactive waste and spent fuel has been an enduring concept for several decades, for almost half a century, and yet there is still no operational geological repository for the disposal of the waste generated by nuclear power plants.
- We still cannot claim to know everything about the phenomena governing the waste management options envisaged, if only because we need to consider exceptionally long time frames. But does this mean that we should wait until we know everything before we act? "Certainly not" is the answer, as it is an illusion to think that we could ever know everything about such a subject. And, in this area as in others, our societies would have missed out on a lot by adopting such a wait-and-see approach.
- Lastly, we can do better than our current planned course of action. Indeed, future scientific advances will probably allow us to envisage more effective, more attractive waste management options. We must work towards achieving that outcome, of course, but potential future developments should be approached realistically. We have seen cases in the past where the ability to deliver certain concepts has been talked up too enthusiastically, and we should not sit back and wait for these future solutions claimed to be ideal to be developed as this could turn into procrastination leading to inertia and gridlock. Yet again, the best approach is to act by also seeking to make the most of solutions that are perhaps less elegant, less perfect, but which could produce proven benefits as of now.

Science, and the resultant technological developments, currently provides a wide range of options for managing spent fuel and waste.

Despite their differences, all these options are a combination of three fundamental principles, three simple ideas provide the basis for any given management strategy:

- Reduce waste at the source (its volume and hazardousness): this is for example what enables reprocessing-recycling, with the removal of uranium and plutonium from final waste;
- Wait, as the characteristic of radioactivity is that it decays over time. This is very effective but there are limits, in particular a sticking point after around 100 years when the issue of the radioactivity of long-term actinides arises;

1. This text was adapted from a speech made on 18 October 2018 at Les Entretiens Européens "The Management of Spent fuel and Nuclear Waste in Europe: Solutions Exist, They Must be Implemented".

- Lastly, sustainably contain, in matrices, containers, geological environments, etc.

Various combinations of these three principles give rise to different options:

- Reprocessing, as in France for example, with the storage of vitrified waste and the recycling of plutonium in MOX;
- Spent fuel pool storage, with a view to future geological disposal in copper containers as in Sweden and Finland;
- Spent fuel dry storage, in suitable containers, with a view to geological disposal or another as yet undecided option (which is the situation in many countries).

Every one of these options has its strengths and weaknesses. They all appear to have a solid scientific basis guaranteeing their feasibility in principle. However, there are still some issues that warrant close attention:

- With regard to the option of waste reduction through recycling, an area in which remarkable results have been achieved in France for almost 30 years by immobilising the most highly radioactive elements in a glass matrix, the issue that still remains unresolved is the long-term management of plutonium. The current outlook for the development of nuclear energy, on a smaller scale than in the past, should delay and maybe even prevent the deployment of plutonium-fuelled fast neutron reactors in certain regions. This concept may gain traction again at a later date, if recourse to sustainable nuclear energy continues (if only because this would lead to a drastic reduction in, or even put a virtual end to, uranium mining). It therefore seems sensible, and important, for research into a subject that is so promising and so appealing on an intellectual level to remain open and active.

But it may also be interesting to explore alternatives, which can be rolled out in the meantime, as this too seems to be a simple matter of prudence.

- In terms of the storage of spent fuel, it is the issue of long-term behaviour that, in my opinion, warrants further and closer examination, not so much for the storage operation per se – which it would seem can now be kept safe for up to a century – as for the future downstream retrieval operations, after several decades, that are inherent in this type of management. This is a seemingly important aspect, but it is perhaps not sufficiently taken into consideration.
- And naturally, geological disposal is a key issue. We cannot in all honesty claim to have complete control over such complex phenomena over periods of time as long as those we need to take into account, with regard to which we need to show humility. It is true, as mentioned earlier, that appropriate scientific approaches have been determined and applied in an attempt to prepare as best as possible for the far distant future. Nonetheless, the issue of uncertainties, and how they are understood and managed in an integrated approach, is crucial at present for all geological disposal projects. For the international community, this remains a major focus of work, especially as the subject lies at the heart of the public's concerns.

So far I have discussed the areas of research that demonstrate how scientific activity allows us to look beyond initial achievements to continuous progress. It might be stating the obvious, but ongoing research in this field is sometimes presented as reflecting the absence of a solution. This is obviously not the case.

For many, the only real solution would be the eradication of long-lived nuclear waste through transmutation. This concept has generated much excitement. The scientific community, especially in Europe, has carried out a great amount of work in this area over the past 20 years, and has achieved some remarkable results, although the potential impact has been poorly understood, perhaps because it has been overly idealised by the people behind it. Transmutation is a very interesting objective, but firstly, it is not a miracle solution (it will leave waste), and secondly, the prospects for its deployment remain very remote.

New ideas are still emerging for ever more advanced, ever more revolutionary solutions, and the way in which these ideas are presented often suffers from the same skewed message, namely that they can be deployed in the near future. This seems very prejudicial on several levels:

- in the short term, it can harm the deployment of solutions available closer to the present time (if it is going to be so much better in the near future, why not wait?);
- and in the long term, once everyone has come back down to earth, it can discredit the word of operators and scientists in the field.

That brings me to the last issue that I would like to address, which is public perception of nuclear waste and its inherent dangers.

Public perception, at its rightful level, of the dangers linked to radioactivity is important for the future of the nuclear industry. Much depends on it, as it is clear that public opinion naturally influences many decisions.

And there is currently a very poor perception of these dangers or risks. There are many reasons for this, the main one in all likelihood being that radioactivity is omnipresent while remaining unseen. The "chemistry of the invisible" as Marie Skłodowska-Curie said. And this opens the door to all kinds of rhetoric and conspiracies.

In a world in which we seek to try to decipher increasingly complex phenomena, in which science is sometimes less deterministic and more "relativistic", it is naturally necessary to adopt a very humble approach given the immensity of what we do not know, while at the same time clearly stating what we do know. In my opinion, all the value of the scientific approach is encapsulated in this combination of humility and discipline.

We are still far from fully understanding the effects of radioactivity on living organisms, but there are things that we do know how to limit and that we do know how to restrict, but that remain largely overlooked.

Admittedly, not everything can be reduced to a scientific approach (there are plenty of other aspects that are a priori respectable when it comes to adopting a position), but I still believe that science must make itself heard. And getting involved in this objective of providing information is a huge responsibility for the scientific community, as once again it is crucial for the future of nuclear energy. It is also an objective that imposes obligations, as to make oneself heard requires credibility, and this takes me back to the pitfalls I referred to earlier. To quote Talleyrand, "All that is exaggerated is insignificant!"

2018 NEA International Mentoring Workshops

By Y. Hah, T. Saito and O. Guzmán

Ms Yeonhee Hah (yeonhee.hah@oecd-nea.org) is Head of the NEA Division, Mr Tomoyuki Saito (tomoyuki.saito@oecd-nea.org) is Nuclear Safety Specialist and Ms Olvido Guzmán (olvido.guzman@oecd-nea.org) is Radiological Protection Specialist in the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety.

(From left): Marie Oshima; Sama Bilbao y León; Sonoko Watanabe; Cait MacPhee; Kayo Inaba; William D. Magwood, IV; Shizuko Kakinuma; Yeonhee Hah and Malgorzata Sneve.

(From left): Amparo García; Adoración Arnaldos; Olvido Guzmán; Matilde Pelegrí; Sama Bilbao y León; Carolina Ahnert; Yeonhee Hah; Rosario Velasco; William D. Magwood, IV; Patricia Cuadrado; Carolina Pérez; Rosa González; Pilar Sánchez'; Susana Falcón; Teresa Palacio; Izaskun García and Tina Taylor.

Despite many efforts made over the past decades, women remain underrepresented in executive positions in science, technology, engineering and mathematics (STEM). Many countries have strived to address such lack of female representation in leadership positions in these fields, yet progress has been slow. To mitigate the possibility of future shortages in the workforce, capacity-building efforts focusing on STEM fields (not limited to nuclear) need to be sustained and reinforced – particularly those aimed at young women, who are significantly underrepresented in these areas as well. It is in this spirit, following its successful debut in July 2017 in Chiba, Japan, that the NEA held two additional mentoring workshops in 2018: one in Tokyo, Japan and the other in Ávila, Spain.

The "Joshikai II for Future Scientists: International Mentoring Workshop in Science and Engineering" was held on 8-9 August 2018 in Tokyo, Japan in co-operation with the Japan Atomic Energy Agency (JAEA), to motivate young female students to explore science and engineering careers, and to suggest ways to overcome any barriers that they may face along the way. The workshop brought together 51 female students from Japanese high schools and junior high schools with highly accomplished women scientists and engineers from Japan and from three additional NEA member countries. During the two-day workshop, mentors discussed the lives, careers and experiences of women in STEM fields through panel discussions, dialogue sessions, hands-on activities and group discussions with students, as well as during a first-of-a-kind session for parents and teachers. As was the case at the first workshop in 2017, a special video address by Hélene Langevin-Joliot, distinguished nuclear physicist and granddaughter of Marie Skłodowska-Curie, was also shown to the students.

In parallel, another NEA International Mentoring Workshop in Science and Engineering was convened for the first time in Europe. The workshop, entitled *Impulsando a las futuras líderes en Ciencia y tecnología,* took place on 24 September 2018 in Ávila, Spain in the margins of the 44th Annual Meeting of the Spanish Nuclear Safety Society. Jointly organised with the Spanish Women in Nuclear Association, and co-sponsored by the Spanish Nuclear Safety Council (CSN), the City Council of Ávila and the Electric Power Research Institute (EPRI), the workshop featured opening remarks by NEA Director-General William D. Magwood, IV as well as a presentation on the NEA-led initiative by Yeonhee Hah, NEA Head of the Division of Radiological Protection and Human Aspects of Nuclear Safety. In his opening remarks, Director-General Magwood told participants, "We encourage you to consider careers as engineers and scientists. We need you."

Incorporating the same objective as those previously held in Japan, the Spanish mentoring workshop gathered approximately 50 female students from high schools with 12 highly accomplished women scientists and engineers from Spain. These mentors included Sama Bilbao y León, Head of the Division of Nuclear Technology Development and Economics at the NEA, who also acted as a mentor for the Japanese workshop this year, and Olvido Guzmán, Radiological Protection Specialist at the NEA.

The NEA has also recently expanded its horizons in this specific area by supporting the Third International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station, which was organised by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) on 5-6 August 2018 in Fukushima, Japan. In the margins of the forum, a student session was held for the first time. The aim was to nurture the future experts who will be taking on important roles in the decontamination and decommissioning of the plant. The NEA gave active support to these initiatives: Director-General Magwood gave a keynote speech and participated in the wrap-up discussion; Head of Division Yeonhee Hah also gave a presentation sharing her professional experiences as a mentor. The NEA encourages its membership to continue promoting science and technology careers at every stage of education, particularly with respect to girls, and to explore ways of attracting, recruiting and retaining women in science and technology fields.

For more information on the NEA International Mentoring Workshop in Science and Engineering series, download the recently published brochure on the NEA website: oe.cd/joshikai2.

The Third International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station on 5-6 August 2018 in Fukushima, Japan.

NEA International Radiological Protection School (IRPS): Preparing tomorrow's radiological protection leaders

by E. Lazo

Dr Edward Lazo (edward.lazo@oecd-nea.org) is Deputy Head of Radiological Protection in the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety.

Since shortly after the discovery of X-rays and natural radiation, experts in both national and international fora have worked towards establishing an international radiological protection (RP) system. International organisations, scientists, regulatory authorities, operators and other stakeholders have contributed to the evolution of this system by sharing state-of-the-art scientific knowledge and experience. The current international RP system is used by virtually every government in the world as a basis for RP policy and regulation, and for nearly all operations involving ionising radiation as a framework for protection of the public, workers and the environment. The system has been built principally by the International Commission on Radiological Protection (ICRP), with significant input from the NEA, national governmental and industrial organisations, the International Atomic Energy Agency (IAEA), and the World Health Organisation (WHO), among others. But while guidance and standards documents from organisations such as the ICRP, the IAEA and the European Commission (EC) present the details of the system including the technical facts, other aspects making up the "spirit" of the RP system – its history, nuances and between-the-line meanings – have not been well documented. This "spirit" is an integral component for truly comprehending how it functions, and these aspects are necessary for successful application of the system. While there are numerous educational programmes addressing the technical and structural aspects of radiological protection, an NEA survey suggested that there is a gap in terms of courses that actually present this thorough system view. It is imperative that this deep understanding be passed on to the future generations of RP specialists and experts – who will replace the many knowledgeable experts planning to retire in the next decade – so that they are in a position to appropriately apply and evolve the RP system.

In an effort to respond to this challenge, the NEA established the International Radiological Protection School (IRPS). The first edition of the IRPS was held at the Centre for Radiation Protection Research (CRPR), Stockholm University, with the support of the Swedish Radiation Safety Authority (SSM). At the IRPS, many of the world's top RP experts shared their experience in such areas as radiological biology, epidemiology, regulation, operation and stakeholder involvement. These experts, having contributed to the RP system's creation, provided a historical overview of how and why the RP system evolved, and what the system is intended to mean.

Objectives and topics that were covered included:

- examining the foundation of the international RP framework – detriment, dose and other fundamentals;
- understanding how the RP system's key features are applied in RP regulation and implementation;
- understanding the state of the art: radiological aspects of biological, epidemiological and social science;
- learning the differences and similarities of principles and standards at the international and national levels (e.g. the ICRP, the IAEA Basic Safety Standards [IAEA-BSS], the European Basic Safety Standards Directives [EU-BSS], the National Council on Radiation Protection and Measurements [NCRP]);
- exploring the RP system: past, present and future, including discussions on the potential direction of the RP system;
- building a system of protection around exposure situations: new approaches in international guidance;
- considering evolving issues: ethics, naturally occurring radiological material (NORM) and public communication;
- building leadership and stakeholder engagement skills as an undercurrent of the more technical aspects of topics described above.

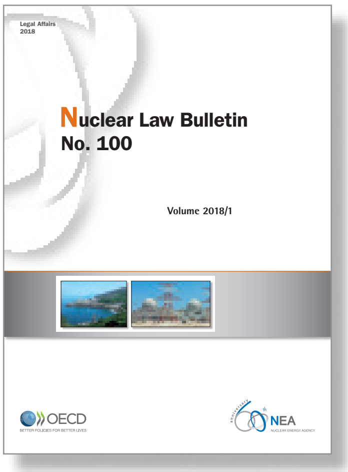
Comments from lecturers and participants suggest that the pilot IRPS successfully transmitted a deeper understanding of the meaning and nuances of the international RP system. Stockholm University, the SSM and the NEA will thus discuss continuing the IRPS in Stockholm, with the possibility of regional editions of the IRPS being held in the context of available resources and regional support. The Committee on Radiation Protection and Public Health (CRPPH) Bureau will discuss this question at its January 2019 meeting, and the CRPPH will be asked, during its March 2019 meeting, whether any members would be interested in hosting and supporting an edition of IRPS.

For more information, please visit www.oecd-nea.org/rp/irps.

The *Nuclear Law Bulletin*: 50 years of legal scholarship

by K. Nick

Ms Kimberly Nick (kimberly.nick@oecd-nea.org) is Deputy Head of the NEA Office of Legal Counsel.



In 1968, the European Nuclear Energy Agency (ENEA) – predecessor of today's Nuclear Energy Agency (NEA) – published the first edition of the *Nuclear Law Bulletin* (NLB). Behind the striking orange cover lay over 100 pages of information on legislative and regulatory activities, case law and administrative decisions, updates from international organisations, information on international agreements, as well as noteworthy pieces of legislation. Now, 50 years, 100 editions and over 10 000 published pages later, this same reliable approach to the NLB remains unchanged. Published twice a year in both English and French, the NLB stands as a unique international publication in the field of nuclear law.

Soon after the publication of its first edition, a noteworthy change was made to the NLB's format, with the first article appearing in 1970. What began as an "information only" resource was then transformed into a platform for professionals and academics to discuss, explain and consider the most relevant and important issues facing the nuclear community. Since this time, almost 200 articles written by nearly as many different authors have been published, including 9 by Professor Norbert Pelzer alone. While nuclear liability remains the most popular subject, current events have naturally led to a shift in priorities. For example, the number of articles written on nuclear safety increased dramatically following the Fukushima Daiichi nuclear power plant accident. This is, in part, what makes the NLB such a practical and informative resource. Whether the legal issues relate to radioactive waste management, environmental protection, non-proliferation, nuclear trade or nuclear security, among other topics, the NLB is always at the forefront of the conversation.

Of course, the NLB's value is measured by how useful it is to its audience. To enhance its utility, an Index was provided from the 10th edition. The plan of the Index is not a replica of the NLB, as it was considered more useful for research purposes to group the information by country and then by international organisations, multilateral agreements, studies and articles, and legal texts, each set out in separate sections. Articles are categorised by topic, and the Index is updated with each new edition of the NLB and made freely available online.

Nuclear law journals have come and gone over time, but none have experienced the same continuity as the NLB. This is due in large measure to the dedication of the national correspondents from all over the world who provide the NLB with updates on recent case law in the nuclear field, developments related to national legislation and regulatory activities, legal texts and news briefs. The NLB also benefits from the input of correspondents from the International Atomic Energy Agency, the European Commission, the United Nations and other international organisations who provide critical insights into these organisations' most recent activities. With almost 100 different correspondents from 60 countries and international organisations, the NLB remains indebted to their work.

The 50th anniversary of the NLB is an important moment to thank those colleagues who created and sustained the NLB for decades, in particular Mr Pierre Strohl and Mr Patrick Reyners, as well as the hundreds of correspondents who have worked with the ENEA and the NEA since the NLB's inception. The NLB would not be what it is today without them. This notwithstanding, the past success of the NLB cannot be guaranteed in the future. To continue providing authoritative and comprehensive information on nuclear law developments, the continued collaboration and contributions from the authors and correspondents who provide the NLB's content is essential.

Anyone interested in writing an article or an academic study for the NLB is invited to review the NLB publication process website at www.oecd-nea.org/law/nlb/pubprocess.html and contact the Office of Legal Counsel (OLC) at nlb@oecd-nea.org. Any comments or suggestions are welcome as well. The NLB remains a product of a global effort to disseminate nuclear law information.

Update on NEA Joint Projects

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, 2 in the area of nuclear science (advanced fuels, and characterisation of fuel debris and fission products), 2 in support of radioactive waste management and 2 in the field of radiological protection. These projects complement the NEA programme of work and contribute to achieving excellence in each area of research.

Advanced Thermal-hydraulic Test Loop for Accident Simulation (ATLAS) Project

Contact: nils.sandberg@oecd-nea.org

Current mandate: October 2017-September 2020

Budget: EUR 3 million

Participants: Belgium, China, Czech Republic, France, Germany, Korea, Spain, Switzerland, United Arab Emirates and United States.

- provide experimental data for resolving key light water reactor (LWR) thermal-hydraulics safety issues related to long-term coolability with partial core blockage, passive core makeup during station blackout, intermediate size loss-of-coolant accidents and design extension condition scenarios such as multiple steam generator tube ruptures;
- the experimental programme is to provide an integral-effect experimental database, which will be used to validate code predictive capability and accuracy of models;
- carry out analytical activities to improve the technical competence among OECD/NEA member countries in the area of thermal-hydraulics for nuclear reactor safety analysis.

Behaviour of Iodine Project (BIP)

Contact: martin.kissane@oecd-nea.org

Current mandate: January 2016-March 2019

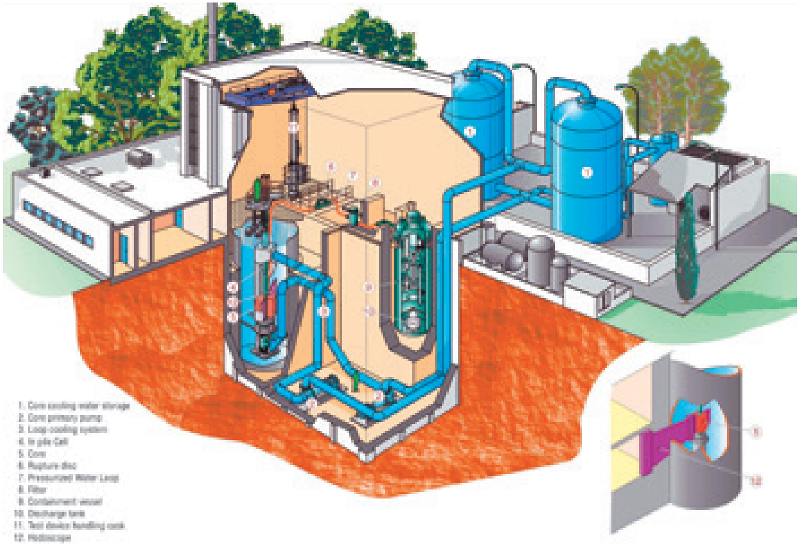
Budget: EUR 1 million

Participants: Belgium, Canada, Finland, France, Germany, Japan, Korea, Sweden, Switzerland, United Kingdom and United States.

- 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);
- 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);
- develop a common understanding of how to extrapolate with confidence from small-scale studies to reactor-scale conditions.

The ATLAS facility.

KAERI, Korea



Cabri reactor with water loop scheme.
IRSN/CEA, France

Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant (BSAF)

Contact: kentaro.funaki@oecd-nea.org

Current mandate: April 2015-June 2018

Budget: EUR 270 K

Participants: Canada, China, Finland, France, Germany, Japan, Korea, Russia, Spain, Switzerland and United States.

- provide information and analyse results on severe accident (SA) progression, fission product (FP) behaviour, source term estimation and comparison with measured plant data within the first three weeks of the Fukushima Daiichi Accident at units 1 to 3, respectively, to support the safe and timely decommissioning of Fukushima Daiichi NPP;
- contribute to understanding of SA phenomena that took place during the accident, through comparisons with participants' analysis results and with measured plant data;
- share the above results with the objective of improving methods and models of the SA codes applied in each participating organisation, in order to reduce uncertainties in the SA analysis and validate the SA analysis codes using data obtained through the decommissioning process.

Cable Ageing Data and Knowledge (CADAK) Project

Contact: ollivilhelm.nevander@oecd-nea.org

Current mandate: January 2015-December 2017*

Budget: EUR 50 K/year

Participants: Canada, Germany, Slovak Republic, Switzerland and United States.

- 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;
- 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;
- 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.

* This project has been discontinued and a final report, NEA/CSNI/R(2018)8, was issued in 2018.

Cabri International Project (CIP)

Contact: martin.kissane@oecd-nea.org

Current mandate: March 2018-March 2021

Budget: ≈ EUR 74 million

Participants: Czech Republic, Finland, France, Germany, Japan, Korea, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and United States.

- extend the database for high burn-up fuel performance in reactivity-induced accident (RIA) conditions;
- perform relevant tests under coolant conditions representative of pressurised water reactors (PWRs);
- extend the project 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)

Contact: ollivilhelm.nevander@oecd-nea.org

Current mandate: January 2018-December 2020

Budget: EUR 75 K/year

Participants: Canada, Chinese Taipei, Czech Republic, Finland, France, Germany, Japan, Korea, Netherlands, Slovak Republic, Spain, Switzerland and United States.

- collect and analyse information on passive metallic and high density polyethylene (HDPE) component degradation and failures to promote a better understanding of underlying causes, impact on operations and safety, and prevention. Detailed objectives and schedules for data submissions will be defined for each calendar year of project operation;
- analyse the information collected in the event database to develop topical reports on degradation mechanisms. Objectives and schedules for the topical reports will be developed for each calendar year of project operation. CODAP will actively seek technical input from the NEA CSNI Working Group on Integrity and Ageing of Components and Structures (WGIAGE). In addition, the Management Board will communicate and co-ordinate as needed with WGIAGE concerning technical matters of mutual interest;
- develop and implement an enhanced web-based event database that supports the creation of standard and custom reports on certain aspects of the database contents. Building on the experience with the existing web-based event database, the new development will address user-friendliness, improved database structure, and analysis tools that enable advanced statistical analyses of the database contents;

- provide ageing management programme support that addresses current operability determination practices, performance of new materials in the field (e.g., dual-certification stainless steels, super-austenitic stainless steels, Alloy 690, Alloy 52/152), and commendable practices of license renewal and long-term operation;
- to facilitate the exchange of the existing and future information amongst the participating organisations as a way to improve the quality of decisions made about components material degradation, ageing management and operability determination. The CODAP database along with other relevant information collected will be used for applications of service experience data with an emphasis on observed trends-and-patterns, past and current degradation mechanism mitigation practices, and risk characterisation of passive component failure events.

Co-operative Programme for the exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD)

Contact: jihtong.lin@oecd-nea.org

Current mandate: January 2014-December 2018 (next mandate 2019-2023)

Budget: ≈ EUR 80 K/year

Participants: Belgium, Canada, Chinese Taipei, Denmark, European Commission, France, Germany, Italy, Japan, Korea, Russia, Slovak Republic, Spain, Sweden, United Kingdom and United States.

- exchange scientific and technical information among nuclear facility decommissioning projects, based on biannual meetings of the Technical Advisory Group, to ensure that the safest, most environmentally sound and economical options for decommissioning are employed.

Fire Incidents Records Exchange (FIRE) Project

Contact: markus.beilmann@oecd-nea.org

Current mandate: January 2016-December 2019

Budget: EUR 75 K/year

Participants: Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Korea, Netherlands, Spain, Sweden, Switzerland, United Kingdom and United States.

- collect fire event experience (via international exchange) in the appropriate format and in a quality-assured and consistent database;
- collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention;
- generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences.
- 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;
- record the characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies.

Fire Propagation in Elementary, Multi-room Scenarios (PRISME) Project

Contact: andrew.white@oecd-nea.org

Current mandate: January 2017-December 2021

Budget: EUR 4.26 million

Participants: Belgium, Finland, France, Germany, Japan, Korea, United Kingdom and United States.

- 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;
- undertake experiments related to smoke and hot gas propagation, through a horizontal opening between two superimposed compartments;
- provide information on heat transfer to cables and on cable damage;
- provide information on the effectiveness of fire extinguishing systems.

Halden Reactor Project

Contact: markus.beilmann@oecd-nea.org

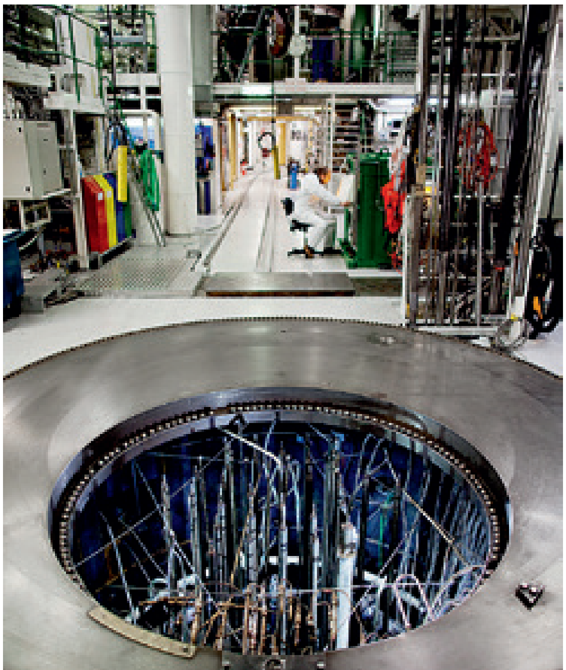
Current mandate: January 2018-December 2020

Budget: NOK 444 million

Participants: Belgium, China, Czech Republic, Denmark, Finland, France, Germany, Hungary, Japan, Korea, Netherlands, Norway, Russia, Slovak Republic, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States and European Commission.

Generate key information for safety and licensing assessments and aim at providing:

- 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;
- 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;
- man-machine systems-advances in computerised surveillance systems, virtual reality, digital information, human factors and man-machine interaction in support of control room upgradings.



View of the Halden reactor hall.

IFE, Norway

High Energy Arcing Fault Events (HEAF) Project

Contact: markus.beilmann@oecd-nea.org

Previous mandate: July 2012-December 2016
New mandate under discussion

Costs covered by the US NRC and in-kind contributions

Participants: Canada, Finland, France, Germany, Japan, Korea, Spain and United States.

Perform experiments to obtain scientific fire data on high energy arcing fault phenomena known to occur in nuclear power plants through carefully designed experiments:

- use data from the experiments and past events to develop a mechanistic model to account for the failure modes and consequence portions of HEAFs;
- 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;
- 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);
- use international collaboration to expand the pool of available test data and acquire authorship involvement in the development of a new US NUREG that consequently would have international standing and applicability.

Hydrogen Mitigation Experiments for Reactor Safety (HYMERES) Project

Contact: markus.beilmann@oecd-nea.org

Current mandate: July 2017-June 2021

Budget: EUR 4.84 million

Participants: China, Czech Republic, Finland, Germany, Japan, Korea, Russia, Spain, Sweden, Switzerland and United States.

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:

- tests addressing the interaction of safety components;
- realistic flow conditions;
- reviews of system behaviour for selected cases.

Information System on Occupational Exposure (ISOE)

Contact: olvido.guzman@oecd-nea.org
oleg.saraev@oecd-nea.org

Current mandate: January 2016-December 2019

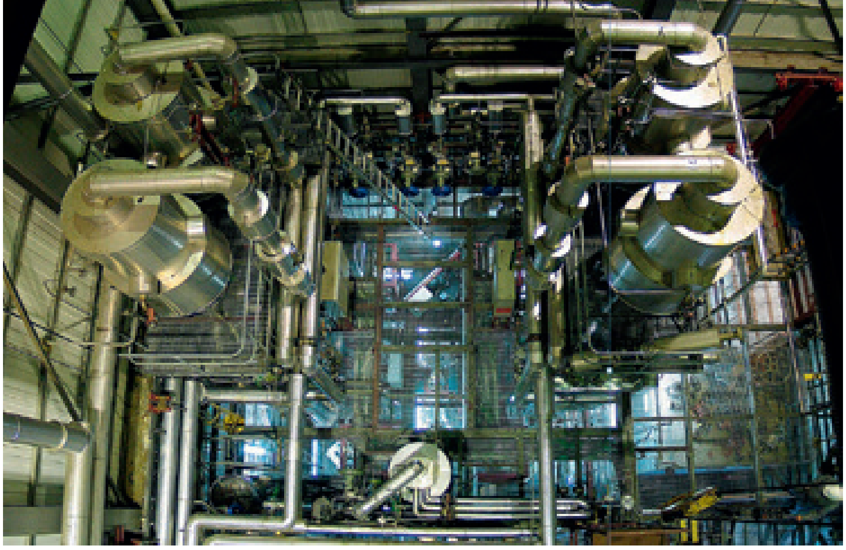
Budget: EUR 396 100

Participants: 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.

- collect, analyse and exchange occupational exposure data and occupational exposure management experience at NPPs;
- provide broad and regularly updated information on methods to improve the protection of workers and on occupational exposure in NPPs;
- 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.

The PANDA reactor pressure vessel.

Paul Scherrer Institute, Switzerland



Top view of the PKL facility, Germany.

Framatome, France

International Common-cause Failure Data Exchange (ICDE) Project

Contact: olli.nevander@oecd-nea.org

Current mandate: January 2015-December 2018

Budget: EUR 140 K/year

Participants: Canada, Czech Republic, Finland, France, Germany, Japan, Korea, Netherlands, Spain, Sweden, Switzerland and United States.

- collect and analyse common-cause failure (CCF) events over the long term so as to better understand such events, their causes and their prevention;
- 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;
- 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;
- 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

Contact: andrew.white@oecd-nea.org

Current mandate: March 2011-March 2019

Budget: EUR 3 million

Participants: Czech Republic, France, Germany, Hungary, Japan, Korea and United States.

Perform integral tests in the high-temperature engineering test reactor (HTTR) in order to:

- provide experimental data to clarify the anticipated transient without scram (ATWS) in the case of an LOFC with occurrence of reactor re-criticality;
- 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;
- provide experimental data to verify the capabilities of these codes regarding the simulation of phenomena coupled between reactor core physics and thermal-hydraulics.

Preparatory Study on Analysis of Fuel Debris (PreADES)

Contact: kentaro.funaki@oecd-nea.org

Current mandate: July 2017-July 2020

Budget: EUR 275 K

Participants: Canada, European Commission, France, Japan, Korea, Sweden, Switzerland and United States.

- collect information for improving knowledge and methodologies for fuel debris characterisation that will support future fuel debris sampling at the Fukushima Daiichi units 1-3;
- identify the needs for fuel debris analysis that will contribute to decommissioning of the Fukushima Daiichi plant and deepen the knowledge base of severe accidents;
- prepare a future international R&D framework on fuel debris analysis.

Primary Coolant Loop Test Facility (PKL) Project

Contact: nils.sandberg@oecd-nea.org

Current mandate: July 2016-June 2020

Budget: EUR 4.78 million

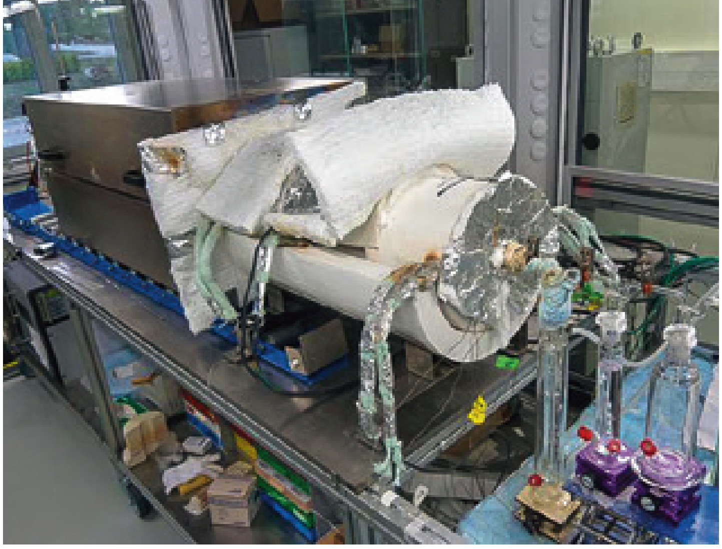
Participants: Belgium, China, Czech Republic, Finland, France, Germany, Hungary, Japan, Korea, Spain, Sweden, Switzerland, and United States.

The objective is to perform integral tests in the PKL-facility to:

- investigate safety issues relevant for current PWR plants as well as for new PWR design concepts;
- focus on complex heat transfer mechanisms in the steam generators and boron precipitation processes under postulated accident situations;
- provide data for verifying computer codes used in safety analyses;
- provide data for further developing these codes for complex scenarios and flow-regimes.

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

IRSN, France



Source Term Evaluation and Mitigation (STEM) Project

Contact: martin.kissane@oecd-nea.org

Current mandate: January 2016-December 2019

Budget: EUR 2.5 million

Participants: Canada, Finland, France, Germany, Japan, Korea, Sweden, United Kingdom and United States.

Improve the general evaluation of the source term, and in particular:

- perform experiments to study the stability of aerosol particles under radiation and the long-term gas/deposits equilibrium in a containment;
- conduct a literature survey on the effect of paint ageing;
- perform experiments to study ruthenium transport in pipes.

Studsvik Cladding Integrity Project (SCIP)

Contact: markus.beilmann@oecd-nea.org

Current mandate: July 2014-June 2019

Budget: SEK 130 million

Participants: Czech Republic, China, Finland, France, Germany, Hungary, Japan, Korea, Norway, Russia, Spain, Sweden, Switzerland, Ukraine and United States.

- 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;
- achieve results of general applicability (i.e. not restricted to a particular fuel design, fabrication specification or operating condition);
- achieve experimental efficiency through the judicious use of a combination of experimental and theoretical techniques and approaches.

Thermal-hydraulics, Hydrogen, Aerosols, Iodine (THAI) Project

Contact: martin.kissane@oecd-nea.org

Current mandate: February 2016-July 2019

Budget: ≈ EUR 4.8 million

Participants: Belgium, Canada, China, Czech Republic, Finland, France, Germany, Hungary, India, Japan, Korea, Luxembourg, Slovak Republic, Sweden, Switzerland and United Kingdom.

The project aims to address remaining questions and examine experimental data relevant to nuclear reactor containments under severe accident conditions concerning:

- the release of fission products from a water pool;
- the resuspension of fission products;
- hydrogen combustion;
- passive autocatalytic recombiner (PAR) operation in counter-current flow conditions.

Thermochemical Database (TDB) Project

Contact: maria-eleni.ragoussi@oecd-nea.org

Current mandate: April 2014-March 2019 (TDB-5)
(New Phase: TDB-6: 2019-2023)

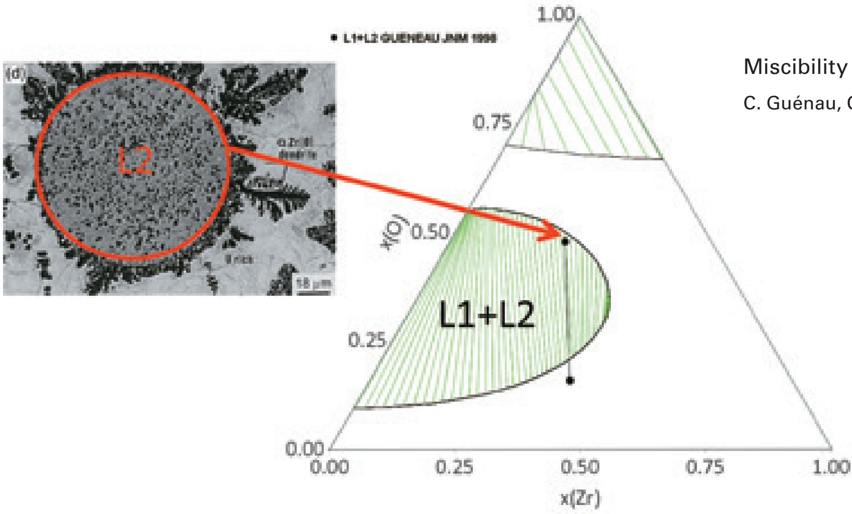
Budget: EUR 1.5 million

Participants (TDB-5): Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, United Kingdom and United States.

Participants (TDB-6): Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Netherlands, Sweden, Switzerland, United Kingdom and United States.

Produce a database that:

- contains internally consistent thermodynamic data of solid and aqueous species for elements of interest in radioactive waste disposal systems;
- documents why and how the data were selected;
- gives recommendations based on original experimental data, rather than on compilations and estimates;
- documents the sources of experimental data used.



Miscibility gap in liquid state.

C. Guénau, CEA France

Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project

Contact: davide.costa@oecd-nea.org

Project agreement: January 2013-December 2017

The project was completed in December 2017. A second phase is under preparation. The agreement from TAF-ID Phase II is being circulated among the participating organisations for signature.

Budget: ≈ **EUR 460 K**

Participants: Canada, France, Japan, Korea, Netherlands, United Kingdom and United States.

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:

- predict the solid, liquid and/or gas phases formed during fuel/cladding chemical interaction under normal and accident conditions;
- improve the control of experimental conditions during the fabrication of fuel materials at high temperature;
- predict the evolution of the chemical composition of fuel under irradiation versus temperature and burn-up.

Thermodynamic Characterisation of Fuel Debris and Fission Products Based on Scenario Analysis of Severe Accident Progression at Fukushima-Daiichi Nuclear Power Station (TCOFF)

Contact: davide.costa@oecd-nea.org

Project agreement: June 2017-December 2019

Budget: ≈ **EUR 760 K**

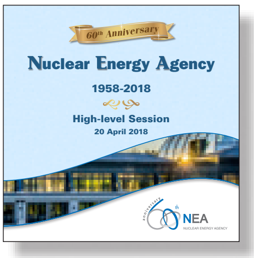
Participants: Czech Republic, European Commission, France, Germany, Japan, Korea, Netherlands, Russia, Sweden and Switzerland (the United States is in the process of joining).

The TCOFF project will provide a framework for the exchange of technical information on topics related to thermodynamic databases available for modelling the fuel/core degradation process, which include thermodynamic functions/models, experimental data, calculation tools, calculation methods for quasi-equilibrium systems, and prioritisation of items for improvement/enlargement, with reference to the accidental scenario at the Fukushima Daiichi nuclear power station (NPS). The project aims to:

- improve the quality and/or inventory of thermodynamic databases, which are used for severe accident analyses with a reference to the severe accident progression at different units of the Fukushima Daiichi NPS;
- conduct joint thermodynamic evaluations of the severe accident progression at in-vessel and ex-vessel phases at units 1, 2 and 3 of the Fukushima Daiichi NPS, aiming at characterising fuel melting; molten core relocation; fission product behaviour; the chemical and phase composition of fuel debris; and the thermodynamic evaluation of the formation of materials, which may potentially be detected at the Fukushima Daiichi NPS.

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

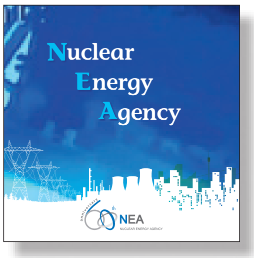
General Interest



NEA 60th Anniversary brochure

16 pages.

Available online at: www.oecd-nea.org/general/history/60th



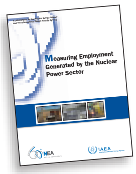
The Nuclear Energy Agency brochure

NEA No. 7398. 28 pages.

Also available in French and Chinese.

Available online at: http://oecd-nea.org/pub/nea-brochure.pdf

Nuclear technology development and economics

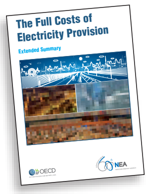


Measuring Employment Generated by the Nuclear Power Sector

NEA No. 7204. 92 pages.

Available online at: https://oe.cd/nuclear-employment-2018

The nuclear energy sector employs a considerable workforce around the world, and with nuclear power projected to grow in countries with increasing electricity demand, corresponding jobs in the nuclear power sector will also grow. Using the most available macroeconomic model to determine total employment – the "input/output" model – the Nuclear Energy Agency and International Atomic Energy Agency collaborated to measure direct, indirect and induced employment from the nuclear power sector in a national economy. The results indicate that direct employment during site preparation and construction of a single unit 1 000 megawatt-electric advanced light water reactor at any point in time for 10 years is approximately 1 200 professional and construction staff, or about 12 000 labour years. For 50 years of operation, approximately 600 administrative, operation and maintenance, and permanently contracted staff are employed annually, or about 30 000 labour years. For up to 10 years of decommissioning, about 500 people are employed annually, or around 5 000 labour years. Finally, over an approximate period of 40 years, close to 80 employees are managing nuclear waste, totalling around 3 000 labour years. A total of about 50 000 direct labour-years per gigawatt. Direct expenditures on these employees and equipment generate approximately the same number of indirect employment, or about 50 000 labour years; and direct and indirect expenditures generate about the same number of induced employment, or 100 000 labour years. Total employment in the nuclear power sector of a given national economy is therefore roughly 200 000 labour years over the life cycle of a gigawatt of nuclear generating capacity.



The Full Costs of Electricity Provision

Extended Summary

NEA No. 7437. 24 pages.

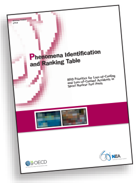
Available online at: https://oe.cd/2pM

Electricity provision touches upon every facet of life in OECD and non-OECD countries alike, and choosing how this electricity is generated – whether from fossil fuels, nuclear energy or renewables – affects not only economic outcomes but individual and social well-being in the broader sense. Research on the overall costs of electricity is an ongoing effort, as only certain costs of electricity provision are perceived directly by producers and consumers. Other costs, such as the health impacts of air pollution, damage from climate change or the effects on the electricity system of small-scale variable production are not reflected in market prices and thus diminish well-being in unaccounted for ways.

Accounting for these social costs in order to establish the full costs of electricity provision is difficult, yet such costs are too important to be disregarded in the context of the energy transitions currently under way in OECD and NEA countries. This report draws on evidence from a large number of studies concerning the social costs of electricity and identifies proven instruments for internalising them so as to improve overall welfare.

The results outlined in the report should lead to new and more comprehensive research on the full costs of electricity, which in turn would allow policy makers and the public to make better informed decisions along the path towards fully sustainable electricity systems.

Nuclear safety and regulation



Phenomena Identification and Ranking Table

R&D Priorities for Loss-of-Cooling and Loss-of-Coolant Accidents in Spent Nuclear Fuel Pools

NEA No. 7443. 82 pages.

Available online at: https://oe.cd/2pN

The present report is a follow up to this status report, documenting the results of a Phenomena Identification and Ranking Table (PIRT) exercise conducted by the NEA. This PIRT exercise identified SFP accident phenomena that are of high importance and yet are highly uncertain, thus highlighting their primary interest for further studies. The report recommends further support for existing experimental programmes and the establishment of a number of new programmes to focus, for example, on large-scale thermal-hydraulic experiments on the coolability of partly or completely uncovered spent-fuel assemblies and the investigation of spray cooling for uncovered spent-fuel assemblies in typical storage racks.

Radiological Protection and Human Aspects of Nuclear Safety

Country-Specific Safety Culture Forum: Sweden

NEA No. 7420. 52 pages.

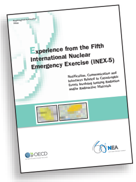
Also available in Swedish.

Available online at: https://oe.cd/nea-cssc-sweden-pub

One of the many important lessons learnt about nuclear safety over the years has been that human aspects of nuclear safety are as important as any technical issue that may arise in the course of nuclear operations. The international nuclear community can work together to identify and address issues associated with components and systems and compare operational experiences, but identifying how human behaviour affects safety and the best approaches to examine this behaviour from country to country remains less common.

Practical experience has nevertheless shown that there are important differences in how people work together and communicate across borders. People's behaviours, attitudes and values do not stop at the gate of a nuclear installation, and awareness of the systemic nature of culture and its deeper aspects, such as the dynamics of how values and assumptions influence behaviours, continues to evolve.

The NEA safety culture forum was created to gain a better understanding of how the national context affects safety culture in a given country and how operators and regulators perceive these effects in their day-to-day activities. The ultimate goal is to ensure safe nuclear operations. The first NEA safety culture forum – a collaborative effort between the Nuclear Energy Agency (NEA), the World Association of Nuclear Operators (WANO) and the Swedish Radiation Safety Authority (SSM) – was held in Sweden in early 2018. This report outlines the process used to conduct the forum, reveals findings from the discussions and invites the nuclear community to further reflect and take action.



Experience from the Fifth International Nuclear Emergency Exercise (INEX-5)

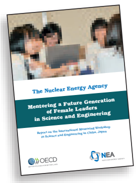
NEA No. 7379. 60 pages.

Available online at: https://oe.cd/2oG

The NEA has a long tradition of expertise in the area of nuclear emergency policy, planning, preparedness and management. Through its activities in this field, it offers member countries unbiased assistance on nuclear preparedness matters, with a view to facilitating improvements in nuclear emergency preparedness strategies and response at the international level. A central approach to this has been the preparation and conduct of the International Nuclear Emergency Exercise (INEX) series.

The Fifth International Nuclear Emergency Exercise (INEX-5) was developed specifically in response to member countries' desire to test and demonstrate the value of changes put in place following the Fukushima Daiichi nuclear power plant accident. Exercise objectives focused on notification, communication and interfaces related to catastrophic events involving ionising radiation and/or radioactive material. The exercise was held during 2015 and 2016, with 22 countries participating in the exercise.

This report summarises the major evaluation outcomes of the national and regional exercises, policy level outcomes, recommendations and follow-up activities emerging from INEX-5 and the discussions at the INEX-5 International Workshop. A set of key needs were identified in areas such as real-time communication and information sharing among countries and international partners, improving cross-border and international co-ordination of protective measures and considering the mental health impacts on populations when implementing protective measures.

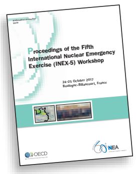


Mentoring a Future Generation of Female Leaders in Science and Engineering

NEA No. 7454. 12 pages.

https://oe.cd/2pP

The NEA mentoring workshops are in line with the initiatives being undertaken by countries around the world to ensure that expertise is maintained in highly technical areas such as nuclear safety, radiological protection and other critical disciplines. Capacity-building efforts focusing on science, technology, engineering and mathematics (STEM) fields need to be sustained and reinforced – particularly those aimed at young women, who are significantly under-represented in many areas. It is in this spirit that the NEA partnered with Japan's National Institutes for Quantum and Radiological Science and Technology (QST) in 2017 to organise its first International Mentoring Workshop in Science and Engineering, on 25-26 July 2017 in Chiba, Japan. The success of this first workshop has led to the organisation of two additional workshops in 2018, both of which are introduced in this brochure – one in Tokyo, Japan, and the other in Ávila, Spain. These workshops are a clear manifestation of the NEA's commitment to maintaining, and further strengthening, its momentum in encouraging a future generation of female leaders in science and engineering fields.



Proceedings of the Fifth International Nuclear Emergency Exercise (INEX-5) Workshop

NEA No. 7442. 54 pages.

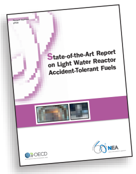
Also available in Swedish.

Available online at: https://oe.cd/2pO

The Fifth International Nuclear Emergency Exercise (INEX-5) was developed in response to NEA member countries' desire to test and demonstrate the value of changes put in place following the Fukushima Daiichi nuclear power plant accident. INEX-5 was held during 2015 and 2016, and was followed by the Fifth International Nuclear Emergency Exercise (INEX-5) Workshop in early 2017. Representatives from 22 member countries, the International Atomic Energy Agency and the European Commission attended the workshop, where participants identified elements emerging from INEX-5 that would help improve international and national arrangements for notification, communication and interfaces related to catastrophic events involving radiation or radiological materials.

The workshop was an interactive experience structured around invited presentations, moderated discussions and breakout groups that addressed the four broad topics of communication and information sharing with other countries and international partners; cross-border and international co-ordination of protective actions; mid- and long-term aspects of recovery; and connections with the work of other international organisations and networks. These proceedings provide a summary of the proposals and recommendations for future work in emergency management.

Nuclear science and the Data Bank



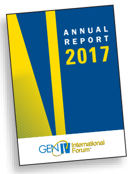
State-of-the-Art Report on Light Water Reactor Accident-Tolerant Fuels

NEA No. 7317. 368 pages.

Available online at: https://oe.cd/nea-ATFs-2018

As part of a broader spectrum of collaborative activities underpinning nuclear materials research, the Nuclear Energy Agency is supporting worldwide efforts towards the development of advanced materials, including fuels for partitioning and transmutation purposes and accident-tolerant fuels (ATFs). This state-of-the-art report on ATFs results from the collective work of experts from 35 institutions in 14 NEA member countries, alongside invited technical experts from the People's Republic of China. It represents a shared and consensual position, based on expert judgment, concerning the scientific and technological knowledge related to ATFs. The report reviews available information on the most promising fuels and cladding concepts in terms of properties, experimental data and modelling results, as well as ongoing research and development activities. It also includes a description of illustrative accident scenarios that may be adopted to assess the potential performance enhancement of ATFs relative to the current standard fuel systems in accident conditions, a definition of the technology readiness levels applicable to ATFs, a survey of available modelling and simulation tools (fuel performance and severe accident analysis codes), and the experimental facilities available to support the development of ATF concepts. The information included in this report will be useful for national programmes and industrial stakeholders as an input to setting priorities, and helping them to choose the most appropriate technology based on their specific strategy, business case and deployment schedules.

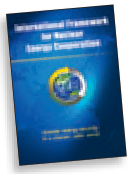
Publications of Secretariat-serviced bodies



Generation IV International Forum (GIF) Annual Report 2017

GIF report. 182 pages.

This eleventh edition of the *Generation IV International Forum (GIF) Annual Report* highlights the main achievements of the Forum in 2017. During the year, several of the GIF Project Arrangements were extended for another ten years, new projects were prepared and others terminated, thereby setting the scene for long-term co-operation among GIF members. Australia, which joined the GIF in 2016, formally acceded to the Framework Agreement in 2017, and subsequently signed the Systems Arrangements for very high temperature reactors and the molten salt reactors. The safety design criteria and guidelines first developed for sodium fast reactors were extended to other systems, and the Education and Training Task Force successfully organised twelve webinars. In the context of rapidly evolving energy markets and efforts to reduce global greenhouse gas emissions, the GIF continued to work on assessing and highlighting the benefits of deploying Generation IV systems with the support of the Economic Modelling Working Group and the Senior Industry Advisory Panel.



International Framework for Nuclear Energy Cooperation

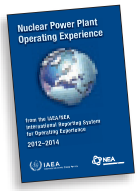
IFNEC brochure. 8 pages.

Available online at: www.ifnec.org

Multinational Design Evaluation Programme (MDEP) Annual Report: April 2017-April 2018

MDEP report. 56 pages.

Available online at: https://oe.cd/2rQ



Nuclear Power Plant Operating Experience

From the IAEA/NEA International Reporting System for Operating Experience 2012–2014

NEA No. 7448. 56 pages.

Available online at: https://oe.cd/2pQ

The International Reporting System for Operating Experience (IRS) is an essential system for the exchange of information on safety related events at nuclear power plants worldwide. The fundamental objective of the IRS is to enhance the safety of nuclear power plants through the sharing of timely and detailed information on such events, and the lessons that can be learned from them, to reduce the chance of recurrence at other plants.

The fi rst edition of this publication covered safety related events reported between 1996 and 1999. This sixth edition covers the 2012–2014 period and highlights important lessons learned from a review of the 258 event reports received from participating States during those years.

The IRS is jointly operated and managed by the OECD Nuclear Energy Agency (OECD/NEA) and the IAEA.

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Version: November 2018

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.

The NEA has 33 member countries: Argentina, Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The NEA co-operates with a range of multilateral organisations, including the European Commission and the International Atomic Energy Agency.

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

For more information about the NEA, see: **www.oecd-nea.org**
Editor: Andrew Macintyre and Janice Griffiths
Design and layout: Fabienne Vuillaume
Editorial assistant: Rhiann Pask
Production assistant: Laurie Moore

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

PRINTED IN FRANCE

Cover page photo credits: Transient Reactor Test Facility (TREAT), Idaho National Laboratory, United States; Advanced Test Reactor Full-Core Model for IRPhE Evaluation – MeshTal Viewer; The ATLAS facility, KAERI, Korea and The Third International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station on 5-6 August 2018 in Fukushima, Japan.

Agence pour l'Énergie nucléaire (AEN)
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt, France
Tél. : +33 (0)1 45 24 10 15
nea@oecd-nea.org **www.oecd-nea.org**

NEA No. 7402