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OECD Boulogne building.


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Nuclear Energy and the NEA: Continuous service during the COVID-19 crisis

The crisis we have been facing over the past several months is unlike any we have ever faced in the era of globalisation and interconnectiveness. All countries have felt the impact, all economies have been affected, all populations are under threat. Despite the return of some countries to an almost normal, yet necessarily more precautious situation, the event is still ongoing and, by most accounts, is likely to be with us in varying degrees of severity for months.

In the short term, an important pillar of any country's pandemic response strategy is a reliable electricity supply. Many parts of the infrastructure essential to modern life – food supply, transportation and public health services cannot function without reliable electricity. The principal threat to the operation of any electricity generating facility during a pandemic is the direct and indirect effects on essential personnel for extended periods.

The nuclear sector, like all other areas of our modern society, has been doing its part to reduce the number of infections. The world's nuclear power plants are operating safely and effectively and are contributing to the reliable grids needed to power the untold millions who are teleworking, the families sheltering at home, and essential medical facilities operating far beyond their intended capacity. But while the energy flows, the sector itself is impacted by the pandemic and must quickly adapt to ever-changing, unprecedented and uncertain circumstances.

It is the norm in the nuclear sector to change processes and practices only after deliberate analyses, with numerous viewpoints taken into account; but today's crisis calls upon all for quick responses. Decisions must be made rapidly in situations that have no complete parallel. Regulators must adjust their plans for inspections. Operators defer outages and modifications to their plants. Technologies that allow people to do their jobs away from normal workplaces must be applied in new and innovative ways. In each country, choices are made in the context of the level of threat to the health and safety of the workforce and the general population. Still, in each country, nuclear safety remains the priority.

With this backdrop, the NEA must support our members as they adjust to the environment created by the COVID-19 crisis. We have worked to establish a means for rapid exchange of ideas and best practices, information about what is working well and what is not. While we hope that the threat from this pandemic will soon lessen, many experts anticipate a considerable risk to public health continuing into September and October, with the potential of a second round of infections. The NEA's ongoing work will serve both immediate necessities and prepare us for the longer term.

In the meantime, the pandemic has been a test of the NEA's own safety culture. I am pleased to report that the same safety culture we highlight in our publications on nuclear operations, putting health and safety first, has been applied to the NEA itself. The entire Agency has been teleworking since 12 March, with little disruption to its work. While important events have been postponed, the work of our committees has continued, software packages from the NEA Data Bank continue to be issued, and we have successfully hosted numerous web events and online meetings since the crisis began – including several online discussions on the topic of the crisis itself.

This success is due to the dedication of the Agency's staff to the work we pursue on behalf of our member countries; to the commitment of our members to the important matters that bring them together from all over the world; and to the confidence of all those who comprise the nuclear technology sector that whatever challenges we face at the moment, a brighter future always lay ahead.

William D. Magwood, IV,
NEA Director-General

Reducing the construction costs of nuclear power[1]

by A. Vaya Soler and M. Berthélemy

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Barakah Nuclear Power Plant, United Arab Emirates.

On 8 August 2020 at 19:52 local time, unit 5 of the Tianwan nuclear power plant (NPP) in Jiangsu province, People's Republic of China, was connected to the grid. The first concrete of this ACPR1000 reactor had been poured on 27 December 2015, meaning that this milestone was achieved less than five years after construction first began (WNN, 2020).

This level of construction performance contrasts with that observed in recent projects in Western OECD countries where projects have been characterised by significant delays and cost overruns. In some cases costs have more than tripled from initial estimates. This poor track record has helped create the perception of the increased overall risks associated with new NPP projects and is weighing on near-term decisions over whether to pursue new developments or not. As a result, nuclear energy may be unable to deliver its expected role in reducing carbon emissions (IEA, 2020).

On the other hand, successes like that in Tianwan demonstrate how the nuclear sector can deliver cost effectively and on a predictable time frame if the right conditions are in place during the planning and execution of these projects. In other words, the problem is not associated with nuclear energy as such but with specific projects.

In light of these trends, in 2018 the NEA formed an ad hoc expert group to consider the issues around reducing the costs of nuclear power generation. The group's objective was to identify industrial strategies and governing frameworks to unlock significant cost reductions in the deployment of large Generation III reactors over the next decade and beyond in OECD countries. The group gathered together participants from academia, the nuclear industry and international organisations to provide a 360-degree view of the economic issues faced by nuclear new build and to collect first-hand insights of ongoing projects.

1. *Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders*, on which this article is based, is available for download from the NEA website.

Nuclear power plants, like all other low-carbon technologies such as solar PV and wind, are capital intensive with a cost structure dominated by upfront investment costs. Of particular importance are the financing costs that can represent up to 80% of the investment costs in the levelised cost of electricity (LCOE). Financing costs include interest accrued during construction as well as the return of capital during the operating lifetime of the plant. Most of an NPP's expenses are incurred upfront during the construction period, thereby making this type of investment highly sensitive to the cost of capital. The uncertainties around construction costs become more detrimental than those costs and any unexpected delay or expense comes at a very high economic penalty. That is why building on time and on budget is a necessary condition to improving the economic performance of nuclear new build.

One of the first insights the group drew was the relevance that they gave to the context when assessing the cost of nuclear power. New build projects are a complex network of interactions involving various stakeholders connected to evolving industrial capabilities and policy decisions. As such, initial cost escalations may be exacerbated, among other factors, by the lack of a detailed design or a particular political environment. Furthermore, most of the ongoing nuclear builds in western OECD countries are first-of-a-kind (FOAK) projects that have come after a long hiatus in nuclear construction with direct consequences for supply chain capabilities. The investment costs of current FOAK projects in some Western countries therefore reflect both the costs of the plant itself and the costs of restoring industrial capabilities. The latter are essentially indirect (i.e. design, supply chain qualification, licensing, etc.) and non-recurring in nature, which means that they will be amortised with timely decisions on subsequent construction projects. With several projects near completion in OECD countries, the next decade offers a window of opportunity to capitalise on the lessons and infrastructure developed from recent Generation III reactors, and to deliver more competitive nuclear power projects. However, historical nuclear construction cost data shows that building more reactors may not necessarily yield cost savings. Cost reductions are also contingent on a number of additional factors.

The experts identified eight key construction cost reduction factors to drive positive and incremental learning of nuclear development in the short and long terms (Table 1). The optimum scenario assumes a programmatic approach in which several units are planned for construction to enable the mobilisation of these factors in the different stages of learning. Drivers can be divided into four main categories that also reflect the main risk dimensions for any nuclear project. This is significant for future projects, as each factor will simultaneously support cost and risk reductions.

The drivers in the first column are essential in early stages of learning when moving from FOAK to post-FOAK. They reflect the main lessons learnt during recent projects and past nuclear programmes. At the end of any FOAK project, the design and the supply chain supporting the associated delivery process have gained in maturity and could be reproduced more easily. By simply freezing the product and replicating it, subsequent units should be cheaper. The benefits of replication are particularly important within the same site (i.e. multi-unit effect). Recent experience from the Barakah project in the United Arab Emirates reveals cost reductions of 60% between the first and fourth unit.

Table 1: Cost reduction drivers at different learning stages

Dimension	Lessons learnt (from FOAK to post-FOAK)	Short- and long-term cost reduction opportunities (from post-FOAK to nth-of-a-kind [NOAK])
Technology	Design maturity	Design optimisation
Delivery	Effective project management	Innovative technologies and processes
Regulatory	Stability and predictability of the regulatory framework	Revisited regulatory frameworks
Policy	Multi-unit and series effect	Harmonisation of licensing and codes and standards

Source: NEA (2020).

The reductions are the result of a better allocation of resources and major productivity gains with the same workforce repeating identical tasks across several units. At the same time, given the organisational complexity of nuclear projects, experienced project management teams and proven tools are needed to set out clear priorities and responsibilities at all levels and stages while dealing effectively with the numerous instances of interface management required. This is globally true as long as the regulatory framework remains stable and predictable. Evidence from the United States shows that the regulatory changes introduced after the Three Mile Island accident were very detrimental to projects under construction as a result of the rework and subsequent loss of efficiency and idling times.

Building on these four core drivers, it is then possible to move cost effectively towards nth-of-a-kind (NOAK) conditions. New cost reduction strategies can be applied concurrently to accelerate the learning process and maximise its benefits. These opportunities are real and have been demonstrated by countries in more advanced stages of learning that approach nuclear new build as a product (rather than one-off projects), exploiting interplays between the product and enabling and construction processes to improve the delivery of new units.

Over the next decade the experience gained with post-FOAK constructions could be used to optimise reactor designs. Potential methods include simplification, standardisation and reclassification of safety components through risk-informed decision-making. In this process, it is essential to follow incremental steps and avoid structural design modifications to minimise potential non-recurring costs that could undermine the positive dynamics of learning-by-doing. In addition, innovative tools and techniques that have already been successfully implemented in other industries can be adopted in the managerial, construction and manufacturing processes. For instance, digital transformation offers an opportunity to enhance traditional system engineering and knowledge management approaches and build more integrated supply chains. Tools such as Product Lifecycle Management can inform all activities and processes throughout the extended enterprise assuring the perfect traceability of information and technical choices, which is essential for industries working to high quality standards in projects with long expected operating lifetimes. The nuclear industry is already deploying these digital tools as well as undertaking the necessary workforce training and organisational changes to maximise their benefits. Modular construction is also well advanced in the realm of Generation III reactors. Traditionally, large "stick-built" plants already incorporate certain levels of factory construction (approximately 30% of the construction costs) for the fabrication of the reactor and turbine block components and control systems. By means of modularisation techniques it is possible to increase this proportion up to 40%. Eventually, modularisation strategies in large reactors face some limitations due to the size of the components and transportability constraints. The ability of the supply chain to deal with the different modules is also key for the successful implementation of these type of approaches.

From a regulatory perspective, safety does not have to be considered as a cost driver. In 2016, GE-Hitachi and the UK Office for Nuclear Regulation (ONR) co-operated on a review of the proposal to build advanced boiling water reactors at Wylfa, in North Wales. Cost reductions of 20% were realised, notably by adapting generic assumptions to local site conditions and plant layout. Regulator engagement at the executive level and regulatory flexibility to challenge initial design assumptions positively contributed to these achievements. At the outset, revisiting regulatory interactions implies a willingness from the regulator to welcome new approaches to ensure that industry responds to safety rules and regulatory decisions.

An aerial view of Hinkley Point C.
Creative Commons, Hydrock

In the longer term (i.e. after 2030), cost savings arising from the harmonisation of codes and standards and licensing have been identified as a promising avenue for cost reductions. Initiatives such as the NEA-led Multinational Design Evaluation Programme (MDEP) and the World Nuclear Association Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL) have demonstrated that is possible to capitalise on the experience of the aviation industry and reach common positions among regulators in a number of areas. Additionally, significant progress has been made with the publication of the ISO 19443 in 2018 for the qualification of the global nuclear supply chain.

At the same time, Small Modular Reactors (SMRs) are gaining recognition as a potential disruptive option to deliver additional economic benefits. Owing to their smaller size and modular construction, SMRs introduce a set of advances at the design and process level that could mean shorter construction lead times and extend the nuclear power value proposition. However, for SMRs to be a credible option by the early 2030s, successful demonstration units must be developed in the 2020s to prove these benefits. In addition, access to a global market that fosters serial construction will be an essential condition to counterbalance the diseconomies of scale associated to their smaller size. Moreover, most of the cost reduction drivers shown in Table 1 are not technology specific and SMRs will therefore benefit from progress made with the deployment of large NPP projects in the 2020s.

Finally, a programmatic approach to deliver competitive nuclear power requires long-term planning conditions that only governments can provide. Government intervention is also justified by the positive externalities of nuclear power in terms of climate and air pollution mitigation, the electricity markets designs that do not provide adequate long-term price signals to invest in low-carbon technologies and potential economic recovery policies. Government involvement can take many forms and plays a key role in addressing the different risk dimensions associated with nuclear new build projects. Policy-related risks can be mitigated by committing to several construction projects under a robust policy framework that gives long-term visibility and confidence to the nuclear supply chain. Governments can also contribute to tackle market-related risks. This is the case for the Hinkley Point C EPR project whose revenues are regulated by a contract for difference. Lastly, government direct or indirect financial participation to a project will also impact construction risks. The underlying objective is to define a risk allocation scheme that, along with the eight construction costs drivers discussed above, lowers the project risk exposure and therefore the cost of capital required by public and private investors.

More recently, the COVID-19 pandemic has been a stark reminder of the critical importance of having a robust electricity infrastructure capable to withstand and recover from major disruptions. Resilience will be at the core of the design and deployment of any future energy infrastructure. At the same time, the stimulus packages under development in different countries provide an excellent opportunity to place the development of a low-carbon resilient infrastructure at the centre of the economic recovery. Including new nuclear power projects in the recovery plans would have the double dividend of reducing the costs of this technology while boosting economy recovery thanks to their significant technological and economic spillovers in the local and national economy.

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Management and disposal of high-level radioactive waste: Global progress and solutions[1]

by T. McCartin and R. Tadesse

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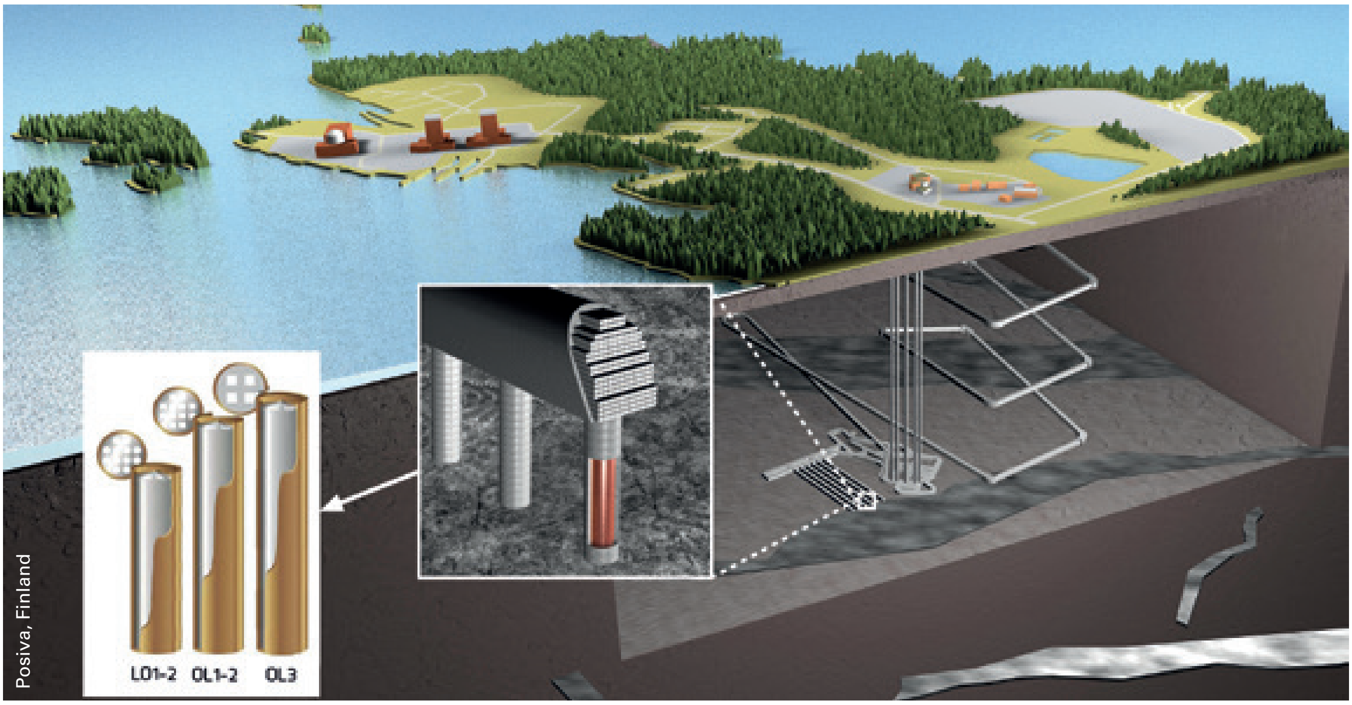


The Onkalo spent nuclear fuel repository.

While the government of each country has the absolute right and responsibility to implement the energy and environmental policies it believes are best, it is paramount that these important matters are informed by objective facts. In the case of the attributes of nuclear energy and the disposal of radioactive waste, debates should be informed by objective facts.

In some parts of the world there has been debate about the "sustainability" of nuclear energy, and the long-term management of spent nuclear fuel and high-level waste (SNF/HLW) is of particular importance in this context. After decades of scientific analyses, engineering tests, development and operation of underground research laboratories, and actual operation of deep geologic repositories, the international scientific community is confident that placing high-level radioactive waste in deep geological repositories (DGRs) is both safe and effective.

The safety strategy for geologic disposal has been developed over many decades. A DGR isolates and contains the spent nuclear fuel and high-level waste over very long time periods through the combination of robust engineered barriers and the intrinsic properties of the host rock that provides a stable safe environment. The passive safety features of the DGR make it possible to protect humans and the environment in the very long term without requiring any maintenance or remediation action by future generations.

1. *Management and Disposal of High-level Radioactive Waste: Global Progress and Solutions*, on which this article is based, is available for download from the NEA website.

A DGR is comprised of multiple safety barriers that increase the robustness of the facility so that safety is not dependent on a single barrier, which is consistent with a defence-in-depth principle, the common practice in the nuclear field for ensuring safety.

The basis for the development of safety cases for the deep geological disposal of radioactive waste is assuring safety over the long period during which the radioactive waste remains hazardous. The largest part of the intrinsic hazard of the waste decreases with time, but some hazard remains for extremely long periods. Safety cases for geological disposal typically address performance and protection for thousands to hundreds of thousands of years into the future. The very concept of the DGR is to dispose the waste in a well-characterised geological formation, stable enough for the science to assure protection of humans and the environment over very long time frames.

Timeframes into the distant future cause all stakeholders to question the confidence in the safety case for a DGR. While it is difficult to guarantee the performance of a human-made construction for several hundred years, scientists agree that DGRs developed in suitable geological formations provide a stable and predictable environment over the very long time frames associated with these geological formations that already span millions of years. The stability of geological formations for siting a DGR is based on a global geological understanding derived from active earth science research that supports stability for geological formations far beyond the time periods required for the long-term containment and isolation of SNF/HLW. The scientific evidence of the selected host rock makes it possible to demonstrate the post-closure safety of a DGR as the proven stability of the geological characteristics and environment provide the multiple safety functions of the DGR in a fully passive way, even should human memory of the DGR be lost.

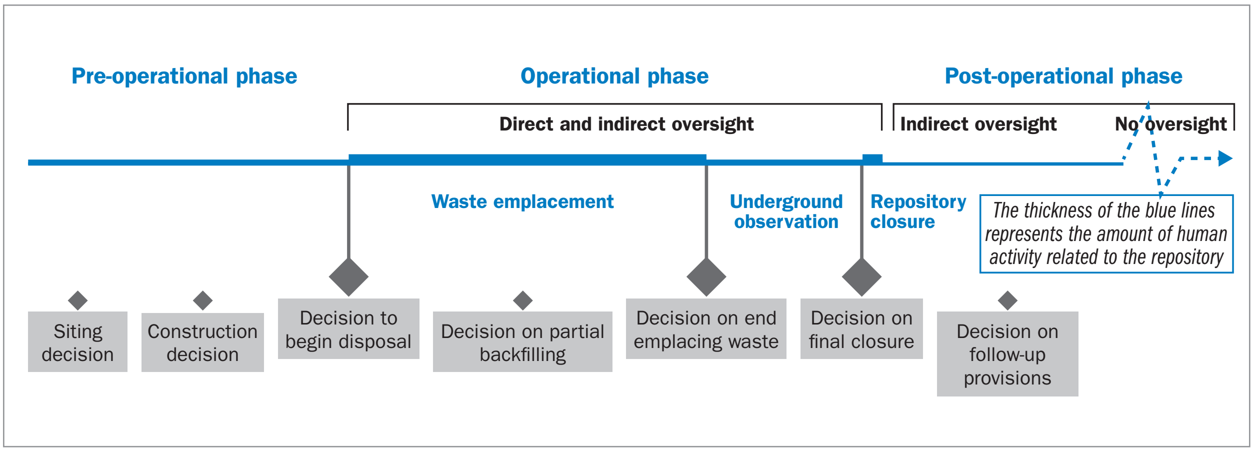
Scientific investigation into the feasibility of DGRs for the safe disposal of SNF/HLW has proceeded for decades at a cautious and deliberative pace that has significantly expanded the volume and quality of scientific information on the safety of geological disposal. Where technical questions arise, they are not questions about the safety or sustainability of the DGR approach but more likely to be engineering issues in the specific approaches taken in some designs. Such issues are expected in a complex undertaking such as the construction of a DGR.

The greatest challenge in many countries to developing high-level radioactive waste disposal repositories is achieving public support and confidence. In countries with advanced DGR projects, both governments and the nuclear industry have invested a tremendous effort in building up a collective awareness on uncertainties and benefits of radioactive waste disposal facilities. In many countries, a more open, transparent and broadly participatory approach to managing radioactive waste is being adopted. A cautious and flexible step-wise decision process that offers the flexibility to reverse decisions when new knowledge becomes available is a common trend. Whether, when and how to move towards geological disposal are decisions for each country. The decision process will be lengthy. Countries should therefore use the time for dialogue with all stakeholders with a view to addressing the long-term technical and social uncertainties.

Public information, consultation and/or participation in environmental or technological decision making must take place in different forums, in different locations and at different times (Figure 1). Assuring national commitment and obtaining strong local and regional involvement in decision making are two essential dimensions of the complex task of securing continued societal agreement for the deep geological disposal of radioactive waste.

Several countries are making very good progress towards the establishment of DGRs. In particular, after a long and careful technical assessment, the Radiation and Nuclear Safety Authority of Finland (STUK) has granted a licence to construct a DGR. This national waste management programme is on track to begin disposal operations by the mid-2020s. There has been limited progress in some other countries, but this is not due to scientific or technological uncertainty but rather because of the careful, deliberative stakeholder processes underway to ensure that the public has confidence in the safety of the facility and the fairness of the criteria used for site selection. Others have experienced much slower progress, and in some cases progress has come to a standstill as options are further reviewed or put on hold while experience is further developed internationally.

Figure 1: Repository life phases and examples of major decision points



View of main drift looking north towards station at 2 150 foot level.

Department of Energy, United States.

While the disposal of nuclear wastes is the responsibility of national governments, they are supported by multinational organisations that collect and share expertise. Principally among these are the NEA, the Vienna-based International Atomic Energy Agency (IAEA) and the European Commission, all of which have various activities and publications addressing different aspects of the long-term management of all types of radioactive waste management and spent fuel. International co-operation can help achieve national solutions – by sharing information, co-ordinating policies, conducting joint research and developing a consensus on international standards. Over the years, technical and scientific co-operation have already been intensive. However, international dialogue at the strategic and policy levels can facilitate the exchange of existing experiences and approaches. In developing co-operation, it would be beneficial for national organisations to take an integrated and holistic view to assure safety and security for pre-disposal facilities and disposal repositories, both in the implementation of HLW management policies, programmes and in their regulatory oversight. Overall, there is widespread reporting of lessons learnt from both failures and successes in communicating technical information to non-technical audiences at an international level or by various international organisations. While certain areas where more research is needed have been identified (e.g. training in risk communication, public outreach techniques and the use of new tools such as social media), there is a need to continue developing approaches for effective dialogue. The NEA Forum on Stakeholder Confidence has been at work on this question for more than a decade and the NEA launched a new two-year initiative in 2019 to investigate the key elements needed for effective regulator-implementer dialogue when developing geological disposal facilities.

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GNDS: A standard format for nuclear data

by M. Fleming

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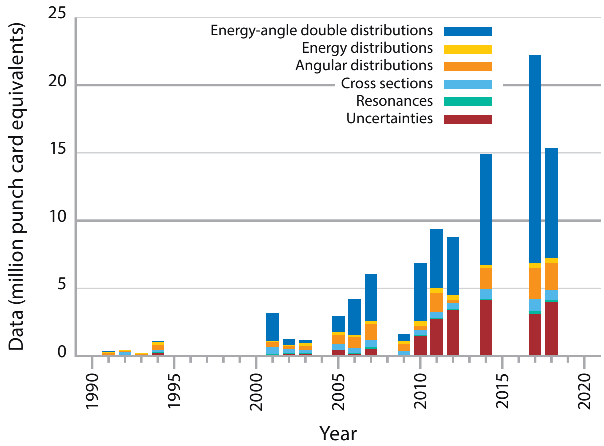
Knowledge of basic nuclear physics is essential for the safe operation of all nuclear facilities. Since the discovery of the neutron, many thousands of experiments have been carried out to carefully quantify how neutrons interact with all elements and isotopes. Coupled with models for the diffusion of particles in a system, these data allow us to simulate parameters in reactors, such as reactivity, and form the basis of our understanding of the operation of all nuclear power plants. These data are used in all nuclear applications, ranging from nuclear medicine to space exploration. National and international programmes have been established across the world to review all available measurements, and to bring insights from nuclear reaction theory and integral inferences from large-scale experiments to create state-of-the-art databases of all nuclear reaction physics. These are referred to as nuclear data libraries.

Many of the world's first computers performed calculations for nuclear applications and the way that nuclear data has been stored hearkens back to this age. The most common nuclear data format used today, the Evaluated Nuclear Data File 6 (ENDF-6), was originally designed for the 80-column punch-card readers available in the 1960s, complete with line numbers from the days when one might have to re-order a stack of paper cards that formed a complex and valuable database. The format has evolved over many decades, being extended to allow more complex descriptions that could be utilised by radically improved machines, in terms of computational power and storage capability. The fact that this format is still in use is a testament to the foresight of the scientists and engineers that created it, but ENDF-6 is now showing its age. Replacing this format and its affiliated system of codes will not only help to better capture the required physical data, but also allow more robust quality assurance, facilitate the interface with modern computing systems, and accelerate the transfer of knowledge and expertise to future generations.

Another benefit of the progress in computing hardware has been the increase in sophistication of theoretical nuclear reaction modelling and inferential algorithms, allowing experts to continually increase the fidelity of nuclear data and reduce the reliance on simplifications and approximations. The availability of these higher-fidelity data, coupled with state-of-the-art uncertainty analysis, is crucial for the advanced simulations that underpin new nuclear technologies. New uncertainty quantification methodologies allow the nuclear industry to better understand their systems and margins, enhance safety and provide more predictive modelling capabilities. These capabilities can increase efficiencies and lower costs. In order to do so, more detailed and accurate data is required – which in turn demands improvements to the standards for data storage that are out-of-date in comparison with modern physics and computing. Accurate uncertainty quantification requires a tremendous amount of correlated input data, [as shown by the trends in Figure 1], which must take numerous complex forms depending on the physics and uncertainties being considered.

Figure 1: The evolution of data contents in major worldwide nuclear data releases since 1990



Translating basic nuclear physics information into application-ready data requires a series of numerical processing algorithms to perform tasks such as Doppler broadening, adding in derived nuclear heating quantities or discretising the data for use in a lattice diffusion code. These processes translate between different data formats, including some with limited or non-existent documentation and requiring complex software that is often closed source and subject to export controls. This has held back progress and created an artificial barrier to accessing and contributing to methods and codes.

In 2013, the NEA launched a project with all the nuclear data evaluation projects from around the world to review the requirements for an international replacement for the ENDF-6 format. Over a three-year process, representatives from all member countries developed an extensive set of requirements that cover not only the necessary nuclear physics, but also rules for data interpolation, the storage of cross-correlations between data, mechanisms to build-in documentation as part of Quality Assurance procedures, and much more. Experts convened by the NEA proposed a new format specification for a Generalised Nuclear Data Structure (GNDS) in 2016 that has been further developed over another three-year process and subjected to rigorous international review. The Generalised Nuclear Database Structure 1.9, published in May 2020, is the outcome of this work.

Alongside the publication, a simple but effective process has been established to propose additions to this extensible new format, as overseen by the NEA. A network of experts will develop and submit proposals that will be reviewed ahead of the annual NEA meeting that prepares and approves new versions of the standard. These experts are members of their national nuclear data evaluation programmes and liaise with stakeholders from their country to prioritise the creation of new features that address emerging needs in modelling and simulation.

This work is co-ordinated with other co-operative projects in the NEA Nuclear Science Programme to directly integrate state-of-the-art developments into the GNDS format. For example, work in thermal neutron scattering organised at the NEA (NEA, 2020b) generated first-of-a-kind uncertainties in scattering kernels that can only be stored in the new GNDS. Recently completed NEA studies on modelling of the fission process and products produced new correlated fission yield uncertainties that are the subject of a new format extension proposal for the next GNDS version.

The international community of nuclear data centres has responded to the GNDS project by adopting GNDS into their workflows and releases. In 2018, Brookhaven National Laboratory released the Evaluated Nuclear Data File (ENDF) version VIII.0 library in the then-unreleased GNDS format and in July 2020 the International Atomic Energy Agency finished processing and verification of the complete TALYS-based Evaluated Nuclear Data Library (TENDL) using the GNDS-1.9 specifications published only two months prior. The Joint Evaluated Fission and Fusion File (JEFF) library project co-ordinated by the NEA has announced that all future libraries will be distributed with GNDS files, and other library projects are developing the capabilities to do so.

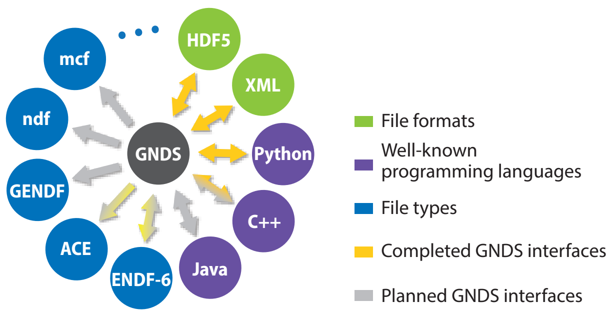
A large body of computer codes have been developed that rely on ENDF-6 formatted data and the refactoring of these to accommodate a wholly new structure from scratch would be a challenging task. This issue can be significantly simplified with the implementation of an application programming interface (API), which serves as an intermediary between the data files and the software that requires the data within those files. In parallel to the GNDS specifications, the NEA hosted a forum for informatics experts to discuss interfaces for the new data that are needed to integrate GNDS files into the ongoing workflows at utilities, technical support organisations, regulators, the research community and beyond. Experts, co-operating under the aegis of the NEA, are designing and implementing new APIs to jump-start this process and prepare users to be able to immediately start adopting the new standard. This has already resulted in multiple APIs being released as open source projects, including the Lawrence Livermore National Laboratory GIDI+ and FUDGE packages, the Los Alamos National Laboratory GNDS toolkit (GNDStk) and the Oak Ridge National Laboratory GNDS extension of the AMPX processing code, with more in development in France and Japan. These APIs are distributed under open licences and have already been integrated into systems that perform nuclear data processing, Monte-Carlo radiation transport simulation and deterministic lattice calculations using discretised physics.

Advanced nuclear simulation codes such as Geant4 (European Organisation of Nuclear Research), SCALE (Oak Ridge National Laboratory, United States) and Mercury (Lawrence Livermore National Laboratory, United States) have already developed full or partial capabilities to interpret GNDS data, with plans to transition to the new standard as validation cases reach maturity. In comparison to the processes required to utilise ENDF or other legacy data structures, integrating GNDS is straightforward due to the adoption of modern programming paradigms and the ability to leverage the wealth of powerful and mature software libraries available today.

GNDS is technically a structure, in that it can be realised in multiple file formats that are commonly used. GNDS can be – or has been – implemented with format technologies such as Hierarchical Data Format (HDF), eXtensible Markup Language (XML) or others, [as shown in Figure 2], and immediately interpreted with standard libraries in any modern computer programming language. These file formats have their own advantages and disadvantages (for example, binary files that can be quickly read but that may sacrifice inter-system portability) and projects may select the format based on their individual requirements while retaining the same data structures.

GNDS has been engineered as a replacement and extension of the ENDF-6 format. As such, it maintains a strict one-to-one translation capability with the legacy file format and files that are compliant with the ENDF format rules. Standard processed outputs, which are needed for nuclear modelling and simulation applications, may be generated by the Lawrence Livermore National Laboratory open-source FUDGE code system. Already in GNDS-1.9 there are features that cannot be translated back into ENDF-6 as there is no part of that format that can accommodate the data. While the US Cross Section Evaluation Working Group (CSEWG) continues to maintain and develop ENDF-6, which will remain in use for at least the short-term future, GNDS will continue to grow and offer capabilities that will only be available to those that switch to the new structure.

Figure 2: Completed and planned interfaces between GNDS and well-known programming languages, file formats and file types



Notes: File formats include the Hierarchical Data Format 5 (HDF5) and eXtensible Markup Language (XML). File types include the Evaluated Nuclear Data Format 6 (ENDF-6), A Compact ENDF (ACE), Group-wise ENDF (GENDF) and the Lawrence Livermore Nuclear Data File (ndf) and Monte-Carlo File (mcf).

Source: Brookhaven National Laboratory.

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NEA (2020b) Thermal Scattering Law S(α,β): Measurement, Evaluation and Application: International Evaluation Co-operation Volume 42, OECD Publishing, Paris. Download the report at www.oecd-nea.org/science/wpec/documents/volume42.pdf

Workshop on Preparedness for Post-Accident Recovery: Lessons from Experience

by J. Garnier-Laplace and H. Ogino

Dr Jacqueline Garnier-Laplace (jacqueline.garnier-laplace@oecd-nea.org) is Radiological Protection Specialist in the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety and Dr Haruyuki Ogino (haruyuki_ogino@nsr.go.jp) is Chief for International Affairs and Radiation Protection at the Radiation Protection Policy Planning Division of the Nuclear Regulation Authority, Japan.

The audience interacting with the presenters.

The Workshop on Preparedness for Post-Accident Recovery Process: Lessons from Experience, co-organised by the Nuclear Energy Agency (NEA) and the Nuclear Regulation Authority (NRA) of Japan with the support of the Nuclear Safety Research Association (NSRA), was held on 18-19 February 2020 at the University of Tokyo, Japan.

Recovery after a nuclear accident is an extremely complex process of multidisciplinary dimensions. Improving preparedness for recovery is a key objective that has been identified by the NEA Committee on Radiation Protection and Public Health (CRPPH). This can be achieved by focusing on a holistic multidimensional approach that will incorporate functional cross-sectoral links between various aspects of emergency impact on a society (e.g. health, environmental, economic, social and cultural). In early 2019, the CRPPH Expert Group on Recovery Management (EGRM) agreed to study the challenge of improving post-accident recovery efficiency and effectiveness.

The February workshop prepared by the EGRM was structured around five themes reflecting the topical issues at stake for recovery: radiological monitoring and dose assessment; waste management; food-related issues; business continuity; and well-being of concerned people and communities. The workshop provided an opportunity to discuss these elements through the perspective of using the lessons learnt to elaborate a framework for nuclear post-accident recovery preparedness. Interactions with Japanese governmental organisations and non-governmental stakeholders facilitated the understanding of successes and remaining challenges in the recovery process in Japan, nine years after the Fukushima Daiichi nuclear accident.

Various initiatives to prepare or implement the recovery process were presented and stimulated rich exchanges between presenters and the audience, thanks to the diverse profiles of participants representing various organisations or associations in Japan (64 participants) or in other countries (21 participants from 6 countries), either governmental or non-governmental, national or local, from the private or public sector, and from the nuclear or non-nuclear sector.

Mr Nobuhiro Muroya,
NEA Deputy Director-General giving
his welcoming address.

Dr N. Ban, Commissioner of the NRA of Japan, opened the workshop by highlighting unresolved problems for evacuees and returnees, including family issues, community severance and, more globally, concerns over well-being: *"There is no doubt that all these difficulties stem from radiological protective actions, but controlling radiological doses without considering human dimension will not solve any problems"*. In his opening remarks, NEA Director-General William D. Magwood, IV pinpointed the complexity of the recovery process where *"there is no one-size-fits-all approach"*. NEA Deputy Director-General, Mr Nobuhiro Muroya, concluded that the NEA, as well as the EGRM, will play key roles in member country preparedness by contributing to the collection of Japanese reconstruction experience after the Fukushima Daiichi nuclear accident, and sharing such lessons learnt with the international community.

Major findings from the topical sessions of the workshop are listed below:

The process for agreeing on the "end-state" objectives of post-accident reconstruction by involving stakeholders in an inclusive manner, is essential and should integrate:

- prevailing circumstances;
- waste management issues;
- all-hazards consideration of resource limitations and a reasonable level of conservatism;
- skilled workforce availability;
- consideration of behaviour changes that are necessary for successful exposure management while at the same time providing decent living and working conditions in a more stable environment.

In the recovery phase, monitoring results play a key role in indicating the evolution of the radiological situation and help people to understand and adapt their way of life to the situation. The monitoring strategies in place should inform dose assessment and address:

- responsibilities among national and local organisations as well as stakeholders;
- the use of data from various monitoring sources;
- the financial and material resources for monitoring needs where it is unlikely that any single country will have enough resources for recovery.

Regarding decontamination strategies, a holistic environmental restoration approach is necessary and should incorporate:

- the exploration of clean-up options identified along with their consequences for waste management;
- the consideration of the impacts of various end-state options, integrating environmental safety, economic factors and social acceptance;
- the dissemination of easy-to-understand information is also a key factor for success in gaining and maintaining trust between the authorities and stakeholders, as well as ensuring sustainable waste management.

It has been nine years since the Fukushima Daiichi nuclear accident and various issues concerning well-being still exist and are clinically observed, both among the evacuees (e.g. loss of "normal way of life" and of interactions inside their community) and among the returnees (e.g. loss of livelihood and infrastructures such as schools, transportation, hospitals). Discussions with evacuees and returnees have demonstrated the important role of counsellors deployed by the government and municipalities, aiming to build trust-based relationships with affected populations. The most important remaining challenge is to find the appropriate balance between local expectations, in terms of healthcare services to appeal to newcomers and younger generations, and real needs (and funding) to develop facilities dedicated to elderly residents.

This is also true for businesses where the challenge is to succeed in matching the long-term wishes of returnees and the real needs of territories during the revitalisation process. With respect to food issues, for instance, several examples illustrated how food safety management is strongly correlated with economic factors through consumer trust, the loss of image for a region and/or a product, and/or the difficulty in maintaining the market for emblematic food products.

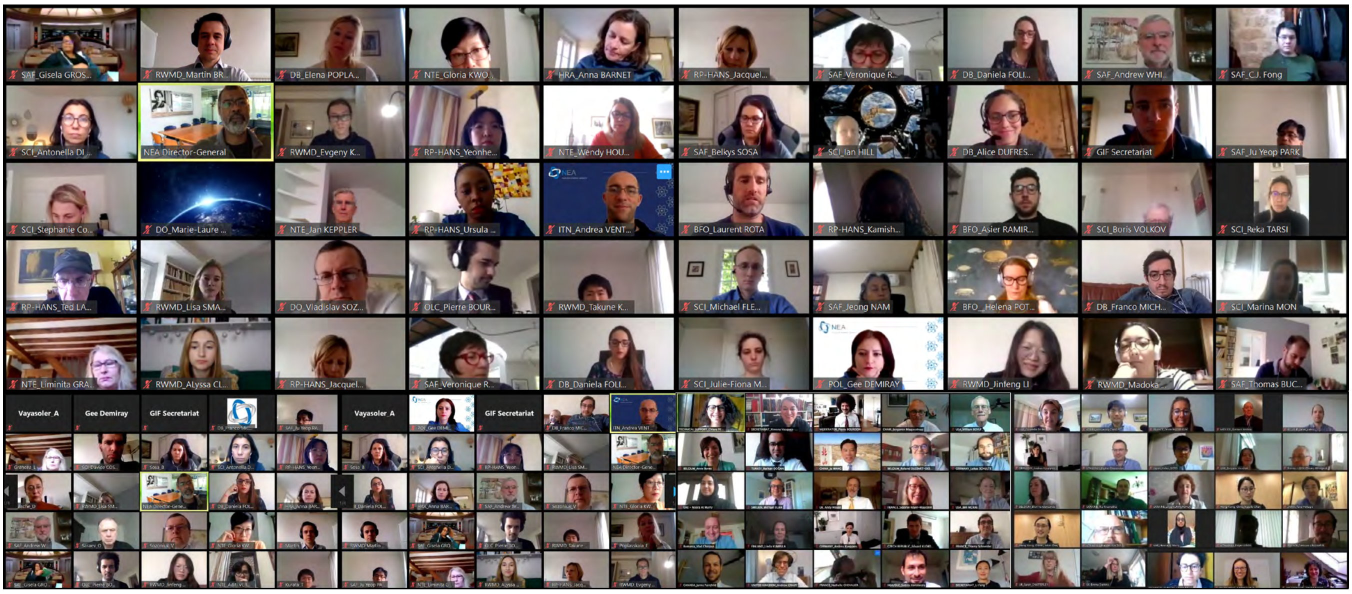
The chair and vice-chairs of the EGRM concluded the workshop by examining the findings from the perspective of preparedness for the recovery process and asking the important question: How would thinking in advance globally, i.e. in a holistic and multi-sectoral manner – balancing health, environmental, economic, social and cultural impacts – help to ensure that the emergency response strategy would tackle the emergency situation without delaying or impeding the recovery process? Preparedness strategy should include actions that harness the resilience of societies and engage local communities. The EGRM upcoming deliverable will also address the novel idea of exercising Post-Accident Recovery Management to evaluate the effectiveness and efficiency of stakeholder involvement, and/or of any other issues at stake for recovery.

The NEA is now preparing a complete summary report of the workshop in the hope that it can offer guidance to countries wishing to capture lessons learnt from experience through the elaboration or update of their nuclear post-accident recovery guidance and national management plans.

Online communications during the COVID-19 pandemic

by K. Martin

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.



As the Nuclear Energy Agency (NEA) has an international composition, many staff members have already experienced the need to adjust to new living norms when they relocated to Paris. Tapping into that experience and resilience to adapt to the completely different new normal that affects every aspect of life has been immeasurably important in recent months.

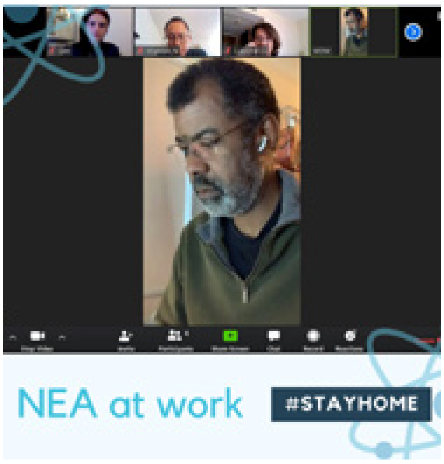
The effects of COVID-19 on the NEA working environment occurred gradually. Initially, there were rescheduled meetings and an air of ambiguity from the various health authorities on how long alternative measures would be required. As the reality of the situation unfolded, it became clear that there would be a new normal and the transition period itself would be a temporary normality.

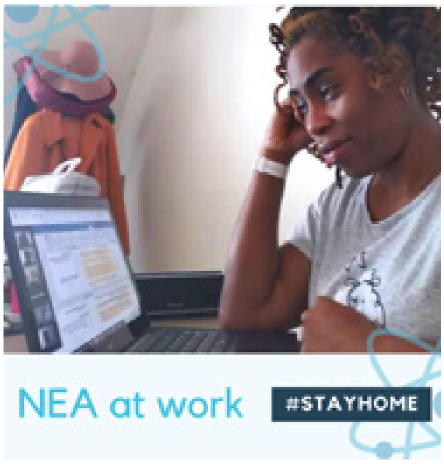
The NEA quickly adjusted and switched to a virtual method of interaction, with the mind-set that this new set up would only be required for a few months. Luckily, staff were readily equipped for this new reality since due to their frequent travel they were already familiar with the tools for remote working. Now, these tools support what is essentially a prolonged mission at home. The NEA has continued to interact with its member countries via video conferences, e-mails and phone calls, in order to ensure that existing connections do not break. The same applies to internal interactions to maintain a collaborative environment, even though a conversation over coffee is no longer a quick walk away. It will take an unknown amount of time to recommence the in-person meetings of committees, working parties and expert groups, and take advantage of the synergy gained from those human interactions. Nevertheless, there is hope that the same collegial attitude that has developed in the current situation will sustain these collaborative interactions when ‘normal’ meeting arrangements resume.

Just as NEA bodies and corresponding staff work on crosscutting topics that can apply to all areas of the nuclear field – for example, human aspects of nuclear safety is applicable to all areas of nuclear safety – the circumstances of the COVID-19 pandemic affect all NEA work areas. All NEA bodies have had to consider the ramifications of the current global health emergency. As it has physically immobilised many people, one hidden benefit of the current situation is the newfound availability of those who are normally constantly travelling (and who now seem to be in non-stop, virtual meetings). It is infinitely easier to schedule a video conference and there is less fettered access to those in leadership roles. These same leaders have sometimes had more time to reconnect with their staff, albeit electronically.

The lack of status quo means that the NEA is going outside normal practices to connect to the various committee and working party members to maintain the momentum of the ongoing work while continuing and redirecting efforts towards seeking excellence in nuclear safety, technology, science, environment and law. In this current climate, teams are staying in touch and checking in – sometimes more often that before – and supporting each other to try to maintain a healthy and positive atmosphere despite the challenges. An online workshop on the challenges of the COVID-19 pandemic for human aspects of nuclear safety was organised, held and the video posted on the NEA website in the time it might have taken to send out a 'save the date' e-mail in the past. The NEA Director-General has held a series of online public chats with energy ministers (a full list follows below).

These are just several examples of a common thread that extends throughout the work of the agency and in the industry at large. Addressing issues that are related to the COVID-19 pandemic may garner similar perspectives and challenges that present new opportunities for collaboration among the different areas of the NEA.





NEA web-based events: A typology

- **NEA WebChat:** An online dialogue led by Director-General William D. Magwood, IV with leaders in the sector on the major issues of the day, open to the public.
- **Expert Roundtable:** A roundtable conversation with experts and an extended Q&A session, aimed at a specialist audience, open to the public.
- **NEA Webinar:** Presentation of recent NEA work, usually the release of an NEA flagship publication, for a general audience, open to the public.
- **Online Workshop/Meeting:** A traditional NEA meeting or workshop held remotely, open to NEA delegates.

NEA WebChats

Dr Rita Baranwal, Assistant Secretary for the Office of Nuclear Energy in the United States Department of Energy – 14 May 2020

As a recognised leader in nuclear innovation, Dr Baranwal drew on her personal experiences to discuss effective leadership, innovation and gender balance in the nuclear energy sector. She also shared her perspectives on the future of nuclear power and career opportunities for the next generation.

The video recording of this WebChat is available at: www.youtube.com/watch?v=wLq5jwp4gVA&feature=youtu.be

How Do We Encourage More Women to Enter the Nuclear Science and Technology Field? – 28 May 2020

Attracting and retaining more women into careers in the physical sciences and technology, as well as enhancing the conditions and prospects for women and girls at every stage of their education and development is an important goal that many NEA member countries are pursuing. In support of these efforts, the NEA is working with its members to explore new and creative approaches to improve gender balance in the nuclear science and technology arena. This online dialogue started with a Young Generation Panel chaired by Dr Fiona Rayment, Executive Director of the United Kingdom National Nuclear Laboratory (NNL) Nuclear Innovation and Research Office (NIRO) and Chair of the UK's Nuclear Skills Strategy Group (NSSG). This was followed by a Leadership Panel chaired by Director-General William D. Magwood, IV and featured executives from regulatory, industry and research organisations.

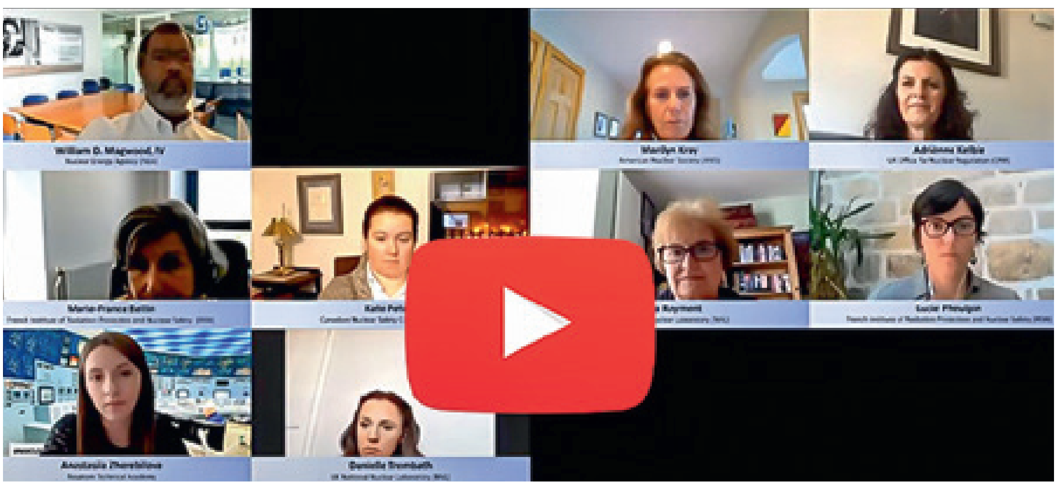
Leadership Panel

- **Adriènne Kelbie**, Chief Executive, United Kingdom Office for Nuclear Regulation (ONR)
- **Marie-France Bellin**, Chairperson of the Board, French Institute of Radiation Protection and Nuclear Safety (IRSN), and Professor of Radiology, Paris-Saclay University
- **Marilyn Kray**, President, American Nuclear Society (ANS)

Young Generation Panel

- **Kate Peters**, Environmental Program Officer, Canadian Nuclear Safety Commission (CNSC)
- **Lucie Pheulpin**, Engineer-Researcher, French Institute of Radiation Protection and Nuclear Safety (IRSN)
- **Anastasiia Zherebilova**, Project Manager, Rosatom Technical Academy
- **Danielle Trembath**, Safety Case Advisor, United Kingdom National Nuclear Laboratory (NNL)

The video recording of this WebChat is available at: www.youtube.com/watch?v=Oobr_Z6ZXjU&feature=youtu.be



NEA WebChat on gender balance in nuclear energy, 28 May 2020.

H.E. Michał Kurtyka, Minister of Climate, Poland – 16 June 2020

As a leading figure in global discussions on climate neutrality and energy-related emissions, Minister Kurtyka, Poland's Minister of Climate and COP24 President, discussed the proposed Energy Policy of Poland until 2040 (EPP2040) and shared his perspectives on the clean energy transition. The conversation also covered topics such as the decarbonisation of the power sector, low-carbon recovery after COVID-19, and new nuclear build in Poland.

The video recording of this WebChat is available at: www.youtube.com/watch?v=vYBvufUTsxM&feature=youtu.be.

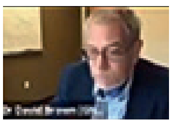
The role of nuclear energy during COVID-19 and beyond – 24 June 2020

The Coronavirus (COVID-19) pandemic has had significant impacts on the global economy and energy sector. It has also underlined the importance of electricity reliability and resilience during major disruptions. The NEA is examining the regulatory and operational impacts of the crisis, and working closely with its members to enable exchanges of policy approaches and best practices around the world. As part of these efforts, the NEA launched a set of policy briefs and hosted a series of discussions that explore the role that nuclear energy can play in the post-COVID-19 recovery, whilst also supporting the path towards a truly sustainable and environmentally responsible energy future.

Discussants

- **William D. Magwood, IV**, NEA Director-General
- **René Nedĕla**, Deputy Minister, Ministry of Industry and Trade of the Czech Republic
- **Agneta Rising**, Director General, World Nuclear Association (WNA)
- **Brent Wanner**, WEO Senior Energy Analyst, International Energy Agency (IEA)
- **Juan Garin**, Policy Analyst, Organisation for Economic Co-operation and Development (OECD) Directorate for Financial and Enterprise Affairs
- **Julia Pyke**, SZC Director of Financing, EDF Energy
- **Atte Harjanne**, Member of the Parliament of Finland and Helsinki City Council

The video recording of this WebChat is available at: www.youtube.com/watch?v=6ZwlLrpwyo4w



The Generalised Nuclear Database Structure Establishing an International Nuclear Data Standard, 8 July 2020.

Expert roundtables

Nuclear Data: launch of new Policy Brief and Specifications for the Generalised Nuclear Database Structure 1.9 – 8 July 2020

Nuclear data are produced by dozens of organisations around the world and shared internationally for the safe operation of nuclear power reactors, waste and reprocessing facilities, and nuclear medicine applications. The most common nuclear data format is the Evaluated Nuclear Data File 6 (ENDF-6) format. Originally designed for 1960s era punch-card readers, this format poses artificial limitations, requires legacy programming techniques, and obliges new scientists and engineers to learn outdated techniques.

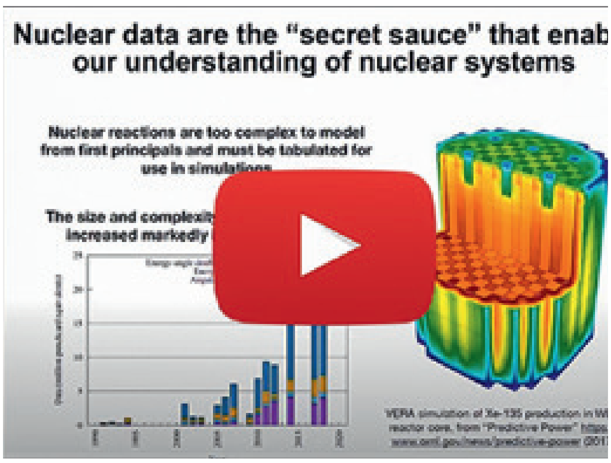
Recognising the need for a new format that embraces modern computer programming paradigms and that can address more sophisticated user requirements, the NEA launched a project in 2013 to review the requirements for an international replacement for the ENDF-6 format. The project convened experts from major nuclear data evaluation projects worldwide and culminated in a new format specification for a Generalised Nuclear Data Structure (GNDS). Following rigorous international review, the new international standard GNDS 1.9 was published in May 2020.

The NEA hosted an expert roundtable discussion on the GNDS 1.9, its use, specifications, and the strategic vision of the project moving forward. The discussion was moderated by Director-General William D. Magwood, IV, and Dr David Brown, Deputy Head of the United States National Nuclear Data Center (NNDC), Manager of the ENDF Library Project, and Chair of the NEA Expert Group on the Recommended Definition of a General Nuclear Database Structure (GNDS).

Panellists

- **Osamu Iwamoto**, JAEA
- **Caleb Mattoon**, LLNL
- **Fausto Malvagi**, CEA
- **Dorothea Wiarda**, ORNL
- **Jean-Christophe Sublet**, IAEA

The video recording is available at: www.youtube.com/watch?v=h9Byrkxr8LE&feature=youtu.be



Building low-carbon resilient electricity infrastructures with nuclear power in the post-COVID-19 era – 10 July 2020

During this panel discussion, participants focused on nuclear power's role in generating electricity reliably and around the clock during the COVID-19 crisis, thereby ensuring the continuous resilient operation of critical services indispensable for coping with the global health crisis and maintaining social stability.

Moderator

- **William D. Magwood, IV**, NEA Director-General

Presenter

- **Sama Bilbao y Léon**, Head, Division of Nuclear Technology Development and Economics

Discussants

- **Pál Kovács**, State Secretary responsible for maintaining the capacity of the Paks Nuclear Power Plant, Hungary
- **Rumina Velshi**, President and CEO, Canadian Nuclear Safety Commission
- **Johan Svenningsson**, CEO and Country Chairman Uniper Sweden
- **Bertrand Magné**, Senior Economist and Energy Specialist, IAEA
- **Marie-Ann Evans**, EU-SysFlex H2020 Project / Technical Manager, EDF R&D

The video recording is available at: www.youtube.com/watch?v=wvzzkzsBcLQ

Nuclear power and the cost-effective decarbonisation of electricity systems – 16 July 2020

Participants in this panel discussion explored how to reconcile climate objectives with economic goals in post-pandemic recovery plans, as well as the role of system costs.

Moderator

- **William D. Magwood, IV**, NEA Director-General

Presenter

- **Jan-Horst Keppler**, Senior Economic Advisor, Division of Nuclear Technology Development and Economics

Discussants

- **Scott Foster**, Director, Sustainable Energy Division, UNECE
- **Kirsty Gogan**, Co-Founder and Executive Director, Energy for Humanity
- **Laszlo Varro**, Chief Economist, IEA
- **JaeKyu Lee**, Professor, Gimcheon University, Korea

The video recording is available at: www.youtube.com/watch?v=zV5wIvUkihk

Creating high-value jobs in the post-COVID-19 recovery with nuclear power projects – 21 July 2020

During this panel discussion participants examined what opportunities the post-COVID-19 economic recovery might provide to create jobs and foster economic development, while continuing to move ahead with the clean energy transition.

Moderator

- **William D. Magwood, IV**, NEA Director-General

Presenter

- **Sama Bilbao y Léon**, Head, Division of Nuclear Technology Development and Economics

Discussants

- **Agneta Rising**, Director General, World Nuclear Association
- **Anton Dedusenko**, Deputy CEO of Rusatom Energy International JSC (REIN JSC)
- **Robin Manley**, Vice President of Nuclear Regulatory Affairs and Stakeholder Relations, Ontario Power Generation
- **Jay Shaw**, Programme Director, UK Nuclear Advanced Manufacturing Research Center (AMRC)

The video recording of the WebChat is available at: www.youtube.com/watch?v=Iyl5AmOn8YY

Unlocking financing for nuclear energy infrastructure – 28 July 2020, 13:00 CEST

The focus of this panel discussion was how, during a period of economic recovery, large-scale and long-term energy infrastructure projects, such as nuclear power plants, might galvanise the social cohesion and economic spillovers required to relaunch general economic activity.

Moderator

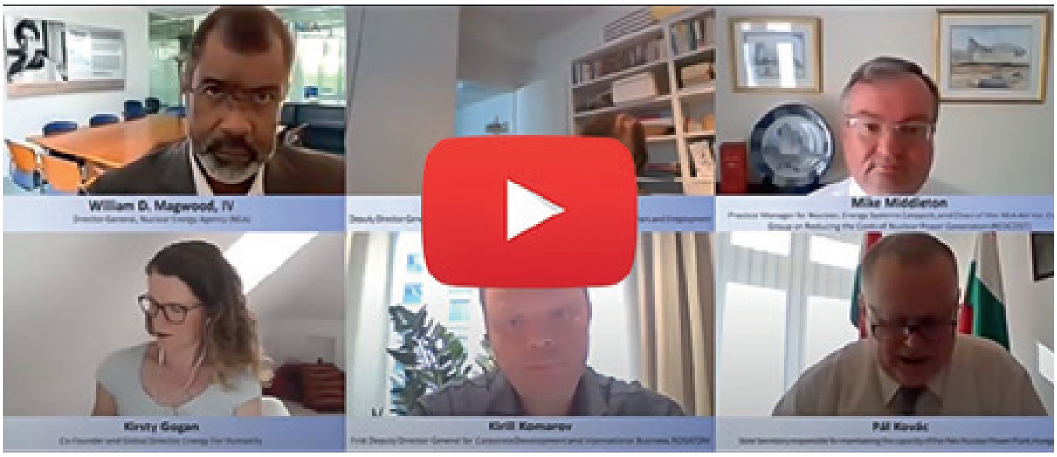
- **William D. Magwood, IV**, NEA Director-General

Discussants

- **Cosmin Ghita**, Chief Executive Officer, Nuclearelectrica
- **Sean Kidney**, Co-founder and CEO, Climate Bonds Initiative
- **Julia Pyke**, SZC Director of Financing, EDF Energy
- **George Borovas**, Partner and Head of Nuclear, Shearman & Sterling

The video recording is available at: www.youtube.com/watch?v=rgF16vdesYg

Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders, 2 July 2020.



NEA Webinars

Human Aspects of Nuclear Safety: Challenges of the COVID-19 pandemic – 9 April 2020

The ongoing COVID-19 pandemic is having a major impact on the workforce around the world, from how people carry out their work under necessary social distancing rules to the unavailability of workers due to sickness or having to take care of others. The nuclear workforce is adapting to these unprecedented conditions and ensuring the safe and reliable generation of nuclear energy around the world. To explore how the nuclear sector is responding to the human and organisational challenges arising from the COVID-19 pandemic, the NEA convened a special workshop, the recording of which was then made available to the general public.

Moderators

- **William D. Magwood, IV**, NEA Director-General
- **Suzanne Dolecki**, Chair of the NEA Working Group on Human and Organisational Factors

Discussants

- **Mark Foy**, Chief Nuclear Inspector, Office for Nuclear Regulation (United Kingdom)
- **Greg Lamarre**, Director General, Canadian Nuclear Safety Commission (Canada)
- **Neil Wilmshurst**, Vice President and Chief Nuclear Officer, Electric Power Research Institute
- **Ingemar Engkvist**, Chief Executive Officer, World Association of Nuclear Operators
- **Maria Korsnick**, President and Chief Executive Officer, Nuclear Energy Institute (United States)
- **Pia Oedewald**, Principal Advisor, Radiation and Nuclear Safety Authority (Finland)
- **William Edward Webster Jr.**, Chairman and Hiromi Yamazaki, President and Chief Executive Officer, Japan Nuclear Safety Institute

The video recording is available at: www.youtube.com/watch?v=IGu1d-RG6II

Unlocking reductions in the construction cost of nuclear: A practical guide for stakeholders – 2 July 2020

The Nuclear Energy Agency (NEA) hosted a webinar on 2 July 2020 to discuss key findings of this report with a panel of key policy and industry experts.

Discussants

- **William D. Magwood, IV**, NEA Director-General
- **Pál Kovács**, State Secretary responsible for maintaining the capacity of the Paks Nuclear Power Plant, Hungary
- **Liisa Heikinheimo**, Deputy Director General (Nuclear Energy and Fuels), the Ministry of Economic Affairs and Employment (MEAE), Finland
- **Kirsty Gogan**, Co-Founder and Global Director, Energy For Humanity
- **Kirill Komarov**, First Deputy Director General for Corporate Development and International Business, ROSATOM
- **Mike Middleto**n, Practice Manager for Nuclear, Energy Systems Catapult, and Chair of the NEA Ad hoc Expert Group on Reducing the Costs of Nuclear Power Generation (REDCOST)
- **Xavier Ursat**, Group Senior Executive Vice President, New Nuclear Projects and Engineering, EDF

The video recording is available at: www.youtube.com/watch?v=PsumawRGIuc&feature=youtu.be

Online Workshops/Meetings

A full list of all NEA meetings and workshops held remotely is available on the NEA website Delegates' Area at www.oecd-nea.org/tools/meeting/

In memoriam: Professor Massimo Salvatores

It is with sadness that we have learnt of the death of Professor Massimo Salvatores on 27 March 2020.

Massimo's name is synonymous with more than forty years of personal dedication to nuclear reactor physics and related science, with many outstanding technical and scientific contributions, the promotion of research programmes and international collaboration, and the training of two generations of young physicists. He was an extraordinarily active and knowledgeable scientist, an inspiring and stimulating person and an exceptional leader of international collaboration through the Nuclear Energy Agency (NEA).

Massimo held a PhD in physics (1963) from the University of Turin, Italy. He joined the French Alternative Energies and Atomic Energy Commission (CEA) in 1977. Very early in his career, he realised the central importance of nuclear data in reactor calculations and became very active in that area. His pioneering work on the application of perturbation theory and sensitivity studies applied to fast reactor analysis is well known. Two of his many publications illustrate well his career-long interest for this field of research: *Nuclear Data Adjustment with Integral Experiments* (NSE, 1973) and *Use of Integral Experiments in the Assessment of Large Liquid Metal Fast Breeder Reactor Basic Design Parameters* (NSE, 1984).

Massimo took a leading role in establishing and leading many activities in the Nuclear Energy Agency (NEA). He served as the Chair of the Nuclear Science Committee, helped create and led the Working Party on Physics of Plutonium Fuels and Innovative Fuel Cycles (WPPR) and was a founding member of the Working Party on International Nuclear Data Evaluation Co-operation and Data Bank JEF nuclear data file project, both of which he chaired in the 1980s and 1990s. The very successful JEF-2.2 file was released during that period and is still widely used today by the nuclear industry.

In the 1980s and 1990s, as head of the CEA Cadarache Reactor and Fuel Cycle Physics Division, Massimo made key contributions to fast reactor core analysis methods, neutron physics experiments, control-rod and sodium-void worth calculations, as well as radiation shielding studies, all of which had important implications for the SUPERPHÉNIX reactor start-up and subsequent operation. Massimo's interests were not limited to fast reactor physics; in fact, his actions had a far broader scope, helping to generate a great deal of momentum for the fields of neutron physics and reactor physics in general and leading to an increase in popularity specifically for the field of fast reactor physics research. He stimulated collaborations with Belgium, Germany, Italy, Japan, the Netherlands, Russia, Switzerland, the United Kingdom, the United States and other countries. He organised the first American Nuclear Society (ANS) International Conference on the Physics of Reactors (PHYSOR) held outside the United States, in Marseille in 1990.

In the 1980s and 1990s, as CEA Research Director, Massimo played a leading scientific role in the development of research programmes on plutonium burners (the European CAPRA programme), and then on actinide and fission product separation and transmutation, both at the national and international levels. He was involved in the NEA Working Party on Scientific Issues in Nuclear Waste Partitioning and Transmutation (WPPT, 2000) and co-authored the well-known NEA 2006 report, "Physics and Safety of Transmutation Systems". He led several international studies and assessments on innovative fuel cycles, plutonium management, partitioning and transmutation technologies and related impact assessments. He proposed unique demonstration experiments and also developed the original concept of a regional fuel cycle with applications to Europe. Massimo later served as Senior Scientific Advisor to the CEA Nuclear Energy Director and from 2007 to 2009 he was Policy Director of the Generation-IV International Forum.

For a large fraction of his career, Massimo was also involved in the education and training of young physicists. For approximately 20 years, he gave lectures at the advanced graduate-level on reactor physics and shielding. He was also the thesis director of numerous PhD students. In 1995, he created the Frédéric Joliot Summer School in Reactor Physics. This Summer School has had considerable success from its start and is still running today.

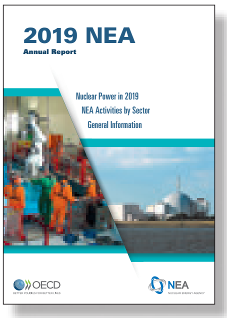
Massimo continued until this year to make many important contributions to the Nuclear Science Committee's activities, including WPEC Subgroup 46 on the Efficient and Effective Use of Integral Experiments for Nuclear Data Validation and four other subgroups that he created and chaired.

During his career, Massimo received many distinctions and awards, especially the prestigious French Academy of Sciences Grand Prix Ampère, the ANS Nuclear Technology Award and the Eugene Wigner Reactor Physicist Award. He was also a Fellow of the ANS and member of the International Nuclear Energy Academy.

Massimo's contributions to the field of nuclear reactor physics are outstanding and his life work will remain an inspiration for current scientists and, most importantly, for the generations of nuclear scientists in the years to come.

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

General Interest



Annual Report 2019

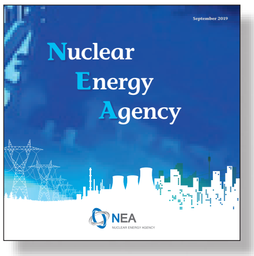
NEA No. 7517. 84 pages.

http://oe.cd/nea-2019-en

Rapport annuel 2019

AEN n° 7518. 84 pages.

http://oe.cd/nea-2019-fr



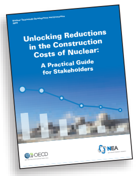
Nuclear Energy Agency

28 pages.

Also available in French, Chinese and Russian.

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

Nuclear technology development and economics



Unlocking Reductions in the Construction Costs of Nuclear

A Practical Guide for Stakeholders

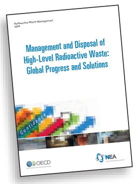
NEA No. 7530. 130 pages.

Available online at:
https://oe.cd/nea-redcost-2020

Today, with the completion of First-of-a-Kind Gen-III nuclear reactors, the nuclear sector is at a critical juncture. These reactors have led in several parts of the world to delays and construction costs overruns that have challenged the competitiveness of nuclear power and are driving the risk perception of future projects. Against this background, a review of historical and recent lessons learnt from nuclear and non-nuclear project offers ample evidence that nuclear new build can be delivered cost and time-effectively.

This study assesses the policy and governance frameworks needed to drive positive learning and continuous industrial performance for nuclear new build.
The study also explores the risk allocation and mitigation priorities needed to define adequate financing schemes for these projects. In the longer-term, it identifies cost reduction opportunities associated with the harmonisation of code and standards and licensing regimes and new innovative designs (i.e. small modular reactors and advanced reactors).

Radioactive waste management



Management and Disposal of High-Level Radioactive Waste: Global Progress and Solutions

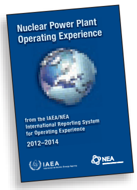
NEA No. 7532. 48 pages.

Available online at:
https://oe.cd/nea-7532-dgr

Radioactive waste results from many different activities in health care, industry, research and power production. All such waste must be managed safely, with the protection of human health and the environment as the highest priority. After decades of research, the international scientific community is now confident that placing high-level radioactive waste in deep geological repositories (DGRs) is both safe and effective.

The government of each country has the absolute right and responsibility to implement the energy and environmental policies it believes are best. In the case of the disposal of radioactive waste, it is paramount that these debates should be informed by objective facts. This report therefore aims to provide the general reader with the current state of knowledge with regards to the management of high-level radioactive waste in DGRs.

Nuclear safety and regulation



Nuclear Power Plant Operating Experience

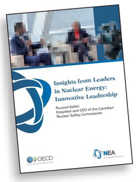
From the IAEA/NEA International Reporting System for Operating Experience 2015-2017

NEA No. 7482. 70 pages.

Available online at: https://oe.cd/3bl

The International Reporting System for Operating Experience (IRS) is an essential system for the international 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 learnt from them, to reduce the chance of recurrence at other plants. The first edition of this publication covered safety related events reported between 1996 and 1999. This seventh edition covers the 2015-2017 period and highlights important lessons learnt from a review of the 246 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 International Atomic Energy Agency (IAEA).

Radiological protection and human aspects of nuclear safety



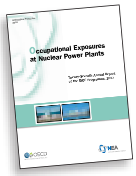
Insights from Leaders in Nuclear Energy: Innovative Leadership

20 pages.

Available online at: https://oe.cd/3ba

Insights from Leaders in Nuclear Energy shares personal insights through a series of in-depth conversations between the OECD Nuclear Energy Agency Director-General and leading figures in the sector. Each conversation explores the current issues and offers new ways to address challenges and aim for excellence.

William D. Magwood IV, Director-General of the Nuclear Energy Agency (NEA), sat down with Rumina Velshi, President and Chief Executive Officer of the Canadian Nuclear Safety Commission, on 17 January 2020. Ms Velshi has extensive experience in the energy sector, including its technical, regulatory and adjudicatory aspects. She visited the NEA to attend briefings on key programmes and activities and to have an open discussion on issues related to leadership in today's nuclear energy sector. In a wide-ranging discussion, she shared her perspectives as a leader in nuclear safety, her long-standing involvement in nuclear energy regulation and her activities promoting careers in science, technology, engineering and mathematics (STEM). The conversation covered the important aspects of leadership, current issues affecting an organisation that promotes nuclear safety, preparation for future nuclear energy technologies and the achievement of a better gender balance in the workforce.



Occupational Exposures at Nuclear Power Plants

Twenty-Seventh Annual Report of the ISOE Programme, 2017

NEA No. 7510. 124 pages.

Available online at: https://oe.cd/3bb

The 27th Annual Report of the International System on Occupational Exposure (ISOE) Programme presents the status of the Programme in 2017.

As of 31 December 2017, the ISOE programme included 76 participating utilities in 31 countries (346 operating units; 55 shutdown units; 8 units under construction), as well as 28 regulatory authorities in 26 countries. The ISOE database includes occupational exposure information for over 489 units, covering over 85% of the world's operating commercial power reactors. This report includes global occupational exposure data and analysis collected in 2017, information on the programme events and achievements as well as principal events in participating countries.

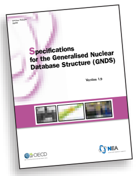
Nuclear science and the Data Bank

Chemical Thermodynamics of Iron – Part 2

NEA No. 7499. 884 pages.

Available online at: https://oe.cd/nea-tdb-13b

This is Volume 13b in the OECD Nuclear Energy Agency (NEA) "Chemical Thermodynamics" series. It is the second part of a critical review of the thermodynamic properties of iron, its solid compounds and aqueous complexes, initiated as part of the NEA Thermochemical Database Project Phase IV (TDB IV), and a continuation of Part 1, which was published in 2013 as volume 13a. The database system developed by the NEA Data Bank ensures consistency not only within the recommended data sets of iron, but also among all the data sets published in the series. This volume will be of particular interest to scientists carrying out performance assessments of deep geological disposal sites for radioactive waste.



Specifications for the Generalised Nuclear Database Structure (GNDS)

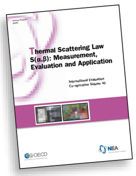
NEA No. 7519. 317 pages.

Available online at: https://oe.cd/nea-gnds-1-9

Knowledge of basic nuclear physics data is essential for the modelling and safe operation of all types of nuclear facilities. The de facto international standard format, Evaluated Nuclear Data File 6 (ENDF-6) format, was designed originally for 1960s era punch-card readers. The replacement of the system of codes built off this format has been recognised as an important initiative.

The ability to use increasingly high-fidelity nuclear physics, coupled to accurate uncertainties, is crucial for advanced simulations. This in turn requires more detailed and accurate data, then requiring improvements to the data storage standards, simultaneously enabling robust Quality Assurance and transfer of knowledge to the next generation.

In 2013, the NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC) launched a project to review the requirements for an international replacement for ENDF-6. The recommendations prompted the creation of a new Expert Group on a Generalised Nuclear Data Structure (GNDS) in 2016 that has used these requirements as the framework for a new format specification. Following rigorous international review, version 1.9 was unanimously approved as the first official published format.



Thermal Scattering Law S(α,β): Measurement, Evaluation and Application

International Evaluation Co-operation Volume 42

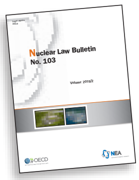
NEA No. 7511. 56 pages.

Available online at: https://oe.cd/3bd

Understanding the nature of neutron scattering in various media at operating temperatures, whether they be reactor fuels, cryogenically cooled neutron sources or any materials at room temperature, is an essential component in the modelling of all nuclear systems. Neutrons that reach these energies, which are millionths of the initial fission and spallation neutron energies, cause virtually all of the fission that occurs in present reactors, including in Generation III+ designs, as well as in several designs that are being proposed for future reactors. As part of a broad range of co-operative activities in basic nuclear science, the Nuclear Energy Agency (NEA) is supporting collaboration between experimentalists, theoreticians and modelling experts to advance the state of the art in nuclear data.

This report reviews progress made by the NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC) Subgroup on Thermal Scattering Kernel Measurement, Evaluation and Application, which brought together a full spectrum of relevant experts to advance the state of the art in thermal scattering law data. The collaboration resulted in 33 new material evaluations, including uranium nitride (UN), silicon carbide (SiC), silicon oxide (SiO_2) and aluminium oxide (Al_2O_3), as well as the re-evaluation of critical materials such as water (H_2O) and heavy water (D_2O), and enhanced evaluations of "nuclear" graphite at multiple levels of porosity and of phase I_h ice. Nuclear data libraries have adopted these data for their most recent releases – including the new Evaluated Nuclear Data File (American) and Joint Evaluated Fission and Fusion (NEA Data Bank) – which are being used around the world as international standards.

Nuclear law



Nuclear Law Bulletin No. 103

Volume 2019/2

NEA No. 7501. 124 pages.

Available online at: https://oe.cd/nea-nlb-103

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

Feature articles and studies in this issue include: "A perspective on key legal considerations for performance-based regulating" and "Technology-neutral licensing of advanced reactors: Evaluating the past and present NRC framework".

Publications of Secretariat-serviced bodies

Generation IV International Forum (GIF) Annual Report 2019

GIF report. 140 pages.

The twelfth edition of the *Generation IV International Forum (GIF) Annual Report* covers actions in 2018 and 2019. In 2018, the *Fourth GIF Symposium Proceedings* was issued in place of the Annual Report.

In 2019 the GIF entirely renewed its Board with new members in all key governance positions. Moreover, for the first time in the history of GIF management, each Vice-chair was granted a three-year mandate, thus assisting the GIF Chairman to better understand the drivers, opportunities and constraints related to three key cross-cutting topics connected with all GEN IV systems: Regulatory Issues; Market Opportunities and Challenges; and Enhancement of R&D Collaborations. In terms of management, GIF has kept the structure that has proved successful in the past.

This Annual Report also includes a list of selected related scientific publications that show the relevance and the high scientific quality of the research carried out by all GIF members.

For the first time, this Annual Report will only be published in an electronic format, available on the GIF Website.

Visit our website at:

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

Version: September 2020

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.

NEA News is published twice yearly. The opinions expressed herein are those of the contributors and do not necessarily reflect the views of the Agency or of its member countries.

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