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OECD Boulogne building.

Photo courtesy of NuScale

NuScale Power's small modular nuclear reactor plant.

Next generation nuclear energy needs next generation thinking

It is truly an exciting time for the nuclear energy sector. Not since the "Atoms for Peace" days have we seen such a burst of innovation, interest and ambition for nuclear energy technology. Dozens of companies, governments, and laboratories around the world are investing huge sums of money, high-level talent, and other resources in the development, design, and deployment of small modular reactors (SMRs) and Generation IV systems.

Following the 2021 United Nations Climate Change Conference, more commonly referred to as COP26, governments stirred to confront the challenge ahead in making massive reductions to carbon emissions. Finding that current paths are not leading to success, some found an increased reliance on nuclear energy to be a key element of the solution space. Several NEA member countries – notably France, Netherlands and the United Kingdom – announced new or reinvigorated plans to expand nuclear capacity to meet the climate challenge.

With the ongoing conflict in Ukraine still reverberating throughout the global economy, many more governments found that energy security was still the most important priority on the agenda. Aspirations and popular visions gave way to the urgent necessity of providing reliable supplies of electricity now and in the future to maintain public expectations for quality of life and economic stability and growth. Plans to reduce nuclear energy capacity came under new scrutiny and some have already been reversed.

The Strategic Plan of the Nuclear Energy Agency 2023-2028 is itself a sea change from recent decades. It notes:

> Nuclear power can play an important role in climate change mitigation as a pillar of energy security in future energy mixes that will become ever-more dependent upon reliable and low-carbon supplies of electricity. Because nuclear energy generates plentiful quantities of electric energy or heat for industrial or residential purposes without emitting air pollutants or greenhouse gases, many countries view it as an indispensable component of their plans to decarbonise their economies. Moreover, nuclear energy has great capacity to play a vital role in future, hybrid energy systems in combination with variable renewable energy and other sources, and providing a range of unconventional products and services such as heat, low-carbon hydrogen, clean water, and isotopes for medical and industrial purposes, for those countries that opt for it.

This ambitious viewpoint, which represents the collective view of NEA member countries (though certainly not the guiding view of those that maintain different policies), encapsulates the global vision for new nuclear energy. It is a vision that supports the precept that reliable, cost-effective access to energy for all is a shared objective; that people in OECD countries have the right to expect to maintain the excellent quality of life that most enjoy and that people in emerging economies have the right to aspire to improved access to electricity, clean water, and the other benefits of 21st century society. It is a vision that these goals need not be in conflict with a healthy planet.

William D. Magwood, IV,
NEA Director-General

COP26: Talking nuclear energy in the global drive towards net zero

by D. Cameron

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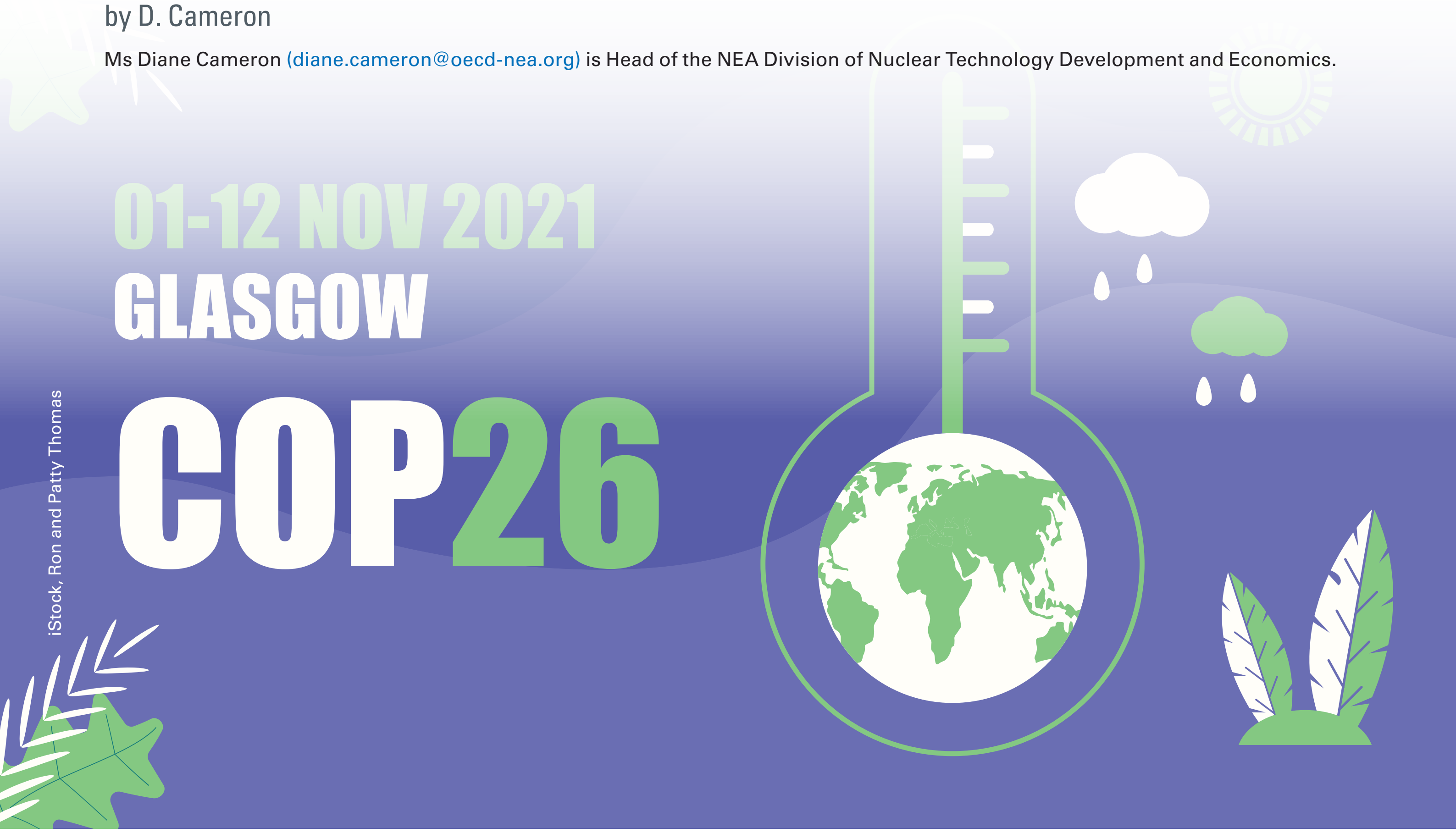


COP26, Glasgow, 1-12 November 2021.

Many major economies committing to reduce their carbon emissions to meet climate change goals are relying on nuclear energy and will be doing so for decades. Global installed nuclear capacity will likely need to triple by 2050 to meet climate change mitigation targets. To do so will require a significant increase in investment and innovation in the sector and, above all, a recognition that the technology has to be a part of the global climate change mitigation efforts.

The COP26 UN Climate Change Conference from 31 October to 12 November 2021 was a turning point in this regard. Since then, nuclear energy has become a more integral part of the global conversation, though this renewed interest now has to be translated into energy and climate policy frameworks.

The NEA participated in the talks with the focus of underlining the role nuclear energy should play in reaching the objective set by the Paris Agreement: limiting global warming to well below 2°C and preferably 1.5°C. This would require achieving net-zero emissions by 2050 at the latest. The NEA delegation participated in and co-organised a series of official COP26 events and organised a side event at the OECD Virtual Pavilion, on 9 November.

Among the pressing questions discussed at the NEA event and COP26 more widely was the need to rapidly mobilise climate and development financing. Multilateral development banks and international financial institutions have a role to play in supporting the emissions reduction projects needed to meet the Paris Agreement goals. Technology neutral policies where nuclear energy would be included in that financing push would help determine a number of countries' success in reaching that goal.

Understanding the true costs of energy

The first step is to understand the true advantages and costs of each energy source. A recent analysis of the levelised cost of electricity by technology showed that the long-term operation of existing nuclear reactors is the most cost-competitive low-carbon electricity solution in many parts of the world. The continued use of currently working nuclear reactors worldwide through long-term operation could avoid 49 gigatonnes of CO_2 emissions between 2020 and 2050.

A system-level approach takes into account the plant-level costs, but also those at the grid level, which entail the costs of maintaining a high security of supply at all times and include the costs of connection, distribution and transmission. This is particularly important in the context of emission reductions, which is seeing a surge in investment in variable renewable energy sources, such as solar and wind farms. These sources have become much more competitive to install in recent years and have contributed to limit the growth of carbon emissions. However, they can pose constraints at the grid level by imposing more fluctuations in supply. The grid-level costs of electricity have come into focus in some countries and regions that have recently experienced blackouts in power supply due to a variety of intertwined factors.

At this level, nuclear power plants have the advantage of helping to stabilise electricity grids by serving as a baseload source of power. In many countries, particularly developing economies, highly polluting coal plants serve as the main baseload source of power – indeed coal accounts for over a third of all electricity and 40% of all carbon emissions.

One of the big achievements at COP26 was the promise by 23 nations to join a 190-country effort to transition away from coal. The move was significant as the group of nations includes five of the 20 top coal power-consuming countries. Replacing coal power plants with nuclear technology is a cost-effective way to shift this electricity production to a low-carbon technology without losing the benefits of a constant and stable source of energy.

A system-level analysis of the costs of energy includes social and environmental costs. These clearly include atmospheric pollution and the impact on land use and biodiversity. They also encompass positive impacts such as employment, economic development and the spin-off effects from technological innovation, which can be significant in the case of nuclear energy.

The key takeaway for policymakers is that the system-level costs of electricity increase as the share of variable renewables grows and carbon emissions become more constrained. However, the precise calculation and optimal policy mix will vary depending on country characteristics, including (for example) access to hydropower and the level of interconnection capacity with neighbouring countries.

New nuclear technologies

The COP26 talks have also highlighted a growing momentum in advances in nuclear technology, including new generation reactor systems as well as small modular reactors (SMRs). This wave of innovation promises to revolutionise nuclear safety and economics.

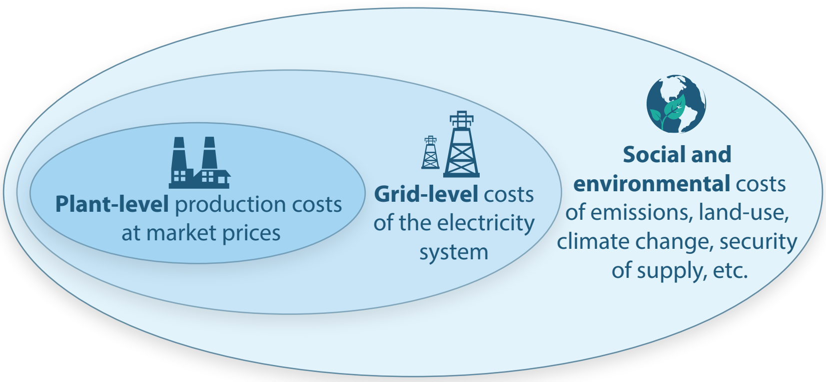
There are several SMR designs at different levels of development and demonstration. They can offer a variety of sizes – from 1 to 300 MWe – and temperatures – from 285°C to more than 850°C. They provide a great deal of flexibility, meaning they can be fitted off-grid, for example in remote communities or mining sites, or used for long-distance shipping, a sector that has struggled to reduce its carbon footprint.

SMRs can offer industrial heat together with electricity, the first real non-emitting alternative to fossil fuel cogeneration. This is particularly attractive for climate change mitigation efforts as industrial heat is a high-emissions activity that has so far proved hard to abate.

Another potential use for advanced nuclear systems is in the production of hydrogen, which is expected to play a leading role for the decarbonisation of hard-to-abate sectors, such as transport, particularly over long distances. Its production, however, is energy-intensive and a good fit for cogenerative, advanced nuclear reactors.

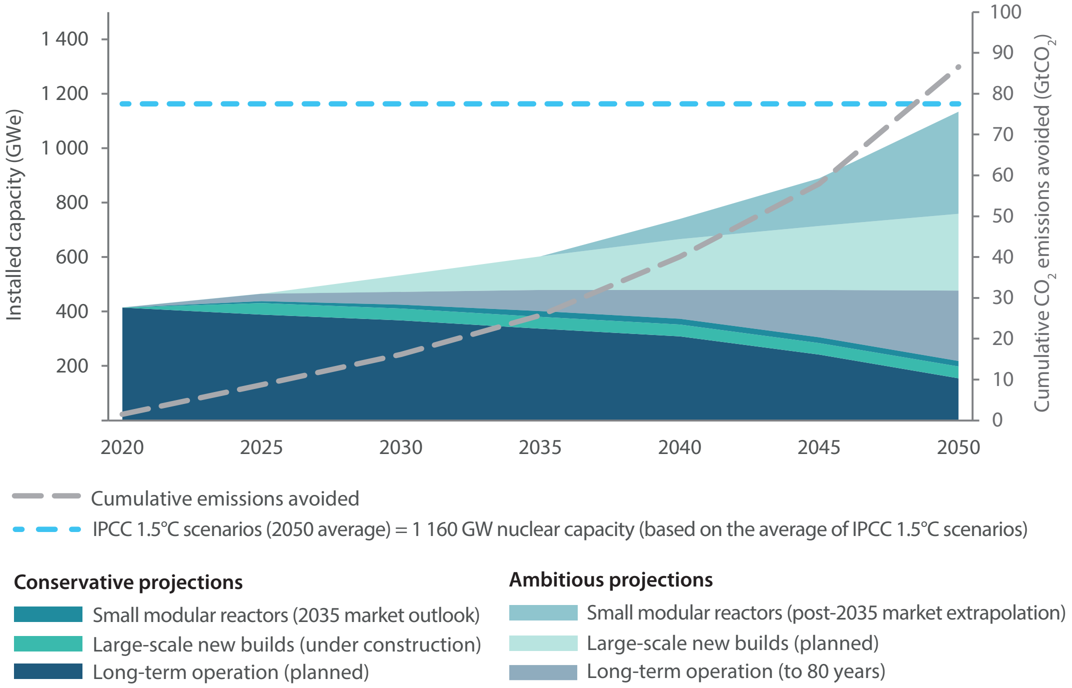
Some innovative designs seek to recycle nuclear waste from existing reactors, reducing the overall amount of spent fuel and high-level radioactive waste that will require final disposal. This can help reduce concerns in the public about radioactive waste, which in some countries has been a key

Figure 1: Understanding the system costs of electricity



Source: Adapted from NEA (2012).

Figure 1: Full potential of nuclear contributions to net-zero



issue when considering nuclear energy. Although there is a scientific consensus that current waste management and disposal methods are safe and technologically mature, the question remains a topic of political debate.

Some SMRs are likely to be commercialised in the coming decade, depending on the level of regulatory efficiency in each country, the available financing models and market dynamics. The NEA estimates that the SMR market could reach 21 gigawatts by 2035, with a more rapid uptake after that. Assuming a build rate that reaches 75 gigawatts a year by 2050, up to 375 gigawatts of installed capacity would be built between 2020 and 2050. This would translate into avoiding 15 gigatonnes of cumulative CO_2 emissions.

This, together with the long-term operation of nuclear power plants and the construction of large-scale Generation III reactors, could lead to some 87 gigatonnes of cumulative CO2 emissions being averted between 2020 and 2050. That is the equivalent of more than two years of global carbon emissions at 2020 levels.

By mid-century, nuclear energy could displace 5 gigatonnes of CO_2 a year, which is more than the entire United States economy emits annually today.

Paving the way for success

The figures above are not forecasts, but what could be achieved with timely policy decisions.

Time is indeed of the essence, as the world is not on track to meet the Paris Agreement targets. Carbon emissions must peak in the next few years and drop to zero by 2100. Instead, they are currently rising after a temporary dip caused by the COVID-19 pandemic restrictions. Reference climate scenarios estimate they will rise another 16% by 2030.

The average of 90 pathways identified by the UN's Intergovernmental Panel on Climate Change to keep global warming to 1.5°C foresees an increase in the use of nuclear energy equivalent to a tripling of nuclear capacity to 1 160 gigawatts. The world presently has about 400 gigawatts of nuclear capacity.

Unlocking the potential contributions of nuclear energy requires a long-term political vision and suitable approaches to regulation, financing and other enabling policies.

Experience shows that under the right conditions nuclear power projects can be delivered in time and within budget. The Barakah plant in the United Arab Emirates shows this can be done even with current nuclear designs. In China and Korea, construction lead-times for large existing nuclear reactor designs with increased safety are around 5-6 years or less.

Any effort to consider or ramp up nuclear energy in a country requires the involvement of all stakeholders to ensure public confidence in all stages of nuclear projects – from mining to R&D, operations, and waste management and disposal. Building trust requires sustained investment in open and transparent dialogue and science communication. Public confidence is not merely a communication issue, but entails complex issues of values, trust and culture.

Since COP26, the public debate around the future of nuclear energy has picked up in intensity from previous years, when many countries – even those that used nuclear energy – refused to give it much recognition.

Many countries are now counting on or turning to nuclear technology as a key part of their climate change mitigation plans. The NEA will continue to support efforts to ensure a safe, environmentally sound and economic use of nuclear energy, including through active engagement at COP27, which will be held in Egypt in November 2022.

Low-carbon energy.

iStock, Ron and Patty Thomas

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A new look at the adequacy of funding arrangements for decommissioning and radioactive waste management

by J. H. Keppler

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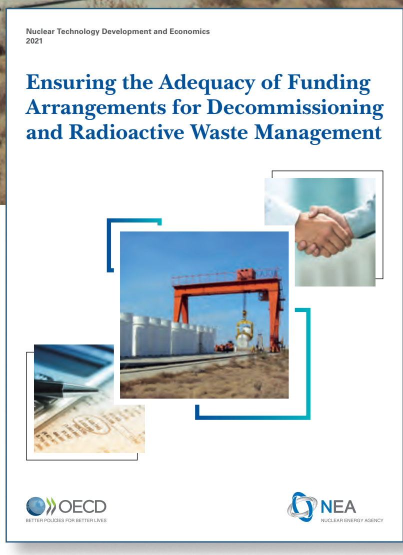
Massive containers hold spent nuclear fuel at safe and secure dry storage facilities.



Financing arrangements for nuclear decommissioning and radioactive waste management need to enable NEA member countries to respond flexibly to changes in technologies and societal choices as many nuclear reactors approach the end of their operational lifetimes and increasing amounts of radioactive waste and spent fuel need to be managed. Due to the very long-term nature of the solutions, ensuring the adequacy of funding is a lengthy endeavour that requires the ability to make major adaptations to changing socio-political, technological and economic circumstances. Overall, funding systems of NEA member countries are sound. Yet, their sustainability will be enhanced by approaching them in the circular and adaptive framework presented in a new NEA report, in which changes in one dimension such as technology, cost, timing, return on assets, lifetimes of nuclear power plants and/or societal preferences can entail changes in all other parameters.

On 21 June 2021, a webinar introduced by NEA Director-General William D. Magwood, IV launched *Ensuring the Adequacy of Funding Arrangements for Decommissioning and Radioactive Waste Management.* Following a presentation by NEA Chief Economist Jan Horst Keppler, lead author of the report, an expert panel of Chantal Cortvriendt (Belgium), Jean-Marc Lefeuvre (France), Dr Fernando Oster (Germany), Bill McCaughey (United States) and Rebecca Tadesse (NEA Division of Radioactive Waste Management and Decommissioning) and presided by Diane Cameron (NEA Division of Nuclear Technology Development and Economics) discussed its findings in the light of country experiences and work at the NEA.

"The ability to credibly demonstrate and communicate long-term solutions – including financial plans – for decommissioning and waste management is central to building public confidence in nuclear energy," Cameron stressed during the discussion that followed.

The report includes a comprehensive conceptual framework as well as 12 case studies from Belgium, Canada, Finland, France, Germany, Japan, Korea, Spain, Sweden, Switzerland, the United Kingdom and the United States, that were prepared in collaboration with NEA member countries. This leads to 15 "Elements of Good Policy Practice" to improve the long-term adequacy of funding arrangements for decommissioning and radioactive waste management. While the ideas behind the elements of good policy practice are general, their implementation will need to take account of differences between countries in the structure of their electricity and nuclear industries, the timing of radioactive waste management solutions, institutional arrangements as well as political commitments and social preferences. Several case studies also demonstrate that NEA countries are already adapting their funding systems to changing realities. However, in some cases this is taking place in an implicit or partial manner and could benefit from a more systematic, circular approach and framework.

There are good reasons for discussing the adequacy of funding arrangements for decommissioning and radioactive waste management in a broader perspective now. As important activities in both areas move from planning to implementation, the question of the adequacy of funding arrangements is becoming a practical rather than a conceptual concern. It remains questionable, however, whether the nuclear operators responsible today for funding will remain active over the whole period of implementation. Timeframes for deep geological repositories (DGRs), for instance, stretch far into the future. In some countries, the management of high-level radioactive waste is also an intensely discussed question socially and politically, which can rapidly change the solutions retained and their costs. Defining and implementing sustainable solutions requires societal processes of deliberation and decision making that have yet to be fully defined and require public involvement. Finally, the new macroeconomic context is questioning many of the financial assumptions of current funding systems.

"This report sets out a holistic approach to decommissioning and waste management and proposes an adaptive and circular approach that takes changing societal circumstances into consideration. The circular approach is based on the viewpoint that changes in society have to be in some way accommodated."

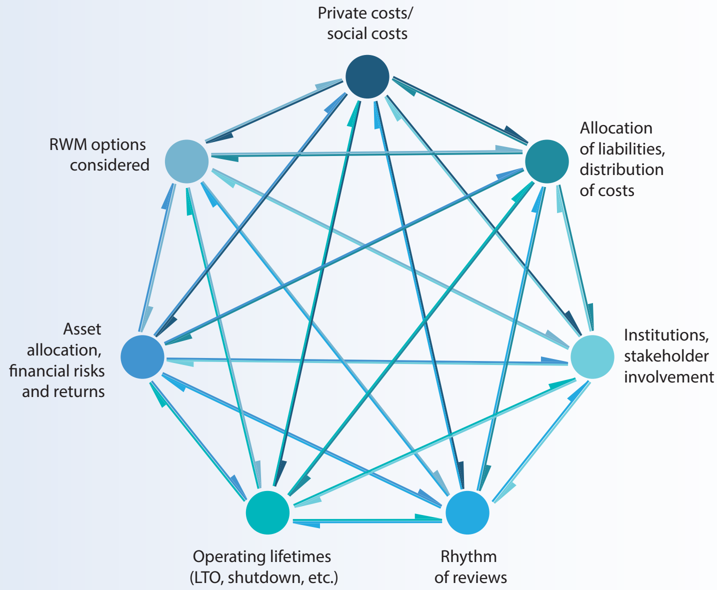
NEA Director-General William D. Magwood, IV

The last point has received increasing attention in recent years as returns, especially on governments bonds, a preferred form of investment in many funding systems, have trended towards zero and a significant share of them yielded negative returns. The options for funding systems to react to such changes all require significant adjustments: increase funding requirements and raise assessed contributions, postpone the implementation of solutions for decommissioning and radioactive waste management, resort to less costly solutions or resort to riskier investment strategies with higher returns. The question of applying environmental, social and governance (ESG) criteria to invested assets further complicates the equation.

Traditionally, funding systems have been discussed using linear decision-making frameworks that establish funding requirements by discounting future estimated costs for a given technical solution. These frameworks have been a useful starting point. However, they assume that key parameters such as technologies and their costs, the discount rate, the return on capital, the operating lifetimes of nuclear power plants or even societal preferences will remain stable for decades. The key message of the new NEA report is that the long-term sustainability of funding systems would benefit from a more flexible and adaptive approach. This requires that all elements of the system are reviewed and realigned at regular intervals. The report sets out five principles of such an adaptive and circular approach:

1. *Interdependence and bi-directional causalities:* All elements of the funding systems are interconnected; causalities are complex and bi-directional.
2. *Endogenous nature of cost estimates:* The costs of decommissioning or radioactive waste management are not an objective, exogenous number but depend on political, regulatory and technical choices and the redrawing of system boundaries.
3. *Adaptability:* All elements, including cost estimations, expected revenues and liability allocation must be able to adapt to changes that are endogenous (e.g. changes in societal preferences) and exogenous (e.g. changes in rates of return).
4. *Possibility of discontinuous changes:* Technological changes and political choices can introduce discontinuous change requiring radical adaptations outside initial assumptions.
5. *Regular revisions with stakeholder involvement:* Revisions must take place at regular intervals that are specified in advance and legitimised by institutional processes that involve all stakeholders.

Figure 1: A graphical representation of the circular approach



The essence of the circular approach is that any element of the system can trigger a necessary evolution of the whole.

The circular approach considers decommissioning and radioactive waste management to be societal and political issues as much as industrial and commercial issues. For instance, the timing, technologies or location of a radioactive waste management solution, like a DGR, are not for an electricity company to decide. Governments, as the stewards of societal preferences, determine them. Explicitly or implicitly, they are also, even now, the ultimate bearers of residual risks. As such, there might be a case in some countries for governments to take on liabilities for radioactive waste management somewhat earlier and more explicitly than is currently the case. This would also allow consistency with a fundamental economic principle on liability allocation, which says that risks and their costs should always be borne by the party best placed to evaluate, reduce and carry them.

Of course, this does not imply freeing operators and their customers from their financial obligations, which are part of the social contract under which nuclear power plants were constructed and operated. Any transfer of liabilities to governments needs to be accompanied by a transfer of the constituted funds. In no way should it create an opportunity for freeriding. Risk premiums or indemnities over and above constituted funds may also be included in such transfers.

The circular approach the report advocates also implies a somewhat broader interpretation of the Polluter Pays Principle (PPP), which is frequently evoked as a normative principle associated with the linear approach to funding adequacy. Following Pigou (1920) and OECD (1972) and updated at regular intervals, the PPP aims at ensuring the internalisation of environmental damages. In the nuclear field, it is usually understood to mean that the operators of nuclear power plants and their customers are liable for the costs of decommissioning and radioactive waste management.

The PPP has served the nuclear community well. It will continue to do so also when approached in a broader perspective. The basic premise of the PPP that welfare maximisation is best achieved through cost minimisation and a clear allocation of liability continues to hold. However, a simple reading of the PPP is based on several assumptions that do not fully apply here, in particular as far as radioactive waste management is concerned. The framework of static optimisation that underlies the PPP assumes that parameters are stable and that causalities are unequivocally one-directional. It assumes, for example, that the total costs of final disposal or repeated recycling are known *ex ante*, the "polluter" has control over them and that technologies are fixed.

The PPP also assumes substitutability at the margin between the private costs of waste reduction and the social costs in terms of environmental quality and public health. It does not easily accommodate discontinuous changes. The marginal logic of PPP is not directly transferable to the context of decommissioning and radioactive waste management. For example, the costs of future solutions are not controlled by nuclear operators.

The essence of the PPP, however, would be fully respected also under a circular approach that would transfer the liability of radioactive waste management to governments, as long as there is also a corresponding transfer of constituted assets. In fact, the underlying spirit of the PPP is that the party that controls the key technical and economic parameters should also organise the trade-off between industrial costs and social benefits and thus assume legal liability and financial responsibility.

Finally, the report introduces a nuance between decommissioning and radioactive waste management regarding the allocation of liability. In decommissioning, where technical solutions are relatively well defined and time frames are consistent with the lifetimes of operators, liability should remain allocated to the relevant industrial enterprises. Things are different in the case of radioactive waste management, where solutions can be far out in the future or subject to evolving political and social preferences. Here, the government is the only actor capable of organising the open-ended social processes leading to sustainable technical solutions.

The report was part of the Programme of Work of the NEA Division of Nuclear Technology Development and Economics (NTE) and was overseen by the Working Party on Nuclear Energy Economics (WPNE) and the Nuclear Development Committee (NDC). It benefitted from much prior NEA work as well as from regular exchanges with the NEA Division on Radioactive Waste Management and Decommissioning (RWMD), the European Commission, the IAEA and, to a particularly high degree, NEA member countries.

Complementing existing approaches with a circular one will strengthen funding arrangements and ensure their adequacy over the long run. The case studies show that such adaptations are already underway in many countries. However, the framework for discussing the adequacy of funding frequently remains a narrow reading of the PPP and uses a static linear approach. By broadening these references, the NEA report aims at contributing to a broad, lively and relevant international conversation on how to approach the adequacy of funding for decommissioning and nuclear waste management.

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Improving gender balance in the nuclear sector

by F. Maher

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Women scientists and engineers pioneered the nuclear and radiological fields, from the ground-breaking work of Marie Skłodowska-Curie and Lise Meitner to the foundational research of Toshiko Yuasa. It is no exaggeration to claim that these women were among the leaders and innovators who established modern nuclear technology. Many of these trailblazers challenged the limited opportunities and expectations for women that were common in the times they lived. Today, women enjoy equal rights and education in most countries. However, despite substantial progress in recent years, women are still significantly under-represented in technical and leadership positions in the nuclear sector. This lack of gender diversity affects the ability of the nuclear science and technology sector to communicate effectively with the broader society and reduces the talent pool needed for technical challenges and innovation. As a result, this issue may have substantial impact on the future use of nuclear technologies for energy, medical, industrial and other vital applications. Therefore, attracting and retaining more women into careers in nuclear science and engineering is an important goal pursued by many NEA member countries.

Task Group on Improving the Gender Balance in Nuclear Energy

To guide data collection and policy development and in response to member country requests for co-ordinated engagement and action, the NEA established a formal task group on improving gender balance in the nuclear energy sector. The NEA High-Level Group on Gender Balance was approved by the NEA Steering Committee on 10 September 2021. The new body builds upon previous high-level activities and is heavily engaged in supporting the efforts of the NEA membership to secure long-term vibrancy, sustainability and innovation in the nuclear field by encouraging women to pursue careers and leadership in science, technology, engineering and mathematics (STEM).

"Women continue to be under-represented in STEM fields, and significantly in nuclear science and technology, where there are few women in leadership positions. This gender gap has important implications for the future of nuclear technology applications in many areas, including the generation of clean heat and power in the decades to come," noted NEA Director-General William D. Magwood, IV.

Spain Mentoring Workshop, October 2021.

The task group emerged from a series of member country meetings on improving gender balance in nuclear energy held in December 2019 and February and June 2021. These meetings found that useful, practical data on the topic is lacking, and is required to better understand the challenges. The discussions also underscored the need for data-driven policy recommendations to target crucial stages in the human resources pipeline, from secondary school to university to the workplace.

Accordingly, the new task group's objectives are to collect and analyse data and best practices in enhancing gender balance and empowering women. The group will formulate policy recommendations to enhance the contributions of women to the nuclear sector, as well as to promote communication on gender issues, engagement and educational activities.

The task group is chaired by Dr Fiona Rayment, Chief Science and Technology Officer at the United Kingdom's National Nuclear Laboratory. As the group's mandate also includes a focus on diversity beyond gender, Dr Rayment has noted the importance of diversity for the sector's success, and has underscored that fostering a culture of equality and inclusion – of which gender balance is a key aspect – will provide opportunities to embrace new ideas and innovations for the future of nuclear energy.

NEA Director-General Magwood emphasised that "the gender imbalance in the nuclear sector also represents a tremendous loss in both qualitative and quantitative terms, as studies show that science and engineering benefit from diverse teams to drive innovation and productivity, and that diverse teams deliver higher performance."

Data collection on women in the nuclear energy sector

Co-ordinated through the task group, the NEA is working to develop policies for substantive action in order to support its members to achieve gender balance in the nuclear energy sector. Since data on women in the sector is lacking, the NEA and its member countries developed a qualitative survey about women's experiences in the nuclear energy sector, which debuted in June 2021 and garnered over 8 000 responses from around the world. The survey was available in eight languages (English, French, Italian, Japanese, Korean, Romanian, Russian and Spanish) and represented the first international snapshot of women's perceptions of gender balance in the nuclear workplace, their aspirations and professional development, barriers and challenges that need to be addressed, and opinions about possible solutions.

In parallel, in the summer of 2021, the NEA developed a data collection instrument and invited member countries to gather granular human resource data from their national nuclear organisations, including the percentage of women in technical and leadership roles, among new hires, attrition and promotions, as well as salaries and career development. The data received came from 96 nuclear organisations in 17 member countries. The NEA gender balance task group reviewed initial results and analysis at its meeting on 18 November 2021. This data and research will fuel the development of international policy and practical recommendations to help countries to turn the tide in the right direction.

The NEA is gathering additional human resources data, including gender-disaggregated information, on graduates in nuclear science and technology and related fields, in partnership with the European Commission's European Human Resources Observatory for the Nuclear Sector (EHRO-N) and the European Nuclear Education Network (ENEN). A report is forthcoming.

Mentoring workshops

The task group's mandate further includes educational activities to encourage young women to study STEM and pursue advanced degrees in nuclear science and technology. Mentoring the next generation has been a consistent theme in NEA high-level meetings on gender balance. Delegates have shared examples of successfully leveraging mentoring or coaching programmes to support career development and ways to support these efforts through public communications and other strategic engagement.

Accordingly, the NEA is expanding its successful international mentoring workshops and exploring options to scale their implementation more broadly worldwide. Twelve NEA mentoring events have been held since 2017 with students in Japan, Kenya, Romania, Russia and Spain, including five in both 2020 and 2021 that used virtual and hybrid models. Seven workshops are planned for 2022. The goal is to encourage young women in high school and university to consider studies and careers in STEM fields and nuclear energy, and to increase their confidence through personal engagement with female mentors. The mentors are distinguished leaders and scientists in nuclear energy or related fields.

The first-ever mentoring workshop organised by the NEA in Africa was held in Kenya on 21-23 July 2021 in partnership with the International Framework for Nuclear Energy Cooperation (IFNEC) and Kenya's Nuclear Power and Energy Agency (NuPEA). The 3-day, hybrid workshop brought together 46 high school students in Kenya with engineers, researchers and scientists from their home country and abroad. The students and national mentors met in person, and the international mentors and speakers joined virtually.

Kenya, which is Africa's seventh largest economy and has a population of 52.5 million people, is embarking on a nuclear power programme to meet future electricity demand and aims to start a nuclear power project around the end of the decade. The NEA engages Kenya through its co-operation with IFNEC.

In October 2021, the NEA held three additional mentoring workshops in-person in Spain, in a hybrid format in Russia, and remotely in Japan. In total, 126 students from 5 countries met with 31 mentors. The first workshop was held on 5 October 2021 in Granada, Spain, jointly organised with Women in Nuclear (WiN) Spain and co-sponsored by the City Council of Granada and the Electric Power Research Institute (EPRI). It brought together 72 female high school students from Spain with 12 mentors.

The second workshop was organised virtually on 12-14 October 2021 in co-operation with Japan's Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF). The 3-day event provided 24 high school students from Japan and Romania the opportunity to meet and interact with 8 mentors.

A third mentoring workshop took place in conjunction with the Third Eurasian Women's Forum held in St. Petersburg, Russia, on 14 October 2021. Held in co-operation with State Atomic Energy Corporation Rosatom, the event attracted around 30 Russian and Turkish students from Peter the Great St. Petersburg Polytechnic University.

The NEA then organised a mentoring session jointly with the Nuclear and Radioactive Waste Agency of Romania for Romanian female high school students on 2 November 2021. The students exchanged views with NEA female scientists and engineers and received a virtual tour of the Radiopharmaceuticals Research Centre in Romania.

Further engagement activities promoting gender balance

The NEA has been actively promoting the importance of improving gender balance and diversity through public engagement. NEA Director-General Magwood is an active member of the International Gender Champions Impact Group on Gender Equality in Nuclear Regulatory Agencies, chaired by Rumina Velshi, President of the Canadian Nuclear Safety Commission. In October 2021, he addressed delegates at the Third Eurasian Women's Forum held in St. Petersburg, Russia by video, highlighting the importance of closing the gender gap to ensure a sustainable, clean energy future. He also participated in the Women in Nuclear Global (WiN Global) 2021 annual conference held virtually in Canada, speaking on a panel about diversity and moderating an event with members of the NEA gender balance task force. He underscored the urgency for nuclear energy leaders to look beyond statistics and create inclusive work cultures that embrace and advance all employees:

"Diversity goes beyond hiring talent from diverse backgrounds. It means creating an inclusive culture that enables everyone to thrive. We know that diverse teams are more innovative and perform better. To unleash those benefits, we need work cultures where everyone feels they can contribute their best. Diversity, equity and inclusion needs to be a priority issue for executive leadership; without it, the nuclear sector will not be able to build the talented, innovative teams it needs."

The NEA is integrating a gender lens into its broader educational initiatives, including the NEA Nuclear Education, Skills and Technology Framework (NEST) and the recently launched NEA Global Forum on Nuclear Education, Science, Technology and Policy. While they have separate scopes of work and missions, these two initiatives are co-ordinated to strengthen the role of the NEA in nuclear education and capacity building and provide support and policy advice to NEA member countries.

With a holistic yet targeted spectrum of activities ranging from data collection to policy formulation to educational engagement, the NEA is working closely with member countries to make significant progress in their efforts to enhance women's representation and contributions to the nuclear energy sector.

Transport of nuclear waste: Materials qualification requirements and nuclear liability

by E. de Boissieu

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Transport by ship of spent nuclear fuel and radioactive waste.

Organising transport of nuclear substances presents a number of challenges, including how to properly qualify the substances from a nuclear liability perspective. The nuclear liability conventions provide for a generic definition of "nuclear substances" (sometimes referred to as "nuclear material" under certain conventions), which gives wide discretion to national legislations in its interpretation. Moreover, the nuclear liability conventions also exclude certain categories of nuclear substances, subject to specific conditions being met, to ensure that the risk associated with their transport may be dealt with under general tort law. The implementation or application of these exclusions is carried out by each concerned country in accordance with its own domestic legislation, which may lead to discrepancies in the qualification of substances to be transported by different stakeholders.

A common understanding of the types of substances covered by the nuclear liability conventions is important to determine whether the specific nuclear liability regime established by such conventions or general tort law would apply in case of damage caused by an accident. The system established by the nuclear liability conventions is based on the following principles: strict liability (or liability without fault) of the operator of the nuclear installation; exclusive liability of the operator; establishing a minimum amount of liability for the operator; limitation upon the operator's liability in time; and obligation on the operator to cover its liability by insurance or other financial security.

This system deviates from general tort law principles. Consequently, the proper qualification, from a nuclear liability perspective, of nuclear substances is particularly relevant in the context of international transport where several liability regimes, whether international or national, may apply to the same carriage. The lack of harmonisation in this area has a practical impact on the organisation of transport of nuclear substances: all carriages need to be covered by a relevant insurance or other financial security to cover liability for damage in case of an accident, and therefore require a clear identification of which legal regimes apply to the substances being transported throughout the whole journey. A clear understanding of the process of qualification of nuclear substances based on the applicable legal regime(s) in countries that an international transport will cross enhances visibility of the requirements necessary to organise the appropriate insurance or financial security (either a compulsory nuclear liability insurance, or a conventional financial security, when relevant).

Since 2019, the NEA Working Party on Nuclear Liability and Transport (WPNLT) has been examining the issue of the qualification of nuclear substances to be transported, and held a topical session on the legal, technical and insurance challenges related to such qualification on 26 June 2019. On 29-30 March 2021, the WPNLT organised a virtual workshop on "The Qualification of Nuclear Substances and Nuclear Liability" with more than 70 experts representing 21 NEA member countries, 2 non-NEA member countries, the European Commission and the International Atomic Energy Agency (IAEA). Representatives from the nuclear insurance industry, the World Nuclear Association (WNA) and the World Nuclear Transport Institute (WNTI) also participated.

During the two-day event, the participants discussed the insurance, legal and technical challenges associated with the qualification of nuclear substances during transport and its impact on the organisation of the insurance to cover such transport, as well as practical solutions to mitigate those challenges. They also addressed the practical implementation of the exclusions of nuclear substances from the scope of application of international nuclear liability conventions. In this context, there was agreement on the need to work towards a common understanding of which nuclear substances are covered by, or excluded from, the nuclear liability conventions and the applicable national nuclear liability regimes.

The workshop participants also concluded on the following path forward concerning the qualification of nuclear substances and nuclear liability:

- clarify for those nuclear substances excluded from the nuclear liability conventions and the applicable national nuclear liability regimes, which liability regime would apply, the relevant financial security requirements (if any) and the availability of insurance;
- facilitate the process to identify which insurance coverage should be put in place by (a) clarifying the interpretation of key definitions and terms provided in the nuclear liability conventions in order to allow a certain harmonisation of the national legislations and regulations, (b) clarifying the assessment that should be made to determine which insurance coverage would apply, (c) establishing a process to identify the excluded substances or material throughout their lifetime, and (d) identifying which entity is most competent to qualify the nuclear substances being transported;
- raise and increase awareness of all the stakeholders involved in international transport and transit of nuclear substances or material of the application of the nuclear liability conventions and national nuclear liability regimes, including the exclusions that apply to nuclear transport.

The workshop offered an opportunity to analyse from a practical perspective challenges related to the qualification of nuclear substances to be transported. It also helped frame issues that stakeholders involved in the organisation of transport of nuclear substances may need to address, in order to facilitate the understanding of the qualification process applied in different countries the international carriage may cross and improve visibility on the relevant financial security/insurance requirements. The Nuclear Law Committee and the WPNLT will continue working on the qualification of nuclear substances based on the outcomes of the workshop.

A rail transportation of spent fuel casks.

Nuclear Energy Institute (NEI)

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A gantry crane places a container on the platform of a road transporter.

Gesellschaft für Nuklear-Service mbH (GNS)

The importance of mental health and psychosocial support in the context of nuclear or radiological emergency

by J. Kruse, M. Zähringer, F. Hanna, Z. Carr and J. Garnier-Laplace

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Emergencies create a wide range of problems at the individual, family, community and societal levels. They can erode the support systems of people affected by a disaster, for example by undermining community structures, and they can increase the risk of various new problems and amplify pre-existing ones (IASC, 2007). While a nuclear disaster might include an additional layer of stress related to radiation risk, the examples of the COVID-19 pandemic, past natural or industrial disasters, and any of the past nuclear or radiological accidents prove that all health emergencies have a common denominator – the impact on mental health and well-being. This makes it all the more important to reflect on how to leverage the guidelines and recommendations of the World Health Organization (WHO) and Inter-Agency Standing Committee (IASC) for managing the mental health and psychosocial (MHPS) consequences of emergencies and disasters (IASC, 2007; WHO, 2020a). These are included in existing global disaster risk reduction strategies (UNISDR, 2015; IASC, 2021), and suggest scaling and harmonising practices across non-nuclear and nuclear sectors and across countries (Carr et al., 2016; 2018).

In this context, the NEA Committee on Radiological Protection and Public Health (CRPPH) in 2019 created the Expert Group on Non-radiological Public Health Aspects of Radiation Emergency Planning and Response (EGNR). Its objective is to develop approaches for the mitigation of non-radiological health impacts and deliver guidance to assist emergency-management decision makers in the implementation of Mental Health and Psychosocial Support (MHPSS) in preparedness and response to radiation emergencies. In June and July 2020, the NEA EGNR, in co-operation with the WHO, organised two interconnected online conferences to explore how the experience and lessons from non-nuclear crises, such as the COVID-19 pandemic, could help countries improve MHPSS in the event of a nuclear or radiological emergency. During these events, international experts shared their experiences, research findings and views on two main issues: mitigation of psychological impacts; and community engagement and resilience throughout the emergency cycle, from preparedness and response to recovery. This article summarises the main findings and outcomes of these events.

Mental health and psychosocial support rooted in a strong emergency response

Managing the mental health and psychosocial impacts of emergencies is an activity that cuts across all types of emergencies, disasters, and conflicts (WHO, 2020a; IASC, 2020b). Radiological or nuclear emergency preparedness, response and recovery planners and managers should take this into consideration and seek close co-operation with stakeholders and response organisations dealing with non-nuclear emergencies, adopting an all-hazards approach (UNISDR, 2015; NEA, 2018, 2021). Mental health effects and stressors differ between various population and age groups. These differences need to be better understood and quantified through assessments, and have to be integrated into preparedness, response and recovery plans (WHO, 2020a; IASC, 2007; Gray et al., 2020).

Through the all-hazards approach, MHPSS is implemented in a multidisciplinary process across multiple sectors, such as health, the environment, the economy and social and cultural aspects (WHO, 2020a). MHPSS should follow core ethical principles like "do no harm" and be accessible to all after an emergency, without discrimination, especially towards the most vulnerable groups in the population. During and after an emergency, risk and crisis communication is of paramount importance to mitigate the mental health and psychosocial consequences of decision making and requires special training for responders (WHO, 2020a). It is essential that staff and volunteers in response organisations are educated and trained in mental health and psychological support issues. Special focus for such education and training programmes should be placed on a multidisciplinary, holistic approach.

Besides following international guidelines, standards and good practice examples of MHPSS operation, each country should adjust their national and local plans and protocols based on an analysis of the cultural, social and economic environment to offer the best response and recovery support in case of an emergency. More research, with secured funding, involving experts from a wider range of disciplines (e.g. sociologists and cross-cultural experts including cultural psychologists) is needed to build evidence on MHPSS intervention and preparedness operations.

Stakeholder involvement as pillar for optimised decision making

People affected by an emergency are first and foremost to be viewed as active participants in improving individual and collective well-being, rather than as passive recipients of services that are designed for them by others (IASC, 2019). Policy makers increasingly find community engagement, and more broadly speaking stakeholder involvement, as key to the decision-making processes. Decision-making outcomes should be elaborated by establishing dialogue to share knowledge in all areas of concern. As a result, decisions are taken based on multiple trade-offs that incorporate the views of all stakeholders affected (or potentially affected) by these decisions. Community engagement is needed in every phase of the nuclear emergency cycle, especially during recovery, where support for community efforts can be developed through risk evaluation and communication (WHO, 2020a). A practical example of successful community engagement in the recovery phase after a nuclear accident is the "mushroom map" (Takamura et al., 2021) that was used in risk communication with residents of the village of Kawauchi in the Fukushima prefecture in Japan. The project worked as a win-win approach where residents shared with

Risk communication activities with residents of Kawauchi.

Source: Prof. Takamura, University of Nagasaki

experts local knowledge on mushroom collection sites and dietary habits. The experts in turn explained how to use the information to estimate the radioactive caesium-related consumption risk. By understanding the risks, anxiety and worries can be reduced in the community. However, when working with community leaders, care must be taken to ensure they represent their wider communities and do not exacerbate existing social tensions.

Another important factor that influences MHPSS impacts of all kind of emergencies, including nuclear and radiological emergencies, is what can be described as community resilience. Research and practice provide evidence that community resilience is a complex combination of various features such as pre-existing knowledge and level of education, community networks and their self-supporting activities, as well as all dimensions of well-being or what defines sustainable living and working conditions (or frequently referred to as "normal" life, i.e. health, employment, economy, housing, livelihood, school, ...). To ensure education/information efficiency in the preparedness stage, there is a need to include a risk-based approach in the curriculum of schools and universities. This long-term education targets younger generations including younger children in the recovery areas. This is also recognised as the most efficient way to target caregivers' worries and fears. "My hero is you" (IASC, 2020a), a children's storybook developed and adapted by IASC to engage different communities, is a good example of how to help children cope with the COVID-19 pandemic and how to strengthen community resilience through education.

In the recovery phase, it has proven to be more efficient for experts to interact with smaller groups of affected people, promoting a more individual approach and learning the backgrounds of participants to engage on that basis. For example, the WHO is targeting COVID-19 responders in communities to engage them by using the illustrated guide to "doing what matters in time of stress" (WHO, 2020b).

Another important point regarding stakeholder involvement is the role of the media, including social media, which are likely to play an important part in risk perception within the affected communities. This requires that risk communication messages be tailored to the audience. Giving the population a greater understanding of any radiological or nuclear hazard may change the risk perception and the ensuing social behaviours, depending on various "mental-print" elements (e.g. cultural, traditional, risk history).

Community engagement and resilience seem to be linked, but more research is needed to clarify how. Questions remain to be examined in more detail, including "what types of preparedness activities are most effective?"; "what evidence do we have that community engagement is strengthening resilience?"; and "are there practical examples of community engagement helping to strengthen resilience, in particular among vulnerable groups?".

Way forward

It has been proven that mental health and psychosocial consequences can have long-lasting influences on those affected. Long-term intervention plans and related resources are needed for several years after a major incident. This is confirmed by the case of the Fukushima Daiichi Nuclear Power Plant accident: nearly ten years after the accident, various well-being issues still exist among evacuees and returnees and clinically observed health problems, including psychological and mental health issues, continue to persist (Maeda and Oe, 2017).

This is why it is essential to have practical approaches and tools to assist proper and unified decision making among emergency managers/professionals/workers in and after the response to a nuclear or radiological emergency. Decision making in nuclear or radiological emergencies needs to shift from a radiological protection-centred strategy to a more holistic view of health protection, including mental health and psychosocial support (Carr et all 2016; 2018). This approach is increasingly promoted by international organisations, as confirmed by the recent launch by the WHO of the framework for mental health and psychosocial support in radiological and nuclear emergencies. Even through there is no one-size-fits-all approach, the adoption of a global generic operational framework addressing mental health and psychosocial needs at the international, national and local levels would certainly be a step forward.

For these reasons, the EGNR, after having reviewed and provided input to the development of the 2020 WHO framework, is now focusing on the translation of general guidelines, recommendations and scientific evidence into concrete actions to be taken at different levels of the decision-making chain. These actions will cover the preparedness, emergency response, and recovery phases and will be based on the five 'Cs' identified by the WHO for the provision of MHPSS in the context of a nuclear or radiological emergency: co-ordination; communication; community resilience and engagement; ethical considerations; and capacity building (WHO, 2020a). The aim is to publish the report by early 2023.

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Improving the long-term management of a nuclear power plant after a severe accident

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The accident at the Fukushima Daiichi Nuclear Power Plant has highlighted the importance of improving preparedness for the long-term management of a nuclear power plant (LTMNPP) after a severe accident. It is necessary for a range of follow-up actions, such as maintaining the plant in a stabilised and controlled state, securing it against further failures and cleaning up waste and debris.

In that perspective, the NEA Working Group on Analysis and Management of Accidents (WGAMA) completed a status report (NEA, 2021) with the objective of:

- reviewing NEA member countries' regulations and guidances, practices, technical bases and issues regarding LTMNPP;
- exhaustively identifying, describing and discussing the main challenges and issues to be addressed;
- proposing recommendations and areas for future investigations to enhance LTMNPP.

A task group of experts knowledgeable in the long-term management (LTM) of Three Mile Island, Chernobyl and Fukushima Daiichi examined the accident management actions implemented after a plant reached a stabilised and controlled state following a reactor or spent fuel pool (SFP) severe accident and up to and including fuel and debris retrieval from the damaged plant, its temporary on-site storage and the transportation to off-site permanent storage (Figure 1).

The experts examined LTM actions that aim at evaluating the plant's damaged state from a physical and radiological standpoint; maintaining a stabilised and controlled state of the damaged plant from a safety perspective; implementing provisions against further failures; cleaning up and decontaminating; managing accident wastes (conditioning, treatment, packaging, storage); preparing and achieving fuel and debris retrieval; and protecting plant personnel from exposure. Off-site long-term management and actions, radiological protection, waste disposal and decommissioning aspects were not addressed in detail by the group.

Based on a questionnaire that was circulated among NEA member countries, it could be concluded that most surveyed countries do not have specific regulations for the long-term phase of a severe accident. Rather, it is commonly considered to be covered by the existing regulations and severe accident management guidelines.

Information from the three major accidents at Three Mile Island, Chernobyl and Fukushima Daiichi was gathered and analysed to provide insight specifically for LTM. Whereas the LTM actions listed above can be considered completed at Three Mile Island, there are still tremendous challenges for LTM at Chernobyl and Fukushima Daiichi with significant developments yet to come. The three accidents have shown that different difficulties and issues may arise for LTM depending on the accident's nature and consequences. The starting points for LTM can vary significantly depending on the short-term accident measures already taken.

The three accidents led to unique national regulatory and licensing requirements and also required the development of complex technical means (e.g. unique systems, equipment and instrumentation), actions and organisations (Figures 2 and 3). The main challenge in implementing LTM in all three accidents is that it had to be started with limited knowledge of the status of the core and the plant, of the risk of evolving to a new instability, and of risks related to the implementation of long-term management actions (LTMA).

Looking specifically at damaged fuel diagnostics and retrieval, the three accidents resulted in distinctive damaged fuel distributions and characteristics, even among the three damaged reactors at Fukushima Daiichi. At Three Mile Island, the fuel retrieval strategy had to be revised after investigations in the reactor pressure vessel. The fuel retrieval was performed successfully with a specific defueling platform where operations were practiced beforehand to limit workers' exposure (Figure 2). At Chernobyl, investigations have shown that ageing through leaching and interactions with atmospheric gas and water may affect the integrity of the damaged fuel, with possible fuel dusting in the long term. At Fukushima Daiichi, uncertainties remain regarding the fuel distribution in the three damaged reactors, the corium composition and its behaviour concerning leaching and ageing effects. The best strategies for damaged fuel retrieval have not yet been established for Chernobyl and Fukushima Daiichi.

Next, the group of experts discussed approaches to long-term management from a general perspective. They defined LTM and its scope and identified the main long-term controlled state functions and the monitoring needed for a safe LTM. Possible LTM "entry states", which depend on the accident progression up to that point, were systematically classified. LTM challenges and issues were identified for each generic entry state. Then, a structured approach to identify and categorise risks related to LTM challenges and issues was developed to guide LTM. Within this approach, a risk-informed, plant-specific classification method of the events, different to the one using generic entry states, is used.

Finally, an action identification and ranking table was developed to point out the knowledge, challenges, open issues and technological gaps related to the main LTM actions, such as maintaining a coolable configuration, ensuring confinement integrity, managing water wastes, solid wastes and effluents, site clean-up and decontamination, and the removal and disposal of fuel from reactors and SFPs.

Based on the material and discussions presented in the status report, the expert group made recommendations on enhancing knowledge in the following areas:

- calculation tools and methods for analysis of reactor and SFP severe accidents to enhance capabilities to predict the stabilised state and the corresponding plant damaged state;
- status of components, equipment, systems, including passive ones, and structures after a severe accident with emphasis on those that contribute to maintaining a stabilised state in the long term;
- long-term phenomena that can affect LTM (e.g. corrosion-erosion reactions, fuel "dusting" and dispersion);
- methods or expert systems for risk assessment for LTM and LTMA optimisation;
- maintaining long-term cooling and sub-criticality:
  - long-term reactor pressure vessel (RPV) resilience for situations where RPV failure has been prevented;
  - long-term reliability of systems and equipment involved in maintaining a coolable configuration to assess failure risks due to induced mechanical weakness (particularly for fixed systems that have withstood challenging SA conditions), due to clogging with debris and due to corrosion-erosion reactions;
  - degradation under severe accident conditions (high dose and temperature) of materials that may form significant amounts of debris, posing challenges for the long-term cooling;
  - development, both for short-term management and LTM of a severe accident, of methods and tools to assess criticality safety margins for damaged fuel considering uncertainties on damaged fuel characteristics (shape, size, distribution, porosity, composition, etc.) and assessment of the potential consequences of re-criticality events in terms of damage to safety equipment and structures and radioactive material remobilisation.
- limiting radioactive releases:
  - knowledge of the remobilisation of radioactive products both in contaminated waters and in the atmosphere should be developed;
  - these phenomena include leaching of debris, dust formation from degraded fuel and remobilisation from radioactive aerosol deposits.

The expert group made recommendations regarding site clean-up, decontamination and waste management. These included that knowledge be capitalised (with feedback from past accidents) and shared and that guidance be provided on:

- best approaches and techniques (cleaning, fixing or implementing protection and confinement measures) for the treatment of various contamination types;
- multi-nuclides analysis methods in highly active severe accident solid and liquid wastes (detection, qualitative and quantitative analyses of major isotopes);
- purification technologies and related processes for highly contaminated severe accident liquid wastes;
- approaches and techniques for handling, routine monitoring and storage of highly active severe accident wastes. This includes defining the criteria by which the mode of waste management is chosen.

Recommendations were made regarding fuel retrieval and disposal. Knowledge should be capitalised and developed on:

- damaged fuel distribution and characteristics and their evolution over time, including ageing and leaching effects;
- cutting and recovery methods and techniques for damaged fuel to minimise contamination dispersion;
- risks related to damaged fuel retrieval (re-criticality, fuel dust formation and dispersion).

Recommendations were made to develop provisions to:

- enhance monitoring of the plant damaged state and its evolution as well as that of the LTMA;
- upgrade equipment, components, systems and structures for LTM;
- develop harmonised practices and the technical means to limit workers' occupational exposure in LTM.

In all three accidents reviewed, there were serious challenges to handling contaminated and leaking cooling water. Therefore, it was also recommended to develop provisions to optimise the management of cooling waters to facilitate LTM:

- During the emergency phase, closed loop cooling should be implemented as early as possible.
- Strategies for flooding and cooling the corium should as far as possible avoid transfer of contaminated waters outside the confinement.
- Methods and criteria to optimise the mode of cooling (such as active or natural cooling with water or cooling in air) in the long term should be developed to minimise contaminated water volumes.
- Use of water with controlled chemistry should be further studied with respect to limiting risks of re-criticality, fission product remobilisation, corrosion, clogging, and for the facilitation of water management in the long term.

The NEA continues to be instrumental in enhancing and sharing knowledge on LTMNPP through joint safety research projects, including post-Fukushima projects and others initiated in 2020 investigating long-term fission products release. It has also run specialist workshops, for example one held in December 2020 on advanced measurement methods and instrumentation for enhancing severe accident management and another, in October 2021, on long-term management and reliability of reactor core and containment cooling systems.

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NEA (2021), *Long Term Management and Actions for a Severe Accident in a Nuclear Power Plant: Status Report,* NEA No. 7506, OECD Publishing, Paris, https://bit.ly/2TGFt9M.

Figure 1: Illustration of timeline of long-term management actions in a nuclear power plant after a severe accident

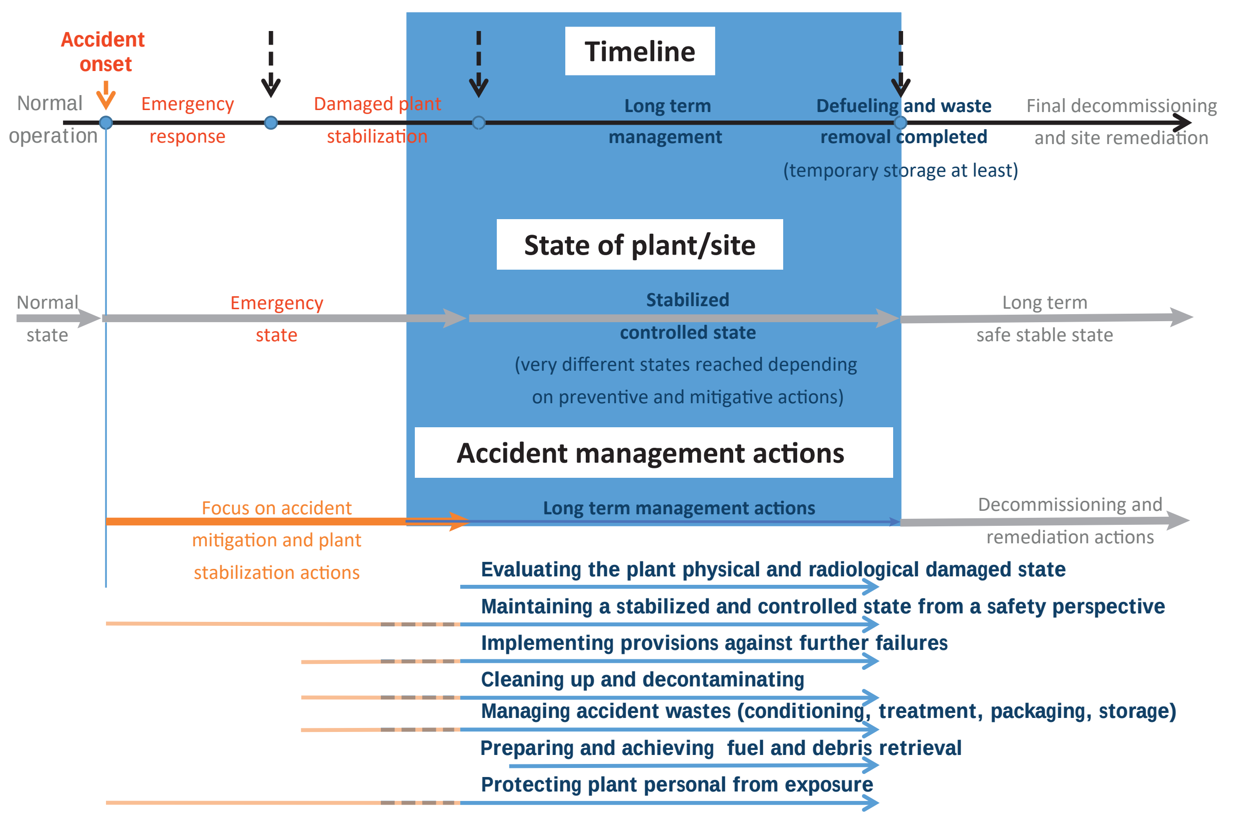
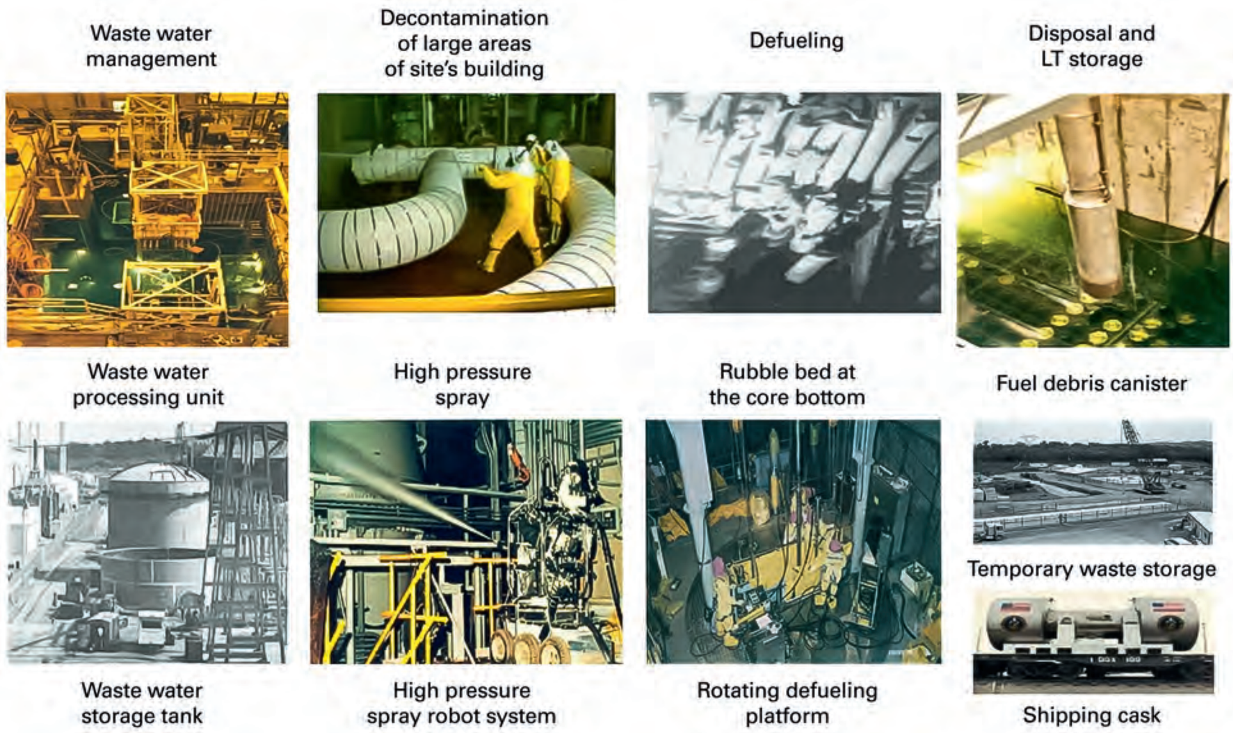
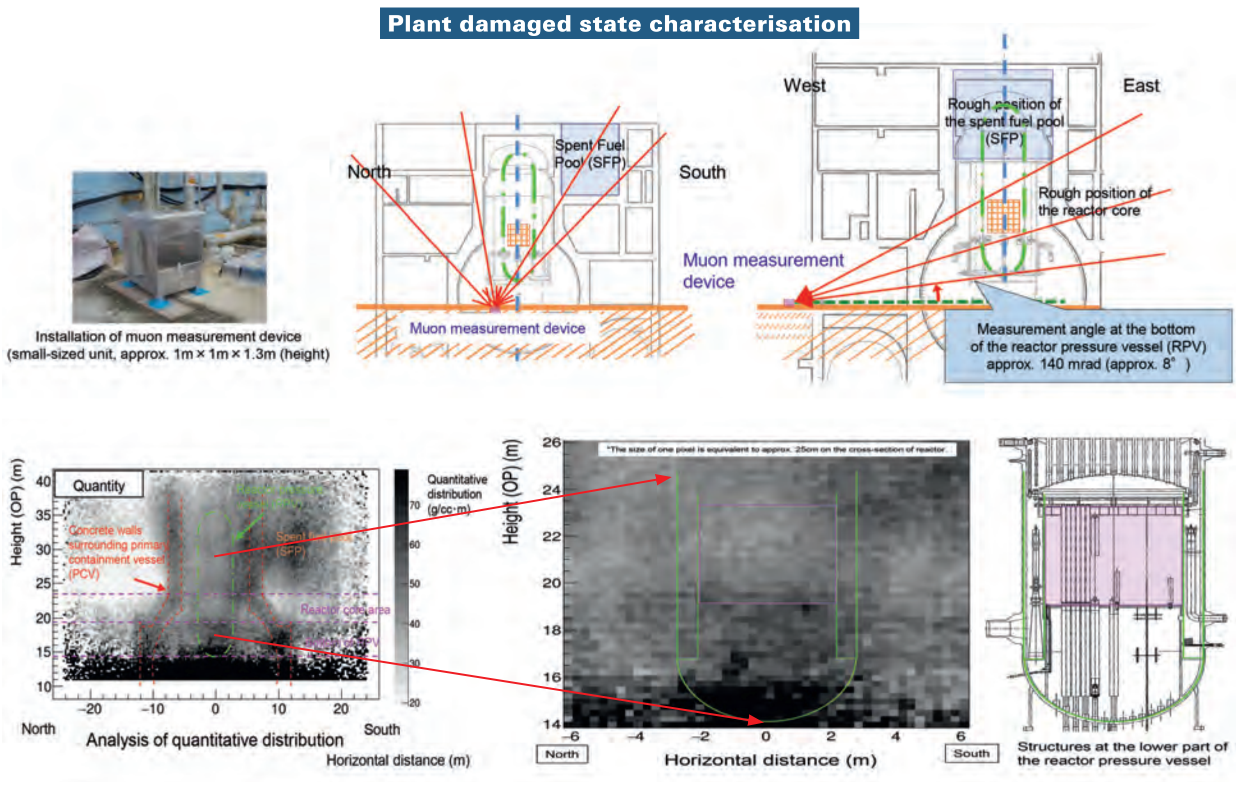


Figure 2: **Insights from Three Mile Island LTMNPP**



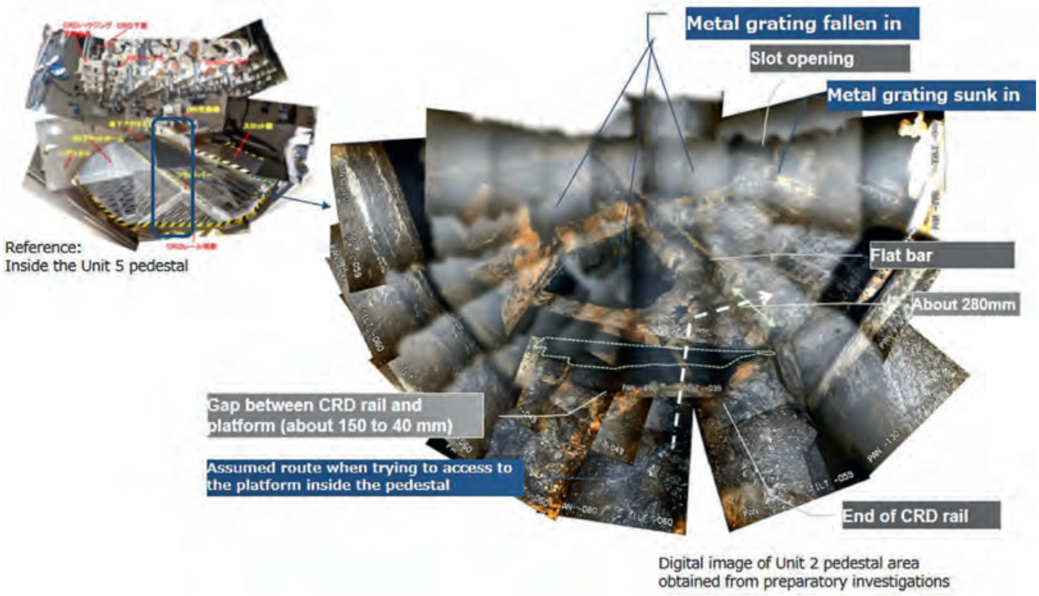
Source: NRC, 2016.

Figure 3: **Insights from Fukushima Daiichi LTMNPP**



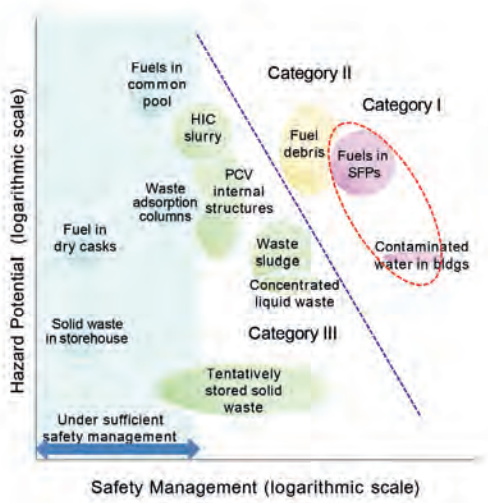
Muon tomography at unit 2

Figure 3 *(continued)*



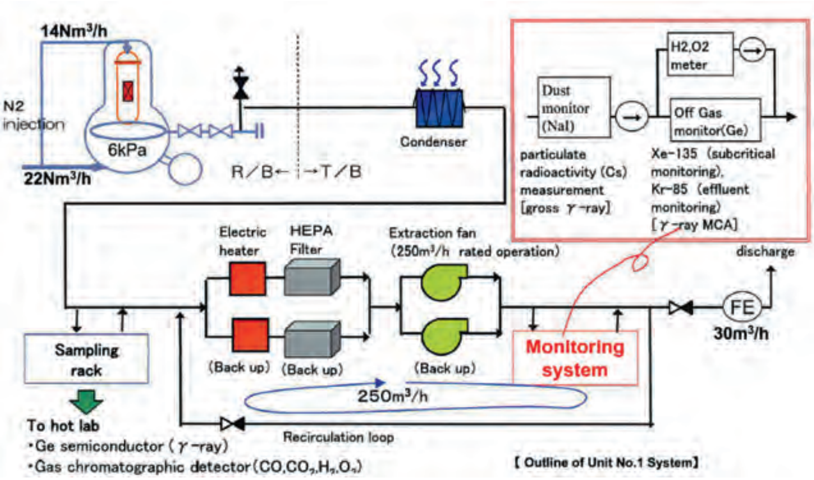
Robotic inspection at unit 2 pedestral

Risk ranking and reduction for LTM



Ranking of hazards and risk components

Monitoring and strengthening safety systems



Gas monitoring system

Sources: NTEPCO, 2016, 2017, 2018; NDF, 2016.

Understanding the characteristics of a trusted regulator

by L. Rousselet

Ms Lelia Rousselet (lelia.rousselet@oecd-nea.org) is a Junior Social Scientist in the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety.

Panel sessions of the NEA Stakeholder Involvement Workshop on Risk Communication, 24-26 September 2019 (Li Hua).

Stakeholder involvement and dialogue are an integral part of the decision-making process, and are requirements for a successful and meaningful nuclear policy. Each step of the nuclear fuel cycle is embedded with broader societal issues, and can therefore raise questions and concerns from stakeholders. In this context, building trust and credibility is critical for successful communication about risk. During the Second NEA Workshop on Stakeholder Involvement, which examined risk communication and was held in Paris in September 2019, these components were highlighted as being particularly pertinent for nuclear regulators, who have a responsibility to the public for safety.

Practical experience has shown that building trust is a complex, continuous and long-term process. Despite the nature of this process being dependent on the national and cultural context, it is possible to identify the key attributes of a trusted regulator and the best practices to build and maintain trust. Moreover, trust has a transnational dimension, and it can be quickly lost if the information and guidance given by a regulator is not consistent and coherent in neighbouring countries. A common framework to define and implement trust should therefore be a priority for nuclear regulators.

In view of this, the members of the NEA Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC) conducted a public survey in February-March 2021 to gather views from the public and stakeholders worldwide on the characteristics of a trusted regulator. The questions focused on the current level of trust between the respondents and their national nuclear regulator; the past successes and failures to build trust; and the solutions to increase and strengthen this trust. The NEA received almost 800 responses from 35 countries.

Among the key results of the survey, 47% of the respondents reported that they fully trust their nuclear safety regulator, whereas 25% declared that they hardly trust or do not trust their regulator. Independence, knowledge/competency and impartiality/objectivity were identified by the respondents as the key attributes of a trusted regulator. The responses also indicate that expert knowledge and experience are reasons for their trust (in countries with a long nuclear history, for example), and that commitment to international standards and guidance brings confidence. Another highlight of the responses is the importance of transparency, access to information and clear communication. The survey also revealed disparities, which could depend on the national context: some responses linked trust with consistency and stability, whereas others highlighted the need to modernise regulations (to adapt to changing environments, new technologies, etc.). There was no clear consensus on the importance of the reporting relationship between the nuclear regulator and the government (or national authorities) and its impact on the level of trust.

The NEA considers trust to be a crosscutting topic, and the results of this public survey will provide insight and orientation for future work of various working parties. In particular, the WGPC, in partnership with the Forum on Stakeholder Confidence (FSC), is building on the results of this survey to prepare what is commonly referred to as a "Green Booklet" (in reference to the cover's dominant colour) on "the characteristics of a trusted regulator", and which will serve as a guideline for NEA member countries.

For more information on the work of the Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC), please visit www.oecd-nea.org/wgpc.

Reference

NEA (2021), *Towards a Shared Understanding of Radiological Risks: Summary Report of the NEA Stakeholder Involvement Workshop on Risk Communication,* OECD Publishing, Paris, https://doi.org/10.1787/6da7e177-en.

The International Radiological Protection School goes online

by J. Kruse, R. Wakeford, C. Clement and J. Garnier-Laplace

Mr Jan-Hendrik Kruse (jan-hendrik.kruse@oecd-nea.org) is a Radiological Protection Specialist in the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety. Professor Richard Wakeford, an Honorary Professor at the University of Manchester, is Chair of the IRPS Advisory Board. Christopher Clement is the Scientific Secretary of the International Commission on Radiological Protection (ICRP). Dr Jacqueline Garnier-Laplace (jacqueline.garnier-laplace@oecd-nea.org) is Deputy Head of the NEA Division of Radiological Protection and Human Aspects of Nuclear Safety.

Over the last decades, organisations involved in policy, regulation and implementation of radiological protection practices across a variety of industries have had the chance to work with highly qualified radiological protection (RP) professionals that have shaped today's RP system. Now, with a majority of those experts retiring or already retired, there is an urgent need to transfer their knowledge on the underlying principles and spirit of the RP system to the next generation.

To address this, the NEA created the International Radiological Protection School (IRPS), in co-operation with the Swedish Radiation Safety Authority (SSM) and the Centre for Radiation Protection Research (CRPR) at Stockholm University. The principal objective of the course is to equip tomorrow's leaders in the RP field with the necessary tools to effectively address RP challenges. To this end, lecturers from across the globe present the history and nuances of international guidance and working experience.

After two in-person events held in Stockholm in 2018 and 2019, the third session of the IRPS was, in light of the COVID-19 pandemic, held virtually on 23-27 August 2021 with 37 participants from 20 countries and 3 international organisations. To adapt the structure of the IRPS to the requirements and constraints of a virtual event, a two-track approach of individual e-learning and shortened live sessions was adopted: the core of the course consisted of online live sessions of around three hours on each of the five course days, complemented by co-ordinated group work on three practical case studies. The live sessions were completed individually by watching pre-recorded video lectures and reading additional material on the different topics provided by the lecturers. This allowed the live sessions to focus on interaction between the lecturers and the participants. The work on the case studies was scheduled before and after the live sessions to allow for the convenient attendance of participants from different time zones. Working on the case studies in small groups promoted interaction between participants and allowed for networking.

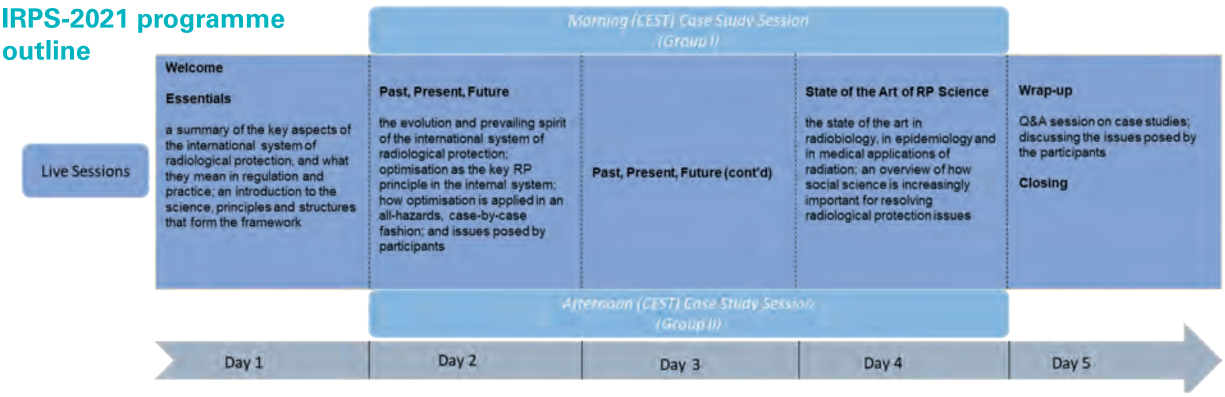
The objectives of the course are to: understand how and why the RP system has evolved to take into account the scientific evidence (i.e. the relationships between the understanding of radiation exposure levels, biological effects and risks to human health and the environment) and the lessons learnt from its application (i.e. in regulatory frameworks and practices); understand how the system is incorporated into the national regulatory frameworks, and how its application varies in the international context; put the RP system into the context of RP culture, while sharing tips to find the best solutions to practical RP issues, and illustrating leadership skills through presentations and case studies; evaluate and discuss how the RP system could evolve and remain state-of-the-art, mainly in the context of the set of recommendations being considered for the next two decades; develop a network of RP excellence among participants from various fields with RP as a common denominator.

To facilitate the implementation of IRPS-2021 online, the NEA created a dedicated online learning platform in co-operation with Oregon State University. Learning material, such as recorded lectures and additional readings, was posted on the platform where the participants could learn at their own pace before the live sessions. The platform opens a number of opportunities for future editions of the IRPS, for example as a tool to optimise the preparation of participants before an in-person event, to arrange hybrid editions of the school to enable many countries and organisations to participate, and as an internal NEA knowledge archive.

Despite being postponed by one year due to the COVID-19 pandemic, more than 37 professionals from 20 countries and 3 international organisations took part in the 2021 IRPS. This level of engagement confirmed the continued interest of the next generation of experts to acquire and build their expertise in radiological protection, as well as possibly positive effects like the simplified logistics and reduced costs of a virtual environment.

For more information and to apply for future editions of the IRPS, please visit www.oecd-nea.org/jcms/pl_27505/international-radiological-protection-school-irps.

IRPS-2021 programme outline



In Memoriam: Doctor Peter Lyons

The NEA community is deeply saddened by the loss of Dr Peter Lyons on 28 April 2021.

During a public service career spanning five decades, Dr Lyons made significant contributions to nuclear science and national security policy in the United States. He served as a Commissioner for the United States Nuclear Regulatory Commission and Assistant Secretary of Energy for Nuclear Energy and spent his career championing education initiatives and improving understanding of nuclear energy.

After undergraduate studies in physics and mathematics at the University of Arizona, Dr Lyons received a PhD in nuclear astrophysics from the California Institute of Technology. In 1969, he took a position at the Los Alamos National Laboratory and, over a period of nearly three decades, served as Director for Industrial Partnerships, then as Deputy Associate Director for Energy and Environment, and finally as Deputy Associate Director-Defense Research and Applications.

In 1997, he joined the staff of Senator Pete Domenici and the Senate Committee on Energy and Natural Resources as a scientific advisor. He helped Domenici in his focus on the non-proliferation of nuclear weapons and endeavoured to promote nuclear energy in both the United States and internationally. He supported the rollout of the Nuclear Energy Research Initiative and the Generation IV Nuclear Energy Systems programme by seeking federal funding for the development of small modular reactors and for the Nuclear Energy University Program, which helps US universities prepare students for a future as nuclear engineers.

From 2005 to 2009, he served as a Commissioner of the United States Nuclear Regulatory Commission and went on to lead the United States Office of Nuclear Energy as Assistant Secretary of Energy for Nuclear Energy from 2011 to 2015. From April 2011 to March 2015, Dr Lyons also led the United States delegation to the NEA Steering Committee for Nuclear Energy.

During his career, Dr Lyons published more than 100 technical papers, presented over 400 papers or talks on technical and policy topics, and served as Chairman of the NATO Nuclear Effects Task Group for five years.

A Fellow of the American Nuclear Society (ANS) and the American Physical Society, Dr Lyons also received several awards during his long career, notably the Henry DeWolf Smyth Award from the American Nuclear Society and the Nuclear Energy Institute, the Alvin M. Weinberg Medal from the American Nuclear Society, and the James Landis Medal from the American Society of Mechanical Engineers. He was recognised by the Nuclear Infrastructure Council with a Lifetime Achievement Award, and, in 2020, the ANS Nuclear Nonproliferation Policy Division presented Dr Lyons with the Dwight D. Eisenhower Award to honour him for his "influential leadership in nuclear technology policy over five decades and for the vital role he played in the nuclear renaissance of the early 21st century."

NEA Director-General William D. Magwood, IV writes, "Pete was an outstanding public servant and an invaluable leader in nuclear energy policy for decades. To me, he was a close partner and advisor over many years, a person of great character and substance, and a good friend. We will all miss him."

Dr Lyons will be remembered for his inspirational drive to educate future generations in the nuclear field. His contributions have left an indelible mark on the landscape of nuclear energy in the United States and beyond.

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

General Interest

Fukushima Daiichi Nuclear Power Plant Accident, Ten Years On

Progress, Lessons and Challenges

NEA No. 7558. 80 pages.

Also available in Japanese

https://oe.cd/4kb

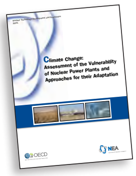
Nuclear Energy Agency

28 pages.

Also available in French, Chinese and Russian.

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

Nuclear technology development and economics



Climate Change: Assessment of the Vulnerability of Nuclear Power Plants and Approaches for their Adaptation

NEA No. 7207. 154 pages.

Available online at: https://oe.cd/n4k1

Climate change will create specific risks and challenges for nuclear power plants and the electricity system as a whole. Extreme weather events caused by climate change – such as floods, storms, heat waves and droughts – have already affected the operation of nuclear power plants. Any increase in the temperature of the water used to cool nuclear power plants can also lead to reductions in their power output due to decreasing thermal efficiency.

This report sets out the adaptation strategies that can be effectively implemented to improve the resilience of existing plants as well as any new installations. The costs of adaptation to climate change can vary significantly depending on the type of reactor, the climate change issues affecting them, as well as the applicable regulations and standards. However, while these adaptation costs can, in some cases, be significant, the costs of inaction – both directly at the plant level and indirectly for the electricity system – are likely to be even higher.

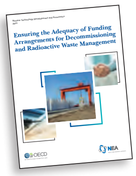
Long-Term Operation of Nuclear Power Plants and Decarbonisation Strategies

NEA No. 7524. 152 pages.

Available online at: https://oe.cd/EGLTO

The existing nuclear fleet remains the largest low-carbon source of electricity generation in OECD countries. In 2021 the average nuclear power plant had already been operating for 31 years and some 30% of reactors worldwide were already operating under long-term operation conditions. The long-term operation of this existing nuclear capacity will be essential over the next decade to keep decarbonisation targets within reach. At the same time, by keeping the long-term-operation option open, countries could also reap a wide-range of socio-economic benefits including more affordable and secure electricity supply. Nevertheless, an increasing number of reactors are being shut down earlier than expected due to policy decisions and increasing market pressures in some regions.

In light of these trends, this study takes a holistic approach to identifying the key enablers for long-term operation of nuclear power plants. The attractiveness of long-term operation lies in its technical maturity, cost-competiveness and ease of implementation: it is a high-value option to support the energy transition while minimising potential risks along the way.



Ensuring the Adequacy of Funding Arrangements for Decommissioning and Radioactive Waste Management

NEA No. 7549. 236 pages.

Available online at: https://oe.cd/4k2

The world's nuclear power reactors are ageing, with the majority approaching the end of their planned operational lifetimes in the coming years. The adequacy of funding for decommissioning and radioactive waste management (RMW) thus increasingly commands the attention of decision-makers.

This report by the OECD Nuclear Energy Agency (NEA) combines a solid conceptual framework with the insights from twelve case studies of NEA member countries to propose a new approach to the adequacy of funding that is both robust and flexible.

Current funding systems in NEA countries are overall adequate. The challenges ahead however are formidable: decommissioning and RWM are moving from design to implementation, returns on assets are low and societal preferences can evolve. The very long-term nature of the solutions, in particular for radioactive waste disposal, is also not easily compatible with the economic lifetimes of the original liability holders.

This requires that all elements of the system – accrued funds, expected future returns, the lifetimes of nuclear power plants, the expected costs of politically sustainable technical solutions and the liabilities for residual risks – are reviewed and realigned at regular intervals. Complementing existing approaches with such a circular approach will strengthen funding arrangements and ensure their adequacy for decades to come.

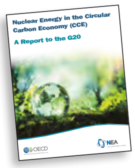
Advanced Nuclear Reactor Systems and Future Energy Market Needs

NEA No. 7566. 76 pages.

Available online at: https://oe.cd/4k3

Energy markets will be significantly different in the future. The electricity generation system is becoming more diverse with the development of energy-related technologies including renewable energy sources, storage technologies and demand-side management. Beyond the electricity sector, various low-carbon energy technologies are being developed to respond to the need to decarbonise hard-to-abate sectors such as heavy industry and long-distance transportation.

In this report the NEA investigates the changing needs of energy markets and the potential role of nuclear technologies as low-carbon energy sources. Focusing on the technical characteristics of advanced nuclear reactor systems, including Generation III/III+ reactors, small modular reactors and Generation IV reactors, it explores the ways these advanced nuclear technologies could address the future energy market needs. The conclusion is that advanced nuclear reactor systems, while complying with the flexibility requirements of the electricity grid and supporting system reliability, have a large potential as alternative low-carbon energy sources for residential and industrial heat supply and hydrogen production.



Nuclear Energy in the Circular Carbon Economy (CCE)

A Report to the G20

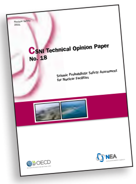
NEA No. 7567. 50 pages.

Available online at: https://oe.cd/nea-cce

This report highlights the potential role of nuclear in contributing to the circular carbon economy as a low-carbon source of electricity, but also as a source of heat and system integration services. It further highlights the essential role played by the existing nuclear reactor fleet in supporting the resilience of the electricity system through the COVID-19 crisis, and the significant role that the nuclear sector can play in post-COVID-19 recovery efforts.

As with all low-carbon technologies, a number of enabling policies are needed for nuclear power to play its full role in the circular carbon economy. They are outlined in the last section of this report. Building on these conclusions, G20 countries could take specific action in a number of areas, both individually and collectively.

Nuclear safety and regulation



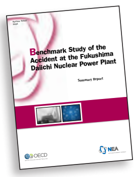
CSNI Technical Opinion Paper No. 18

Seismic Probabilistic Safety Assessment for Nuclear Facilities

NEA No. 7486. 36 pages.

Available online at: https://oe.cd/4k4

Seismic probabilistic safety assessment (SPSA) is a systematic method for examining and evaluating the risk from earthquake-initiated accidents. The significant advances in the area of SPSA since the initial publication in 2002 of *Technical Opinion Paper No. 2: Seismic Probabilistic Safety Assessment for Nuclear Facilities* by the OECD Nuclear Energy Agency have prompted its revision. The objective of this report is to provide the up-to-date international view on the state of the SPSA as it is currently being applied, including a description of the main elements of SPSA. While the uncertainties associated with seismic hazard and the determination of seismic failure probabilities are typically large, the inclusion of SPSA in a risk assessment results in a more complete risk picture, and thus enables more meaningful PSA applications.



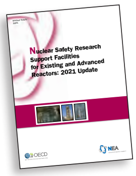
Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant

Summary Report

NEA No. 7525. 66 pages.

Available online at: https://oe.cd/4k6

Understanding the accident at the Fukushima Daiichi Nuclear Power Plant is important for safe and timely decommissioning of the reactors. This objective, together with the development of better computer codes for analysis of severe accidents, was the aim of the benchmark study conducted under the auspices of the OECD Nuclear Energy Agency. Through the diversity of the modelling codes and approaches, and the use of parametric studies, it has been possible to identify the more likely scenarios that can fit with the limited data available from the accident. The insights gained from the project will help guide research into severe accident behaviour, improve severe accident computer codes, develop accident mitigation and response at nuclear power plants, support regulatory oversight related to severe accidents, and inform policies on the development and deployment of nuclear technology.



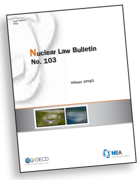
Nuclear Safety Research Support Facilities for Existing and Advanced Reactors: 2021 Update

NEA No. 7565. 100 pages.

Available online at: https://oe.cd/4k7

Experimental facilities in nuclear energy are key to addressing safety issues. The recent loss of some critical infrastructure, from facilities to industry expertise, has therefore become a concern for many countries. In response, the Nuclear Energy Agency (NEA) has launched several efforts to address the matter as outlined in this report. Current safety issues, research needs and research facilities associated with currently operating water-cooled reactors in NEA countries are all addressed. Also included is an assessment of the present needs to maintain experimental databases. The Senior Group of Experts on Nuclear Safety Research, which produced this update of the 2007 report on the same issue, noted the success of previous reviews in helping maintain critical infrastructure and make a number of recommendations to preserve key research facilities and capabilities.

Nuclear law



Nuclear Law Bulletin No. 105

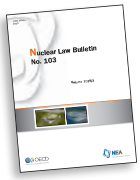
Volume 2020/2

NEA No. 7534. 120 pages.

Available online at: https://oe.cd/nea-nlb-105

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: "Environmental impact assessments and long-term operation of nuclear power reactors: increasing importance of environmental protection in the European Union?", "Forging a clear path for advanced reactor licensing in the United States: approaches to streamlining the NRC environmental review process" and "Slovak legal system for ensuring feasible nuclear back-end system implementation".



Nuclear Law Bulletin No. 106

Volume 2021/1

NEA No. 7597. 56 pages.

Available online at: https://oe.cd/nea-nlb-106

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.

The following study is featured in this issue: "Recognition and enforcement of foreign judgments on civil liability for nuclear damage".

Publications of Secretariat-serviced bodies

Generation IV International Forum (GIF) Nuclear Energy: An ESG Investable Asset Class

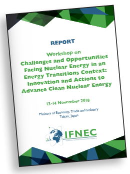
September 2021

133 pages.

Available online at: https://www.gen-4.org/gif/jcms/c_179256/gif-final-esg-010921

This report has been produced by a finance industry taskforce set up in 2020 by the Economic Modelling Work Group (EMWG) of the Generation IV International Forum (GIF) to consider the nuclear industry's ability to report against Environmental, Social and Governance data collection and accounting metrics (ESG). Reporting well against ESG allows nuclear energy to be considered as an investable asset class; thereby allowing nuclear companies and projects to access climate finance. The report has been produced by the finance community for the finance community.

The report establishes not only how nuclear energy, as an asset class, has the potential to report well against a wide range of ESG; it highlights the importance of wide ranging, consistent and standardised ESG reporting to determine the credentials of all energy companies across their lifecycles and throughout their supply chains. The report discusses how ESG fit within international frameworks, including the UN Framework Convention on Climate Change (1992), the Kyoto Protocol (1997) and the Paris Agreement (2015), and how ESG are linked to the Green Bond Principles, while examining the relationship between ESG and the various taxonomies and other policy documents being developed around the world.



Workshop on Challenges and Opportunities Facing Nuclear Energy in an Energy Transitions Context: Innovation and Actions to Advance Clean Nuclear Energy

13-14 November 2018

20 pages.

Available online at: https://www.ifnec.org/ifnec/jcms/g_14355/workshop-on-challenges-and-opportunities-facing-nuclear-energy-in-an-energy-transitions-context-innovation-and-actions-to-advance-clean-nuclear-energy

The seven panel sessions addressed many important issues, including:

- Challenges to decarbonization in meeting the Paris Agreement.
- Nuclear energy crossroads and challenges faced by countries backing away from nuclear.
- Energy future and the contribution of nuclear in achieving clean energy.
- Cost-effectiveness/competitiveness of nuclear energy.
- Public perception and confidence in nuclear energy projects.
- Radioactive waste management and disposal – multinational repositories.
- International platforms to strengthen nuclear energy cooperation among countries.

Multinational Design Evaluation Programme (MDEP) Annual Report: April 2018-April 2019

MDEP report. 28 pages.

Available online at: https://oe.cd/4k9

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Version: Mai 2022

NEA
NUCLEAR ENERGY AGENCY

The Nuclear Energy Agency (NEA) is an intergovernmental agency established in 1958. Its primary objective is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes. It is a non-partisan, unbiased source of information, data and analyses, drawing on one of the best international networks of technical experts.

The NEA has 34 member countries: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia (suspended), the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, 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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Cover page photo credits: Transport by ship of spent nuclear fuel and radioactive waste (Svensk Kärnbränslehantering, SKB); NuScale Power's small modular nuclear reactor plant (photo courtesy of NuScale) and Stakeholder (Shutterstock, SFIO CRACHO).

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