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NEA News

60 years

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NEA News

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60 years


Today, with the 21st century well underway, we must now look to the future. There are new problems to address and new visions to implement. Nuclear energy is still a success around the world, but its continued success requires that it evolve. The NEA is here to support member countries as this evolution proceeds.
William D. Magwood, IV
Director-General, Nuclear Energy Agency (NEA)
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Director-General William D. Magwood, IV

Comments at the NEA 60^{th} Anniversary High-Level Session

NEA Director-General, William D. Magwood, IV speaking at the 60^{th} Anniversary High-Level Session.

In a very real sense, the story of nuclear science and technology is the story of the 20^{th} century. In the beginning, Becquerel identified radiation in 1896. The Curies discovered radium in 1898. Einstein published the theory of relativity in 1905. Rutherford induced the first nuclear reaction in 1919.

The progression from science to application, which began with medical applications – both beneficial and fraudulent – was accelerated after Otto Hahn, Fritz Strassman and Lise Meitner concluded in 1939 that there was something happening in uranium besides interesting chemistry. Nuclear fission was born.

This must have been the single most exciting moment in physics, as scientists all over the world quickly recognised that the world had changed forever.

We can only speculate how differently history might have unfolded had this discovery come at a time of peace instead of at the threshold of mankind's greatest and most violent era. Had Europe not been at the eve of World War Two, would Szilárd, Teller and Wigner have rushed to Einstein to press him to write his famous letter to President Franklin D. Roosevelt?

At the end of the war, nuclear was no longer primarily the province of physicists, but increasingly the domain of technologists. With the horrors of war behind them, this era brought forth people with an eye towards a better future for all humanity, and they believed nuclear energy to be the key.

They envisioned hammering the nuclear sword into the greatest ever ploughshare, setting civilisation on the path to progress with limitless, inexpensive energy that would enable the development of a better, fairer society. President Eisenhower's "Atoms for Peace" speech in 1953 captured this spirit and placed it at the centre of international thought.

This vision coincided with another vision – the vision of a restored, revitalised Europe. Implementing the Marshall Plan, the Organisation for European Economic Co-operation (OEEC) – the predecessor of the OECD – set forth to explore how nuclear energy could serve as the cornerstone of the development of a revitalised Europe. In step with President Eisenhower's call, the OEEC established the Working Party on Nuclear Energy in 1955, followed by the establishment of the Steering Committee on Nuclear Energy in July 1956.

The NEA Senior Staff in 1963.

The Steering Committee established the Group of Governmental Experts on Third Party Liability in the Field of Nuclear Energy, and this group – which is the predecessor of the NEA Nuclear Law Committee – first met in January 1958.

Finally, in February 1958, the OEEC statute that had passed in the previous year went into effect and established the European Nuclear Energy Agency with all of the 17 member countries of the OEEC.

This marked a rapid pace of nuclear research and development in Europe. The Agency had at its heart a research mission. The Halden Reactor Project soon followed, as did the Dragon High Temperature Gas Reactor project.

As Europe progressed, so too did the Agency. Nuclear energy was a major success in Europe, providing clean, reliable electricity for decades. The vision for European redevelopment was accomplished, and nuclear energy was a part of that story.

In the years that followed, more and more countries joined the Agency. When Japan became a member in 1972, the ENEA became a truly international agency and was renamed the Nuclear Energy Agency (NEA).

The NEA responded to the needs of its members, providing the services that they needed as events unfolded. In the wake of Chernobyl, the NEA established the Incident Reporting System and created the Committee on Nuclear Regulatory Activities (CNRA).

I first became involved with the Agency in 1994, during the time that I was political appointee of the Clinton Administration and one of the few people so anointed who knew what an SWU[1] was and could reliably spell "neutron". I became the US delegate on the Nuclear Development Committee (NDC).

Aside from my office mate during my first year as a young scientist at Westinghouse – who was on a one-year assignment from IHI Corporation[2] of Japan – this was my first exposure to international discourse. The first surprise was that the United States was seated next to Spain and that this was considered alphabetical order.[3] A few years later, I led the US delegation to the NEA as its representative on the Steering Committee. This happened a short time after Luis Echávarri became Director-General.

Between Luis and I, our leadership covers a full third of the history of the NEA, although his part is a bit longer than mine. Our tenures and those of the Directors-General before us saw many impressive successes.

Today, with the 21st century well underway, we must now look to the future. There are new problems to address and new visions to implement. Nuclear energy is still a success around the world, but its continued success requires that it evolve. The NEA is here to support member countries as this evolution proceeds.

A colleague from China recently told me that in Asia, 60 years is seen as the first cycle of life.

For the NEA, the next cycle begins now.

William D. Magwood, IV,
NEA Director-General

1. SWU = separative work units.
2. IHI was formerly known as Ishikawajima-Harima Heavy Industries Co., Ltd.
3. The country name plates for international meetings at the OECD are generally in French, and thus "Espagne" precedes "États-Unis".

Fukushima reconstruction: Society, economy and community

by E. Lazo, K. Funaki, I. Otsuka and V. Lebedev

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Kawauchi Village in Fukushima.

Tomioka Town during a festival for the reconstruction of the Futaba coastal area in Fukushima.

Immediately following the 2011 Great East Japan Earthquake and related tsunami, evacuation orders were implemented in three zones surrounding the Fukushima Daiichi nuclear power plant. These evacuation orders have today been lifted in many towns, leaving only some high dose areas where returning remains difficult.

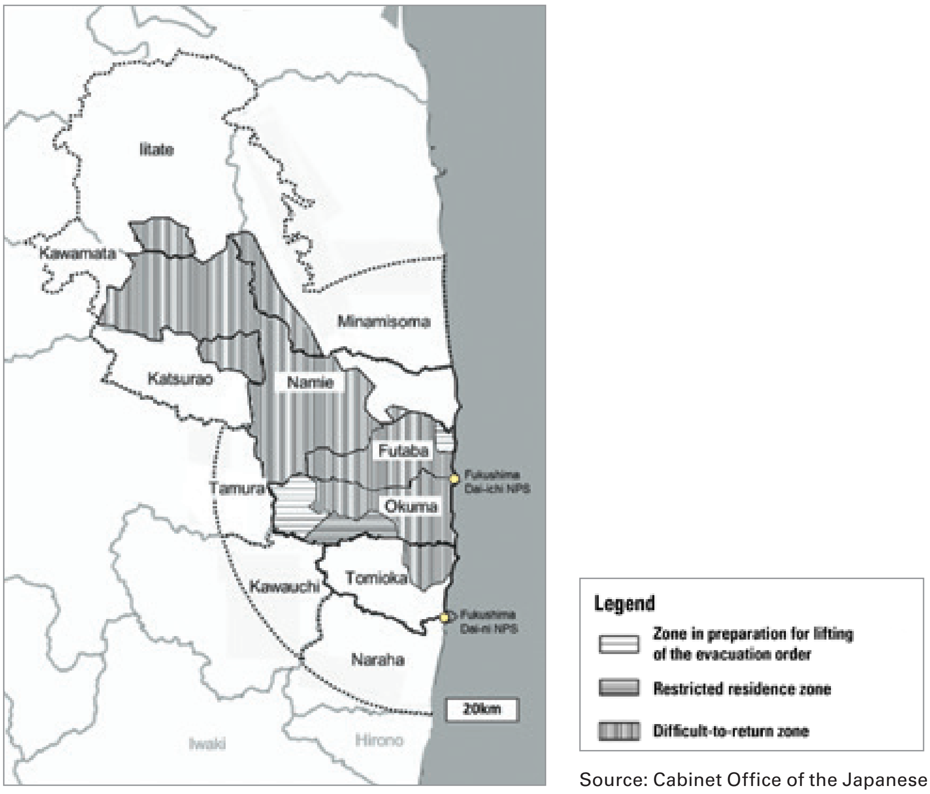
Projects being carried out under the "Fukushima Innovation Coast Initiatives" have been making progress in building new industrial infrastructures and helping to reconstruct the lives and livelihoods of residents. Ensuring the safety and stability of the Fukushima Daiichi site in terms of the risks associated with fuel and radioactive waste management has been key in this regard. The Fukushima Daiichi nuclear power plant is currently in a stable configuration and is moving towards full characterisation of its status and radiological condition while making progress with decommissioning plans. Approaches to the treatment of accumulated processed water and fuel debris retrieval strategies are also under development. Yet many challenges remain to be addressed both on-site and off-site. Public trust in rehabilitation efforts is improving but remains an obstacle to the realisation of the overall vision for local revitalisation.

International and collaborative support from local and international entities is continuing, and the NEA is one of many organisations providing support to reconstruction efforts through a number of international activities. Following an article on decommissioning progress in the June 2017 edition of *NEA News*, this article describes reconstruction efforts in the region more generally.

Reconstruction after evacuation

In the municipalities and areas where evacuation orders have been lifted as of April 2017 (see map on page 6), reconstruction is at last fully underway. A "difficult-to-return" zone remains encompassing six municipalities, while the number of people who are still not permitted to return to their homes has declined from 81 000 in August 2013 to 24 000. These 24 000 people are mainly from Okuma and Futaba – where the Fukushima Daiichi nuclear power plant is located.[1] Returning evacuees have been categorised into three groups. The first group consists of former residents who were able to return to their homes very early after evacuation orders were lifted in 2014, for example in Tamura and Kawauchi.

Figure 1: Conceptual diagram of areas under evacuation orders



Source: Cabinet Office of the Japanese government.

In these areas, around 70% to 90% of the residents have returned. The second group is represented by Naraha and Odaka in Minamisoma, where evacuation orders were lifted in 2015 and 2016, respectively, and where 20% to 35% of residents have returned. Society has recovered its vitality in these four areas. The third group concerns areas where the evacuation order was lifted later, around April 2017, in Tomioka, Iitate and a part of Namie. The number of evacuees who have returned to their homes in these areas remains limited.

Progress in restoring key infrastructure has been made in all of the affected areas in Fukushima – for example, reconstruction of the Joban expressway passing through the Hamadori coastal area was completed in 2015 and operation of Japan Railway's Joban line was resumed in 2017, except between Tomioka and Namie.

Restoration plans were also recently approved for Okuma and Futaba, where there still remain large "difficult-to-return zones". Revision of the Act on Special Measures for the Reconstruction and Revitalization of Fukushima in May 2017 enabled municipalities to designate specific reconstruction areas in these zones where restrictions for living will continue over the long term.

Economic restoration will be an essential element of these plans, allowing former residents to return to their homes and rebuild their lives. The reconstruction of businesses and services, as well as an acceleration of new industry development, will be crucial elements. Among entities that have been registered in the 12 municipalities from which residents were evacuated, only 28% have restarted their businesses in the original location, while 25% have had to be relocated.

Creating a new entrepreneurial spirit and advanced R&D activities will help to revitalise employment and the local economy in general. The 17 new industrial complexes that have been constructed since the accident in 12 municipalities will contribute to such momentum. Already, the number of companies operating in industrial complexes developed before the accident has increased from 35 to 49, with a large diversity of sectors represented and ranging from wearable IoT ("internet of things") product manufacturing to the development of Lithium-ion batteries.

A continuing dialogue to address residents' post-accident concerns

The Fukushima Daiichi NPP accident has highlighted the importance of stakeholder involvement in decision-making processes that involve radioactivity and/or exposure to radiation. Since November 2011, the NEA has been involved in a series of 19 stakeholder dialogue meetings initiated by the International Commission on Radiological Protection (ICRP) in different areas of Fukushima prefecture.

The objective of these meetings was to find ways to actively support local populations in their efforts to address the challenges involved in the long-term rehabilitation of their living conditions. Large-scale accidents result in extremely complex situations for the people involved and can include interrelated aspects such as radiation risks; personal financial and employment concerns; family issues; local infrastructure and economic issues; psychological concerns; compensation issues; or concerns in relation to social structure.

The most recent (19th) ICRP Dialogue was held in Minamisoma City in February 2018.[2] This was the second dialogue held in Minamisoma, the first having taken place in May 2014. The results from the discussions in February demonstrated that significant progress had been made in all areas. Some of the topics of discussion were related to the following issues:

- the creation of trusted and available data that have been gathered by locals, with a process that involves measurements similar to "official" government measurements so as to "validate" government measurements;
- a better, clear-language understanding on the part of residents of the low-dose effects of radiation;
- the community spirit that has been built through the creation of groups and venues for social exchange;
- the community dialogue in Minamisoma that has been created among residents with limited municipal assistance;
- the general sense that social, economic and infrastructure issues have replaced radiation exposure as priority issues;
- the apparent decrease in social discrimination against Fukushima residents, partly because Fukushima issues have become less central in the national debate.

While the shift – broadly from an attitude of radiological concern to a more forward-looking perspective – can be seen in those who remained or have returned to affected areas, it seems that those who have not returned have not experienced this same evolution. Although local, cultural traditions and historic ties continue to influence evacuees – "pulling them home" so to speak – many continue to feel "forgotten", or "left out" of local decisions. For many, the decisions that concern the use of land that is no longer suitable for agriculture, for example for the installation of solar farms, are particularly hard to accept. Indeed, the significant change to the agricultural landscape can be shocking for those who return for visits, in the same way that it has been saddening for residents involved in the decision making. The region was an agricultural one for most of its history, and food products have always been a key aspect of residents' lives.

Public concerns about food safety: Addressing reputation issues

The region affected by the accident was primarily known and appreciated for its many food products, including rice, vegetables, beef, persimmons and peaches. It was also well-regarded throughout Japan for its fisheries. In the aftermath of the accident, however, populations both in Japan and abroad were concerned about consuming food products from the Fukushima prefecture. In Tokyo, for example – located approximately 240 km south of the Fukushima prefecture – some shops stopped carrying specific food items entirely immediately after the accident, simply because the best examples were commonly from the Fukushima region.

Japanese authorities have thus implemented agricultural practices that help ensure the high quality of food and feed from the region. Food consumption criteria have been established that follow approaches stipulated by international standards/guidelines (i.e. Codex guidelines) and that are numerically extremely low (see Table 1 below). Food monitoring/inspections have also been conducted for a significant number of samples every year. These measures have been combined to ensure that food entering the domestic and international markets meets stringent Japanese food standards.

Fishing has resumed on a trial basis more than 10 km offshore from the Fukushima Daiichi NPP, and catches are gradually increasing. The number of species that can be caught has also increased, and as of April 2018, only seven species still cannot be fished. Fishery products have also been monitored and inspected on a weekly basis in accordance with the guidelines adopted by the Nuclear Disaster Response Headquarters of the national government.

Table 1: Regulation limits

(Unit: Bq/kg)

Japan		EU		United States		CODEX**	
Standard limits* under food sanitation act		Council regulation (Euratom) 2016/52		CPG sec. 560.750 radionuclides in imported foods – Levels of concern		CODEX STAN 193-1995	
Drinking water	10	Drinking water	1 000				
Milk	50	Milk	1 000				
Infant foods	50	Infant foods	400			Infant foods	1 000
General foods	100	General foods	1 250	All foods	1 200	General foods	1 000

* Standard limits in the above table are used to ensure that radiation doses received are below a certain level; they are not necessarily the boundaries between safety and danger.

** CODEX: An international intergovernmental body set up by the UN Food and Agriculture Organization (FAO) and the World Health Organization (WHO) for purposes including to protect consumer health and ensure fair trade in food. It produces the international code on food (the Codex Alimentarius).

Source: Created by the Reconstruction Agency (Japan) based on material from the Ministry of Health, Labour and Welfare.

Inspection of food products from Fukushima prefecture.

In spite of these improvements, some food products from Fukushima prefecture continue to have a negative reputation. In December 2017, an inter-ministerial taskforce chaired by the Minister of Reconstruction decided to adopt and release strategic guidelines to address consumer concerns and to strengthen risk communications (Reconstruction Agency, 2017). These guidelines clarify priority issues in an effort to address stakeholder concerns.

The NEA organised the International Workshop on Post-Accident Food Safety Science in November 2016 so that international experts could present the world's best post-accident food safety science and showcase the work being carried out in Japan to ensure that only high-quality food, which, meets governmental standards, is being produced.[3] State-of-the-art scientific approaches were presented for assessing radiation exposure from the consumption of food containing caesium-137 and other radioactive substances, and for measuring radioactivity levels in rice, fruit, vegetables and livestock. The approaches being taken in Japan were shown to respect both state-of-the-art science and lessons learnt from the Chernobyl accident.

Towards regional economic revitalisation: Accelerating international R&D collaboration

A second meeting of the Ministerial Council on the Fukushima Innovation Coast Framework – a key element for the Fukushima reconstruction programme to accelerate economic revitalisation and new industry creation – was held in April 2018. The programme aims to develop innovative technologies, including robots and energy-related, medical and environmental technologies along coastal areas in Fukushima prefecture. The framework has adopted 34 R&D projects proposed by business entities and research institutions across Japan, with support from both national and local governments. The Ministry of Economy, Trade and Industry (METI) has released a report introducing these projects, which range from initiatives to recycle waste materials such as plastic or carbon fibre using new technologies to leveraging IoT technologies so as to build large-scale vegetable production plants.

Figure 2: New research and development centres in Fukushima

In its Intensive Promotion Plan, the Fukushima prefectural government has designated 15 municipal areas in a Hamadori coastal area as the "Fukushima International Research and Industrial Area". The plan aims to attract overseas researchers to cutting-edge research in Fukushima, while contributing to accelerated recovery of the region and human resource development, particularly in nuclear decommissioning and radiological protection, robotics, energy related issues, agriculture and fishery, the environment and recycling, and information and publications (i.e. archiving base).

The Japan Atomic Energy Agency (JAEA) has also been playing a central role in advancing this initiative, more specifically in the area of nuclear decommissioning and radiation. The JAEA has built three international R&D centres and is attempting to accelerate R&D projects and human resource development in partnership with Tokyo Electric Power Company Holdings (TEPCO), the Nuclear Damage Facilitation and Decommissioning Support Corporation (NDF) and the International Research Institute for Nuclear Decommissioning (IRID). Figure 2 provides more information on the activities of these R&D centres.

The NEA has been working to help identify important R&D initiatives and to organise international joint research activities in the fields of nuclear waste and decommissioning, as well as in nuclear safety. Discussions have resulted in important input and proposals to help set out the long-term plans for the research centres cited above. Discussions are expected to lead to the initiation of international joint research projects involving research centres in Fukushima and a number of overseas experts and researchers. Among the groups involved in these discussions are the NEA Expert Group on Fukushima Waste Management and Decommissioning R&D (EGFWMD), the Expert Group on Characterisation Methodology of Unconventional and Legacy Waste (EGCUL) and the Senior Expert Group on Safety Research Opportunities Post-Fukushima (SAREF). The NEA also initiated a new, international joint research project – the Preparatory Study on Fuel Debris Analysis (PreADES) – in 2018, and preparations are ongoing for an NEA "Workshop on the Application of Remote and Robotic Systems in Nuclear Back-end Activities – Ways Forward in System Implementation" to be held in January 2019 (see Box 1).[4]

Box 1. NEA support to the Fukushima International Research Hub

The NEA has been working to identify important R&D areas and to organise international joint research activities in fields such as radioactive waste, decommissioning and nuclear safety. The Agency has continued to work closely with Japanese authorities to assist the Fukushima International Research Hub with initiatives relating to waste and fuel debris characterisation, decommissioning planning and remote technologies.

Waste characterisation

The NEA is currently assisting in the development of a characterisation methodology for Fukushima Daiichi radioactive waste through the Expert Group on Characterisation Methodology of Unconventional and Legacy Waste (EGCUL), under the aegis of the NEA Radioactive Waste Management Committee (RWMC). The aim is to share knowledge and experience on the characterisation of a large amount of unknown waste and to provide international feedback on the characterisation methodology developed in Japan. Waste characterisation is a key factor in developing a waste management strategy. The group includes specialists from Japanese organisations such as JAEA, the Nuclear Regulation Authority (NRA), TEPCO and the NDF, alongside experts from around the world with experience in waste characterisation.

Fuel debris characterisation

A new NEA international joint research project entitled the Preparatory Study on Analysis of Fuel Debris (PreADES)[5] has been launched with the participation of 15 research organisations from 7 countries and the European Commission. A kick-off meeting was held in January 2018 at NEA headquarters. The objectives of this project are to: 1) collect information to improve knowledge and methodologies for fuel debris characterisation that will support future fuel debris sampling, 2) identify needs for fuel debris sample analysis, and 3) prepare a future, international R&D framework on fuel debris analysis. PreADES is one of two near-term projects recommended by the Senior Expert Group on Safety Research Opportunities Post-Fukushima (SAREF)[6] established under the NEA Committee on the Safety of Nuclear Installations (CSNI). The group recognises the importance of fuel characterisation to both safety research and decommissioning planning, and is working to propose a process for identifying opportunities to advance safety knowledge and support decommissioning strategies for the Fukushima Daiichi NPP.

Remote technologies

In January 2019, the NEA is organising a "Workshop on the Application of Remote and Robotic Systems in Nuclear Back-end Activities – Ways Forward in System Implementation".[7] The purpose of this workshop is to facilitate international dialogue between parties interested in developing and implementing remote and robotic systems in projects concerning radioactive waste management and decommissioning (i.e. the back-end of the nuclear fuel cycle). The workshop will discuss possible joint undertakings and activities that could support and facilitate the further implementation of robotic systems in back-end activities.

Encouraging future generations to lead reconstruction efforts

The younger generation will play a key role in implementing the Fukushima Innovation Coast Initiatives and in overall reconstruction efforts. It is thus vital to restore and further develop education and human resource infrastructures. In the Hamadori coastal area, educational programmes and research activities have been revitalised and improved for high school and middle school students in close co-operation with the industrial sector.

Most notably, the Fukushima Prefectural Futaba Future School, a public high school to be transformed into a junior/senior high school, was inaugurated in Hirono in April 2015. With its unique education programme, Futaba Future School aims to encourage its students to take on the roles of rebuilding the region from devastation. The school is seen by the Japanese population as a symbol of the Fukushima reconstruction efforts because of its pioneering, practical, project-based learning (PBL), which encourages students to reinforce their vision of the future in the face of reconstruction efforts.

High school students in Fukushima were in fact instrumental in helping to measure radiation levels in Fukushima and throughout Japan after the accident. In partnership with foreign counterparts, six high schools in Fukushima along with four in other parts of Japan joined with four high schools in France, eight in Poland and two in Belarus to measure and compare individual external radiation doses. In total, 216 high school students and teachers wore an electronic personal dosimeter or "D-shuttle" for two weeks and kept a journal of their whereabouts and activities. This comparative study of radiation levels has since been cited by scientific authors in the peer-reviewed *Journal of Radiological Protection.* The students' study, "Measurement and comparison of individual external doses of high-school students living in Japan, France, Poland and Belarus – The 'D-shuttle' project" (Adachi et al., 2015), showed that Fukushima radiation levels are similar to those found in other places, with levels on the French island of Corsica being the highest of those measured in the study.

Shortly after the accident in 2011, the OECD Secretary-General Angel Gurría visited Japan to express the OECD's commitment to supporting Japan's recovery and reconstruction efforts. The OECD Tohoku School project[8] was launched in close collaboration with MEXT and local stakeholders from affected regions, with the Fukushima University acting as the operational body to ensure local leadership, local ownership and local innovation. The aim of the project was to help high school and junior high school students in the Tohoku area to overcome their losses through practical, project-based learning that both supported the region's recovery and helped them to develop valuable competencies, skills and resilience for the future. The final event of the project was held in Paris in 2014, France, where 100 students who had lived through the Great East Japan Earthquake and related tsunami shared their experiences in revitalisation efforts.

As a follow-up project, in 2015, the Japan Innovative School Network (ISN) was launched by the University of Tokyo with support from the OECD. The ISN aims to develop and disseminate the new educational models required in the 21st century through global collaboration in both research and practices in the field. In the first three years from 2015 to 2017, the ISN focused on the creation of a model for regional revitalisation, and a second phase has begun in 2018. ISN is one of the school networks participating in the OECD project "Future of Education and Skills 2030".

The NEA and OECD will continue working to help Japan with reconstruction and revitalisation efforts in Fukushima, both on-site and off-site, while sharing important lessons with other countries.

Visit of Tohoku junior high school students to Paris, France in 2014.

Box 2. An update on decommissioning progress

Because the three damaged Fukushima Daiichi reactors are under continuously monitored injection water cooling, a stable configuration has now been maintained at the site. Although fuel debris remains in the reactors and containment vessels, the volume of contaminated water generation is decreasing. This decrease in the volume of water is a result of ground water being pumped through a sub-drain well system and through the frozen walls installed around the reactor buildings.

The removal of spent fuel from spent fuel pools was completed in unit 4 in December 2014, and the installation of a dome-shaped structural roof was recently completed in unit 3. Fuel removal operations will have started by the end of 2018. Japanese organisations are currently working on strategy planning to initiate the retrieval of fuel debris. Investigations using remote-controlled equipment and robots, supplemented by computer simulation analyses, are ongoing to evaluate the conditions of fuel debris and fission products remaining in the vessels and containments.

The site work environment has also improved as a result of rubble removal and paving works, to the extent that workers are now allowed to wear general work clothes in 95% of the total area, while for some time after the accident they needed full face masks and protective suits. The Fukushima Daiichi site will nonetheless continue to be a challenging work environment. Looking ahead to the next 30 to 40 years, it will be indispensable to improve working conditions so as to maintain the motivation of individuals working on-site.

Engaging local stakeholders in the decision-making process related to such work has become increasingly important. One example is the large volumes of accumulated water containing low-concentration tritium (processed with the multi-nuclide removal system) that are currently stored in tanks on-site. Any decisions on the treatment of this water must involve local stakeholders. An expert group called the "Tritiated Water Task Force", which was formed under the government's Committee on Contaminated Water Treatment, evaluated multiple technical options and compiled a report in June 2016. As the next step in the process, another sub-committee was established in November 2016 to further discuss issues and options from broader perspectives that include social issues.

To support these recovery efforts, TEPCO has been making its own attempts to recover trust and improve relationships with local stakeholders and the public, revealing plans to invite 20 000 visitors to the Fukushima Daiichi nuclear power plant each year. TEPCO also published a Virtual Tour web page in March 2018 (TEPCO, n.d.).

Notes

1. Approximately 50 000 people have still not returned to their homes, both inside and outside of Fukushima prefecture. This number includes voluntary evacuees from non-restricted areas. For more information, see www.pref.fukushima.lg.jp/uploaded/attachment/259959.pdf.
2. For further information on the ICRP dialogues, see www.icrp.org/page.asp?id=188] and www.fukushima-dialogues.com/.
3. For more information on the workshop, see www.oecd-nea.org/rp/workshops/foodsafety2016/index.html.
4. For more information on the workshop, see www.oecd-nea.org/download/robsysnba/.
5. www.oecd-nea.org/jointproj/preades.html.
6. www.oecd-nea.org/nsd/csni/saref.html.
7. www.oecd-nea.org/download/robsysnba/.
8. For more information on the OECD Tohoku School project, see http://oecdtohokuschool.sub.jp/english.html.

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TEPCO (n.d.), Inside Fukushima Daiichi (web page), www.tepco.co.jp/insidefukushimadaiichi/index-j.html.

Photos provided by the Cabinet Office of the Japanese government.

In the last edition of *NEA News*, an article on the restart of the Cabri Reactor in Cadarache, France set out details of how the NEA Cabri International Project (CIP) studies the behaviour of advanced fuels in pressurised water reactor accident conditions. The short article, "TREAT: A new element in the international nuclear science infrastructure" that followed the Cabri article undertook to include a more extensive discussion on the Transient Reactor Test (TREAT) Facility in Idaho, United States in a subsequent edition of *NEA News*.

After the Cabri restart, and the first CIP experiment on 16 April 2018, the restart of the TREAT research reactor is important news for the international community. In a world where the number of such facilities has dramatically decreased – with the most recent permanent shutdown being announced at the end of June 2018 by operators of the Halden Reactor – the situation has become critical. The start or restart of research reactors is therefore of strategic importance for the future of nuclear technology and for the safety of reactors around the world. To help mitigate this critical situation, the NEA considers it essential to invite large research facilities to work in a co-ordinated manner in order to meet current experimental needs by optimising their capacities and developing related investment. The NEA is therefore happy to welcome a contribution from Idaho National Laboratory technical specialists, who present the capacities made available to the research community by the restart of the TREAT reactor.

The Transient Reactor Test (TREAT) Facility: A new era in fuel safety research

by D. Wachs, N. Woolstenhulme, C. Jensen, D. Chichester and D. Broussard

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After more than 20 years in standby mode, the Idaho National Laboratory (INL) launched the Resumption of the Transient Testing Program in 2014 amidst a renewal of interest in advanced reactor technologies over the previous decade, and particularly after the Fukushima Daiichi accident in 2011. The Transient Reactor Test (TREAT) Facility was thus officially authorised by the US DOE to re-initiate operations in August 2017, over a year ahead of schedule and more than USD 20 million under budget.

The TREAT facility is located at INL Materials and Fuels Complex (MFC) near Idaho Falls, Idaho in the United States. It is an air-cooled, graphite-moderated, heterogeneous test facility designed to evaluate reactor fuels and structural materials under conditions simulating various types of transient overpower and undercooling situations. The TREAT facility was originally commissioned in 1959 to support a broad range of nuclear reactor fuel safety research programmes. It was, however, placed in standby mode in 1994 following the cancellation in the mid-1980s of the United States Department of Energy's Integral Fast Reactor (IFR) Programme.

TREAT's unique design offers the ability to simultaneously support multiple nuclear fuel programmes across a wide range of applications, from accident-tolerant fuels (ATF) for light water reactors (LWRs) and advanced fuels for sodium-cooled fast reactors to very high-temperature fuels for nuclear thermal propulsion. A parallel programme is ongoing to develop the necessary near-term experimental capabilities and to support the long-term evolution required to meet the scientific needs of future users.

The TREAT facility

The TREAT facility is closely integrated with Idaho National Laboratory's comprehensive suite of nuclear technology research and development facilities, which include the advanced test reactor (ATR) and laboratories devoted to fuel fabrication, post-irradiation examination, materials science and used fuel management. The INL uses these facilities to investigate the full research and development (R&D) life cycle of fuels that are being developed for a wide range of advanced nuclear fuels programmes. TREAT is, in effect, supporting the fuel safety research needs of these programmes.

The TREAT reactor has generated several thousand reactor transients during its operation since 1959, and hundreds of experiments have been performed for a wide variety of reactor development programmes. The reactor is capable of generating an array of shaped transients that can be of interest to fuel safety researchers. These shaped transients span the full range of transient conditions across:

- design-basis accident scenarios, including both natural shaped pulses that match reactivity insertion accident (RIA) conditions, and power steps that simulate the transition from steady state operating power into decay heat modes that match loss-of-coolant accident (LOCA) conditions;

- beyond-design-basis accident scenarios that can result in significant disruption and relocation of fuel because of either overpower or undercooling conditions.

Such a range of transient shapes can be realised thanks to the rapid movement of the control rod drive system. The transient rods are hydraulically driven and can be ejected from the core at speeds of up to 356 cm/sec. The rod position is computer controlled by the automatic reactor control system. Movement is pre-programmed prior to the transient and can be dynamically manipulated by trigger signals emanating from experiment instrumentation. The energy deposited in the experiment is limited by a combination of the total reactor energy deposition (<2 500 MJ) and the experiment-specific power coupling factor (PCF) measured in joules/gram in the test specimen per MJ of reactor power. Typically, enough energy will be available to melt or even vaporise the nuclear fuel sample, if desired by the experimenter.

TREAT reconstitution and commissioning tests

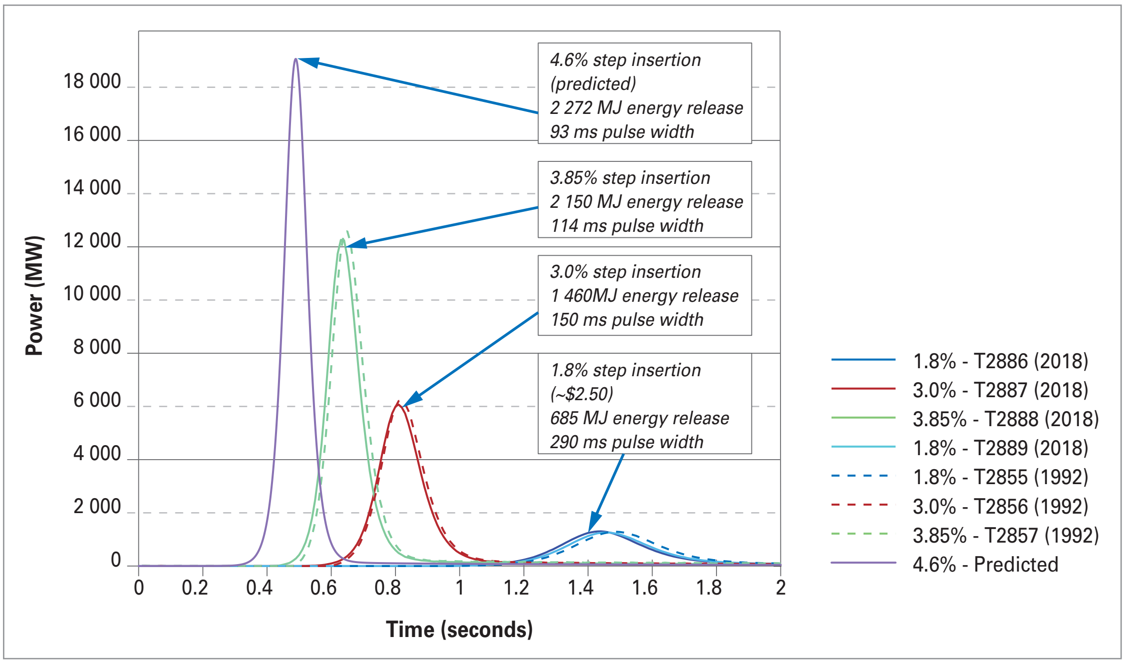
The INL has a long history of conducting in-pile transient testing to generate the necessary data for the development, design and licensing of nuclear reactor technologies. Thousands of experiments have been conducted in specialised transient testing facilities in addition to the TREAT facility, including in the Special Power Excursion Reactor Test (SPERT) facility, the Power Burst Facility (PBF) and the Loss-of-Flow Test (LOFT) Facility. As the missions for these reactors were met and the Zry-UO_2-based nuclear fuel technologies matured, demand for such facilities waned, which led to most being decommissioned by the mid-1980s.

The TREAT facility has been continuously upgraded since its creation in 1959 so as to meet evolving user needs. This flexibility became a hallmark of the facility as it was able to easily adapt to contemporary technology development needs over several decades. The most substantial upgrade was completed in 1988 and included a full modernisation and refurbishment of the facility and its critical supporting sub-systems – for example the automatic reactor control system and high-speed, rod drive systems.

Reinvigorated demand for the testing of data over the past decade led to further upgrades to the TREAT facility. In 2011, the US DOE formally recognised the need for transient testing capabilities and subsequently initiated studies to identify potential pathways to recover these capabilities. Within a year of this decision, the earthquake and its impact on the Fukushima nuclear facilities in Japan gave rise to the US DOE Accident Tolerant Fuel Development Programme and an aggressive desire to deploy ATF technologies by 2022. The drive to recover transient testing capabilities was thus dramatically accelerated, with TREAT selected as the preferred option in 2014 and scheduled for restart before the end of 2018. The resumption of operations was achieved by implementing a restart from the extended outage strategy that focused on evaluation of age-related degradation mechanisms and updated standards or requirements. Systematic inspection and maintenance or repair of reactor systems served to both revitalise each reactor system and to train the new operating staff. Fuel assemblies were replaced with Borated poison assemblies to facilitate integrated system testing when using the reactor in a "simulator" mode. Such a novel approach to restarting the TREAT facility was central to surpassing the cost and schedule targets for the resumption of operation.

The pinnacle of the restart programme was a series of natural pulse trial transients meant to replicate transients conducted prior to the facility being placed in standby mode. These three transients, at successively larger reactivity step insertions, are shown in Figure 1. It should be noted that the power histories are virtually identical for those conducted

Figure 1: Comparison of the historic TREAT transients and trial transients at restart



Note: Step insertions result in natural shaped pulses. As the step insertion increases, the pulse width narrows and the total energy released increases. The plot intentionally shows the 1992 and 2018 curves slightly out of phase for clarity of comparison.

in 1992 and 2018, and that modern reactor analysis tools were demonstrated to predict all critical reactor performance criteria with improved accuracy (e.g. peak fuel temperature in instrumented fuel assemblies).

Experimental programme

While TREAT is envisioned to support a wide range of advanced reactor missions, the near-term priority of the facility will be to ensure the development and licensing of ATF designs for use in current generation LWRs. Accomplishing this mission requires that a combination of integral, semi-integral and separate effects transient tests be executed with the intention of assessing different aspects of ATF performance, of demonstrating fuel safety criteria, and of developing and validating advanced fuel performance analysis codes for future use in design and licensing.

As such, the priority of the transient testing programme will be to develop the experimental infrastructure necessary to engage in prototypic design-basis accident simulations for both RIA and LOCA performance of these fuel designs. Experimental capabilities entail three complementary scientific branches: the ability to deliver a relevant shaped nuclear transient, to design irradiation test vehicles that allow exposure of the sample to the desired thermal-hydraulic, mechanical-chemical environment during the test, and to characterise the test sample's response to this combined environment with the instrumentation required. Active development is underway in all three of these critical areas.

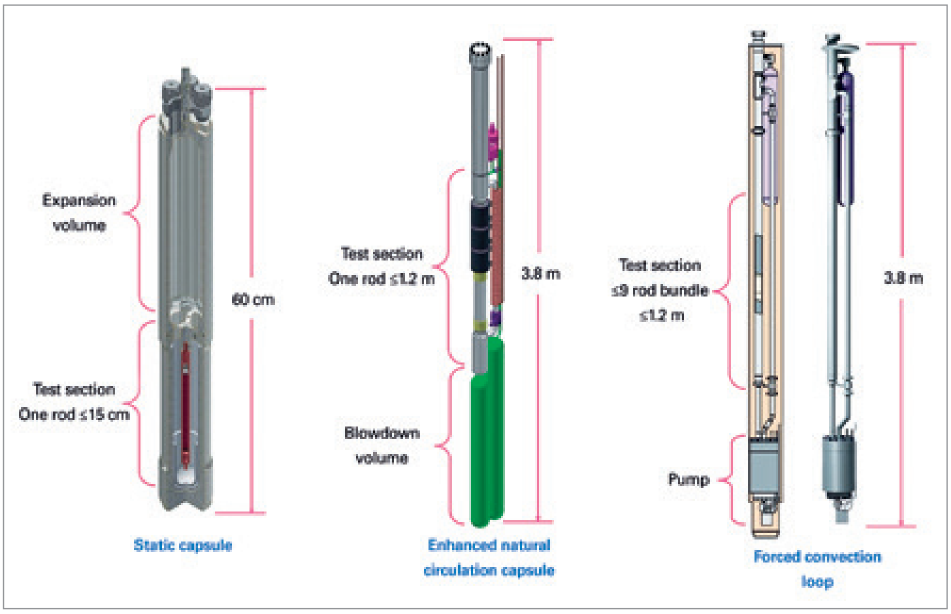
RIA events in LWRs are typically postulated to have pulse widths of 45-75 ms at full width, half max. In pulse mode, TREAT's maximum allowable step insertion of ~4.6% $\Delta k/k$ when combined with rapid reintroduction of the transient rods can produce ~90 ms full width pulses at half maximum pulse width in order to represent LWR reactivity insertion accidents. Demonstration and optimisation of these types of transients are currently underway at the TREAT facility. Enhanced negative reactivity insertion methods and pulse-narrowing core strategies are also under development, with prototype testing to begin in 2018. The results are predicted to enable TREAT to approach 45 ms full width at half max pulse width.

Alternatively, LOCA simulations can be performed in the TREAT facility by operating at elevated constant power in "flat-top" mode in order to thermal-mechanically condition the fuel prior to the transient. Because the fuel is only operated for a short period of time and fission product build-up is non-prototypic, the reactor power is subsequently reduced to simulate decay heat during the blowdown and reflood phases of the LOCA. These flat tops are achieved by the gradual removal of the transient rods from the reactor until they are fully withdrawn, or the reactor temperature is sufficiently high to prevent continued operation as a result of natural reactivity feedback mechanisms. A similar methodology is also being evaluated to support ramp and rapid power shift testing.

Because the TREAT core is air-cooled and open, all containment functions for the experiment must be provided by the experiment vehicle, which includes any potential experimental debris or radionuclides that may have been released from test specimens. Consequently, TREAT experiments are typically fully self-contained and are delivered ready for insertion in the core, with minimal external support system requirements. TREAT's unique core design allows the experimenter freedom to accommodate large test vehicles by removing as many of the 10 x 10 cm fuel assemblies as are required to accommodate the device. Typical experiment device configurations fit within 10 x 20 cm (displaces two assemblies) or 25 cm diameter (displaces nine assemblies) footprints. The fuelled length of the core is ~1.2 m (although test fuel can extend beyond this region if necessary) and test devices can be up to ~4 m long.

A suite of LWR-specific test rigs are currently available or being developed for near-term deployment, including a static capsule system, an enhanced natural circulation capsule and a forced convection cooled loop system (as shown in Figure 2).

Figure 2: Schematics of TREAT-based LWR test devices: (from left to right) the static capsule, the enhanced natural circulation capsule and the forced convection test loop



The Transient Reactor Test (TREAT) Facility located at the INL Materials and Fuels Complex.

The TREAT restart team on 14 November 2017 immediately after achieving first critical (since 1994).

These devices are based on modular design strategies that allow for rapid reconfiguration to support evolving experimental needs, while simultaneously standardising critical interfaces that govern requirements ranging from programmatic (i.e. instrumentation interfaces) to pragmatic (i.e. cost-effective safety basis development). The static capsule is filled with water at high pressure and temperature, and is suitable for fuel performance studies on the early stages of rapid transients (e.g. RIAs). The enhanced natural circulation capsule can deliver dynamic coolant conditions that initiate at prototypic pressure and temperature, and can be followed by rapid depressurisation, steam exposure and reflood/quench. Each stage is closely synchronised with the nuclear transient being delivered by the TREAT core. A more complete simulation can be achieved using the forced convection loop system. This latter system allows for higher pre-transient operating powers and testing of mini-fuel pin bundles (4-9 pins). The availability of forced convection may also allow for exploration of post transient coolability of disrupted fuel systems.

The objective of testing is to evaluate the response of test samples in these unique environmental conditions. For transient phenomena, it is particularly important for the response to be characterised during the event in order to capture the progression and transitions in critical phenomena. The conditions under nuclear accident simulations can be remarkably severe and require the development of specialised instrumentation to survive while at the same time delivering high-quality data in a prompt manner (~1 ms in some cases). State-of-the-art instruments developed around the world are being adopted or adapted for use in TREAT in order to measure changes during the experiments, for instance in neutron flux, temperature, pressure, dimension or composition. Notable systems include the fast neutron hodoscope, which allows for real-time monitoring of fuel motion during transients. This device will be of particular value for the study of fuel fragmentation, for example, or relocation and dispersal during postulated LOCAs.

The in-pile capability described above is closely integrated with state-of-the-art post-irradiation examination capabilities co-located at the INL Materials and Fuels Complex. Experiments will be examined non-destructively at the Hot Fuel Examination Facility (HFEF) using high-resolution neutron tomography, prior to disassembling the test vehicle, and then subjected to a standard suite of non-destructive exams of the fuel sample. The option is also available to then conduct cutting edge destructive exams at the Irradiated Materials Characterization Laboratory (IMCL) using modern materials science (i.e. optical microscopy, scanning electron microsope-focused ion beam [SEM-FIB], electron probe microanalysis [EPMA] and transmission electron microscopy [TEM]) and material property (i.e. thermal and mechanical property) characterisation tools.

Test programme schedule

Following the completion of reactor commissioning tests in January of 2018, a series of studies are now being conducted at the TREAT facility to develop and demonstrate the shaped transients of interest to the ATF programme and to characterise the nuclear conditions in the test position that will be used for the experiments. Beginning in 2018, approximately 20 instrumented transients will be conducted to initiate the test programme. This initiation will include a series of transients on fresh LWR fuel rods to validate the energy deposition parameters and to qualify instrumentation systems for future use. The static capsule test vehicle will complete commissioning in 2019 and will be deployed for RIA testing on fresh and irradiated ATF fuel samples (pre-irradiated in the INL's advanced test reactor). The enhanced natural circulation capsule will be commissioned in 2020 and will begin being used for LOCA, late stage RIA, and potentially for ramp testing on fresh and pre-irradiated LWR and ATF samples. Pre-irradiated samples may be supplied either by the advanced test reactor (ATR) or via lead use rods irradiated in commercial power reactors. The forced convection loop is anticipated for deployment in 2024 to support higher order studies that may be necessary to expand current fuel safety criteria envelopes that accident tolerant fuel designs offer.

The unique flexibility of TREAT and its experimental systems will allow many separate effects studies to be executed in parallel to the mainline advanced test reactor programme. Tests studying a diverse range of behaviours are already being designed and prepared for near-term execution. The ability to decouple the nuclear conditions from the sample environment has proven to be a valuable tool for the advanced modelling and simulation community. TREAT will also support the transient testing required to continue development of advanced reactors, in particular through the test programmes related to sodium-cooled fast reactor fuels. The development of these fast reactor fuels is progressing rapidly and is anticipated to reach the execution stage in the next few years.

The Full Costs of Electricity Provision: A new NEA report

by J.H. Keppler

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Shutterstock, De Panimoni

City panorama.

Electricity production, transport and consumption affect every facet of life in the advanced market economies of the countries that make up the Nuclear Energy Agency (NEA) and the Organisation of Economic Co-operation and Development (OECD). Market prices and production costs account for an important share of the overall economic impacts of electricity. Over at least the past two decades, however, there has been growing recognition that this market value of electricity is not the whole story and that the social and environmental impacts of electricity provision are affecting individuals, economies and societies in ways that have not been captured by market prices.

Concerns about anthropogenic climate change have strongly reinforced such a stance. The impacts of local pollution from electricity generation on health and longevity, as well as the fear of major accidents on lives and ecosystems, have also been weighing heavily on policymakers and on the public for many years. Employment and technological developments are additional issues that have come to the fore in discussions on electricity generation and provision.

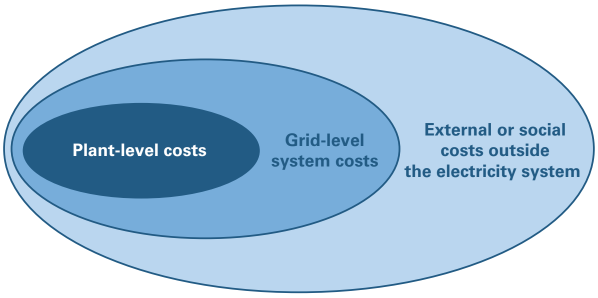
It was with the objective of examining the true market value of electricity that the NEA recently released *The Full Costs of Electricity Provision*. The NEA Director-General William D. Magwood, IV, summarised the importance of this issue at the report's launch:

"What this report reveals is that the notion of 'electricity cost' that we often use today, the levelised costs of electricity (LCOE), is just a part of a much bigger picture. While LCOE is a useful tool to compare the costs of baseload technologies in regulated systems, it leaves out many decisive aspects of the costs of electricity. In particular, the grid-level system costs and the social costs that are not captured by LCOE are too important to be ignored any longer."

The "social costs" beyond the plant-level production costs measured in LCOE are referred to as external effects, externalities or simply social costs. While not reflected in market prices, researchers can nevertheless fairly well identify the external impacts of electricity generation and provision, often measure them and sometimes even monetise them partially or tentatively. As far as social costs are concerned, one must distinguish in the electricity sector between the grid-level system costs and genuine externalities. The former refer to the costs that technologies impose on the system as a whole and include the costs of extending, reinforcing or connecting to the grid, but also the costs of maintaining spinning reserves or additional dispatchable capacity when the output of some technologies – typically, wind and solar photovoltaic (PV) – is uncertain or variable.

Beyond plant-level and system costs, a third, even broader category of social costs includes impacts on the well-being of individuals and communities outside the electricity sector. Such costs include the impacts of local and regional air pollution, climate change and the costs of major accidents, as well as land use and resource depletion. Social costs can also include the impacts of different power technology choices on the security of energy and electricity supply, employment and regional cohesion or on innovation and economic development. The full costs of energy provision should thus include the totality of these three categories: plant-level costs, grid-level system costs and external social costs (see Figure 1).

Figure 1: Different cost categories composing the full costs of electricity provision



Source: NEA, 2018.

The Full Costs of Electricity Provision addresses the different aspects of the full cost issue, for example by exploring the key concepts pertaining to full costs and social costs and by outlining the policy implications of full cost accounting in the electricity sector. Since the early 1990s, when a raft of major studies on energy externalities was launched, accounting for the full costs has become part of the work of a large constituency of researchers. Despite the evident importance of full costs, accounting for them remains difficult. From researching biophysical dose-response function, calibrating dispersion models and probabilistic assessments to the contentious issue of monetary valuation, different groups of experts need to be co-ordinated in large-scale, multi-year efforts to arrive at robust results. The objective of this report was not to replicate these broad systematic efforts but to identify priority areas – such as limiting air pollution, reducing greenhouse gas emissions and properly allocating system costs – that warrant specific, new research.

Air pollution, climate change risks and system costs constitute the largest uninternalised costs

One important factor highlighted by this report is that the social costs on which policymakers, the public and the media routinely focus are not those that constitute the greatest uninternalised impact on well-being. Decommissioning and storage of waste, for instance, constitute significant costs for nuclear power. However, these "economic costs" are internalised through the provisions constituted by electricity producers and passed on via prices and tariffs to customers. The same holds true for natural resource depletion, where markets ensure that the exploitation of commercially valuable, primary energy sources such as coal, oil, gas or uranium follows a path that is optimal for both present and future generations.

Major accidents involving energy structures – whether oil spills, gas pipeline explosions, dam breaches, mining disasters or nuclear power plant accidents – are fortunately rare enough during the life cycles of all power generation technologies to not figure prominently in the accounting of full costs. Nevertheless, because of the concentrated hardships involved, they receive an extraordinary amount of attention from the media and from the general public. Such attentional bias can also extend to the specific technology. For instance, although the greatest number of fatalities during major accidents are recorded in coal mining and hydroelectricity – two technologies that generate little public concern – oil spills, and nuclear accidents in particular, instead receive a degree of media and policy attention that is disproportionate compared with the extent of damage and human casualties they may cause.

Table 1: Summary of accidents with more than five fatalities*
(1970-2008)

Energy chain	OECD		EU27		Non-OECD	
	Accidents	Fatalities	Accidents	Fatalities	Accidents	Fatalities
Coal	87	2 259	45	989	2 394[a] 162 818 1 214	38 672 5 788 11 302 15 750
Oil	187	3 495	65	1 243	358	19 516
Natural gas	109	1 258	37	367	78	1 556
Liquefied petroleum gas	58	1 856	22	571	70	2 789
Hydroelectric	1	14	1	116	9[b] 12	3 961 26 108
Nuclear[c]	–	–	–	–	1	31
Biofuel	–	–	–	–	–	–
Biogas	–	–	–	–	2	18
Geothermal	–	–	–	–	1	21
Wind[d]	54	60	24	24	6	6

* From the Energy-related Severe Accident Database (ENSAD); a) Coal: first line non-OECD total; second line non-OECD without China; third line China 1994-1999; fourth line China 2000-2008; b) Hydro: first line non-OECD without China; second line China; c) Note: Fatalities from the Fukushima Daiichi NPP accident in 2011 are not included in this table, but it should be noted that the accident resulted in no immediate, radiation-related fatalities; d) Wind: only small accidents.

Source: Adapted from Burgherr and Hirschberg, 2014.

Antartic melting glacier in a global warming environment.

High voltage line.

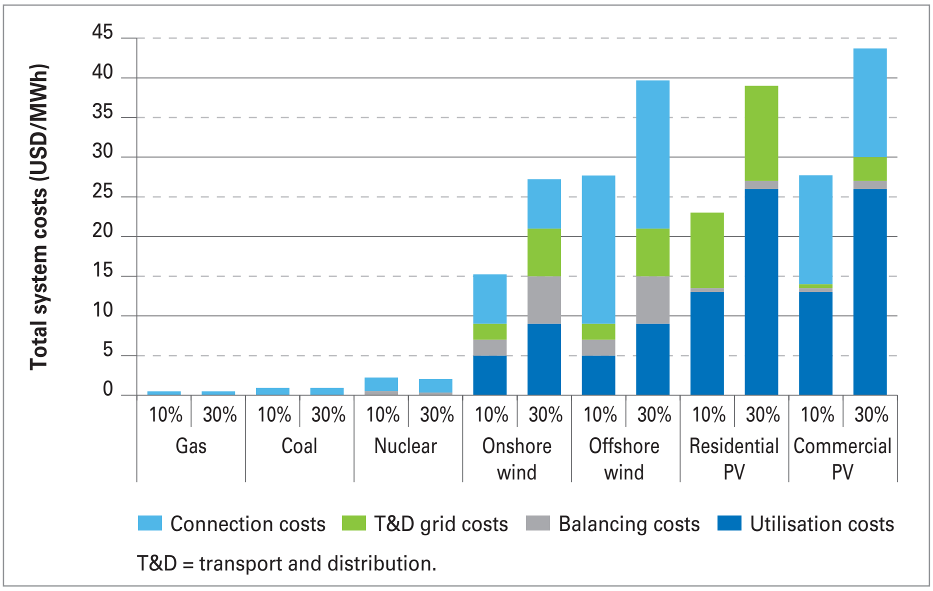
Some factors can explain the dissymmetry between public and policy attention on the one side and the overall severity of impacts on the other. Oil spills and nuclear accidents are characterised by two facts that are particularly uncomfortable for the public. First, their impacts can extend over long time frames, while the vast majority of the damage wrought by a mining accident or the explosion of a gas pipeline is immediate. Second, many of the impacts cannot necessarily be discerned visually, such as damages due to radiation or the impact of hydrocarbon pollution through the food chain, which require sophisticated measurements to be properly assessed. The intuitive reaction of a public avid to understand a traumatic accident is frequently to insist that "the true extent of damages is hidden".

Overly strong concerns about certain forms of social costs can to a certain extent be explained, but the lack of attention to the most severe forms of social costs is simply unjustifiable. Policymakers should be obliged to address the social costs of electricity provision from a 360° perspective. In doing so, it becomes obvious that air pollution constitutes the biggest uninternalised cost of electricity generation. It is also an intensively studied area with stable research protocols, consistent methodologies and converging results. According to the World Health Organization, it is the world's largest single environmental health risk: across the world, 3 million deaths a year result from ambient air pollution, with electricity generation based on fossil fuels playing a major role. Household air pollution – much of it resulting from a lack of electricity – causes an additional 4.3 million deaths per year. Most of these deaths occur in low- and middle-income countries. However, welfare losses caused by air pollution in OECD countries alone are estimated to amount to more than one trillion USD, or roughly 3% of gross domestic product.

The full costs of climate change are difficult to assess with precision, but climate scientists routinely estimate them as being in the trillions of US dollars. One of the more difficult issues in the exercise of estimating such costs is taking into account the very high uncertainty involved, which makes it impossible to fit possible outcomes into a stable probability distribution. It is possible, however, to identify an order of magnitude value of USD 100 per tCO_2, which is included in the ranges provided in studies on the likely costs of climate change. Reducing greenhouse gas emissions to reduce the risk of climate change has a special role in this context.

System costs, and in particular the system costs of variable renewables such as wind and solar PV, are another under-reported subset of full costs. Consisting of grid costs, balancing costs and utilisation or profile costs, the results are country- and technology-specific, and they increase over-proportionally with the penetration level. Central estimates of total system costs show a range of costs of USD 15 per MWh for onshore wind, USD 20 per MWh for

Figure 2: Grid-level system costs of selected generation technologies for shares of 10% and 30% of VRE generation



Source: NEA, 2012.

solar PV and about USD 25 per MWh for offshore wind at a penetration level of 10%. At a 30% penetration level, system costs increase significantly, reaching about USD 25 per MWh for onshore wind and about USD 40 per MWh for solar PV and offshore wind. In comparison, system costs for dispatchable technologies such as nuclear, coal and gas are at least one order of magnitude lower, i.e. below USD 2 per MWh.

Given the rising shares of wind and solar PV in electricity provision, their system costs can therefore be measured in the billions of US dollars. These costs are most likely to increase further, and yet outside the circle of electricity market experts the issue is virtually unknown.

Measures exist

Through reports such as *The Full Costs of Electricity Provision*, the NEA is putting the spotlight on attentional biases as a means of ensuring that policy attention is attuned to all of these above areas, which have large and verifiable social costs. Once all of the different subsets of full costs have received the attention they deserve, well-understood instruments for internalisation can be applied. Such policy instruments fall into three broad categories:

- Price- and market-based measures that directly internalise social costs into market prices.
- Norms, standards and regulations, which are frequently not stringent enough.
- Information-based measures at the heart of modern internalisation. Support for research and innovation belongs here, as does taking part in the policymaking and rule-setting processes.

Successful measures often combine aspects of the different categories mentioned above. An important example in this context is emissions trading, which combines the setting of a quantitative standard with the creation of a market that allows a price for the externality to emerge. Information and education can further improve the effectiveness of economic incentive measures. At the same time, synergies exist between measures addressing the different social costs of electricity generation. Any measure that reduces air pollution from fossil fuels, for instance, will also reduce carbon emissions and vice versa. In addition, such actions will usually produce beneficial side effects in terms of reduced resource depletion and improved security of energy supplies.

The distributional impacts of the different measures of internalisation are frequently the most significant barrier to the internalisation of external costs. While these impacts are real and must be addressed, appropriate measures of compensation should be put in place. Such compensation measures are relatively simple to implement and are, if well done, fully compatible with efficient internalisation.

Effective measures to internalise social costs therefore do exist. In order to push them through, however, governments must face up to their responsibilities. The gap between full costs and private, market-based costs is precisely related to the inability of private actors to take into account all relevant information about welfare effects. "Transaction costs" is the catch-all term that economists have coined to designate the barriers that impede arrangements, which in principle would be mutually advantageous since the gains of winners would be larger than the costs for losers.

When the lives and well-being of millions of people are at stake, governments have an obligation to put into place incentive structures that will reduce transaction costs and enable new arrangements to ensure significant welfare improvements. The key policy areas are, again, the prevention of air pollution and the reduction of climate change risks. Providing better information and organising reliable research on the issue of full costs is an integral part of this effort. Measured against the scale of the externalities discussed, the required funds for such research would be negligible.

Accounting for and internalising the full costs of electricity provision is extremely important if we are to fully take advantage of the energy transitions under way in many countries. If well done, internalising full costs will allow policymakers and the public to make better informed decisions along the path towards fully sustainable electricity systems.

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Insights into the global uranium market

by L. Grancea

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Geomartin

Paleao-Rollfront at Dead Tree Creek, Mt. Painter Gebiet, South Australia.

Although mined in a similar fashion to other metals, uranium is regarded as unique among worldwide commodities, both for historical reasons related to its past military usage and because of its importance as a key material for energy security of supply, given that it is primarily used as fuel in nuclear power plants. As a result of this strategic value, governments have been extensively involved in the production, trade and use of uranium. A number of important factors need to be considered when looking at the global uranium market picture.

The first is cost. When compared with coal, oil and gas, the cost of fuel in the production of nuclear power represents only a small percentage of the total production costs of generating electricity. Even when conversion, enrichment and fuel fabrication costs are added to those of uranium concentrates, together with the cost of used fuel management and waste disposal, the overall cost of fuel for new nuclear plants generally represents no more than 20% of the total cost, compared with up to 80% in fossil fuel fired plants.

A second, important feature of the nuclear fuel cycle is its international dimension, meaning that uranium mined in Australia can be converted in France, enriched in the United Kingdom and then fabricated as fuel rods in Sweden for a reactor located in Finland. This international dimension and the existence of significant uranium inventories have led to the development of "exchanges" (or swaps) within the nuclear fuel market as a means of avoiding the need to transport materials from place to place as these materials go through the various processing stages in the nuclear fuel cycle. Trading in uranium has consequently become a highly regulated market, with national and multinational regulations being put in place throughout the fuel cycle to ensure that safety and non-proliferation objectives are met. These regulations are administered by governments, regional organisations such as the Euratom Supply Agency (ESA), and by the International Atomic Energy Agency (IAEA).

A third factor to be kept in mind is that most uranium continues to be traded through long-term, multi-annual contracts, which are based on estimated utility requirements. Nuclear plant operators usually contract mining companies – either directly or via intermediaries – for the supply of uranium concentrates. The "spot uranium market" refers to the day-to-day trading that takes place among various traders, brokers, producers and utilities, and normally involves less than 20% of supply. Unlike other commodities, there is no terminal clearing marketplace such as the London Metal Exchange (LME). Exchange traded funds (ETFs) have, however, been created to allow investors both to invest directly in, and to hold, uranium inventories.

Finally, and, like other commodity markets, the uranium market has a history of volatility. The reasons for the fluctuations in uranium prices are largely related to demand, as well as to perceptions in relation to market scarcity. Uranium market prices are moderated based on both supply-demand fundamentals that capture the production cost curve and on the availability of secondary uranium sources. These secondary supplies include government and commercial inventories, uranium from underfeeding in the enrichment sector, recycled uranium and plutonium from spent fuel, re-enriched depleted uranium tails and highly enriched uranium (HEU) down-blending.

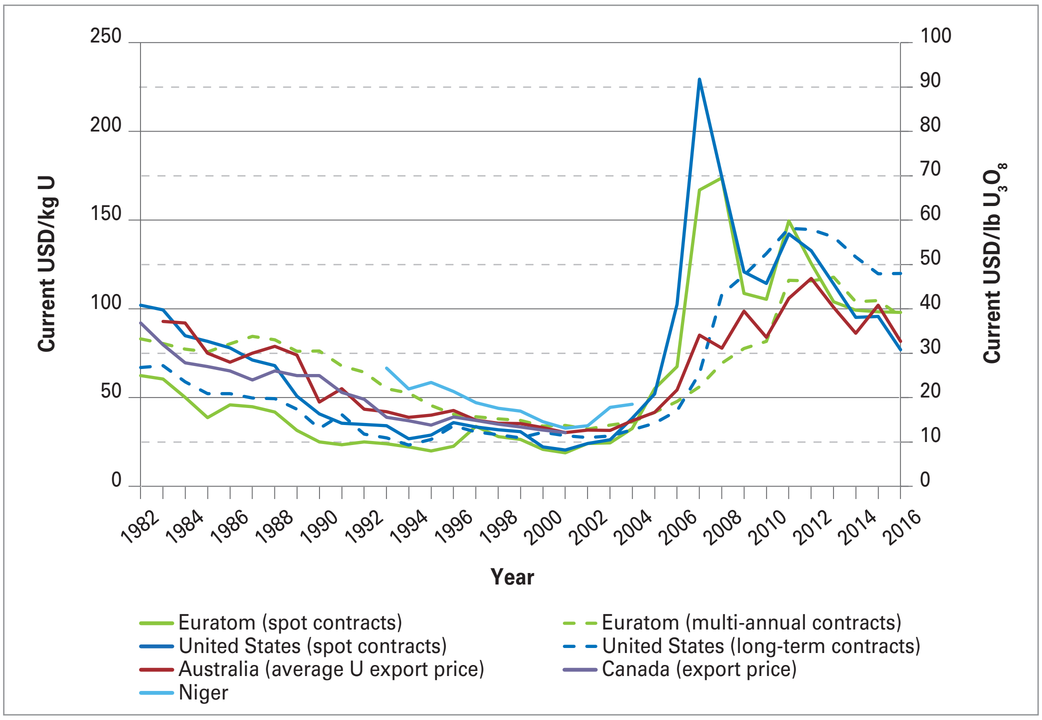
Uranium market price developments: 1980-2018

Price indicators that illustrate uranium price trends for both long-term and short-term (spot price) contract arrangements have been published periodically by national and international authorities, including Australia, the United States and Euratom. Australian data record, for example, average annual prices paid for exports, whereas data from Euratom (ESA) and the United States Energy Information Administration (EIA) show costs of uranium purchases in a particular year. While Canada and Niger had published export prices for specific years, both countries have discontinued the practice. Figure 1 provides an indication of annual prices reported by all sources for both short-term and longer-term purchases, as well as exports.

The figure shows that uranium prices trended downward from the early 1980s through to the mid-1990s. This downward trend resulted largely from the overproduction of uranium combined with a heightened availability of secondary sources during this period. The trend resulted in significantly reduced expenditures in many sectors of the global uranium industry – including exploration and production. The bankruptcy of an important uranium trading company around the same time led to a modest recovery in prices from late 1994 through to mid-1996, but the regime of low prices returned shortly thereafter.

Beginning in 2002, uranium prices began to increase, rising to levels not seen since the 1980s and then rising even more rapidly through 2005 and 2006, with spot prices reaching a peak through 2007 and 2008, before falling off rapidly, recovering somewhat in 2011 and declining again in 2012 (see Figures 1 and 2). In contrast, European Union and US long-term price indices continued to rise until 2011 before levelling off in 2012 and then starting to decline again in 2017. Fluctuations in these latter indicators do not correspond with the 2007 and 2008 peaks in the spot market or the degree of declining prices since 2011 because they reflect contract arrangements made earlier under different price regimes. Australia's average export price has generally followed the trend of other long-term price indices, but with greater variation, since it is a mix of spot and long-term contract prices. Depending on the nature of the purchases (long-term contracts versus spot market purchases), the information available indicates that prices ranged between USD 77/kgU and USD 120/kgU (USD 30/lbU_3O_8 and USD 46/lbU_3O_8) at the end of 2016.

Figure 1: Uranium prices for short- and long-term purchases and exports (1982-2017)



Source: Australia, Canada, ESA, Niger and the US EIA.

1. Euratom (ESA) prices refer to deliveries during that year under multi-annual contracts.

2. Beginning in 2002, Natural Resources Canada (NRCan) suspended publication of export prices pending policy review. Niger also suspended publication of export prices since 2004.

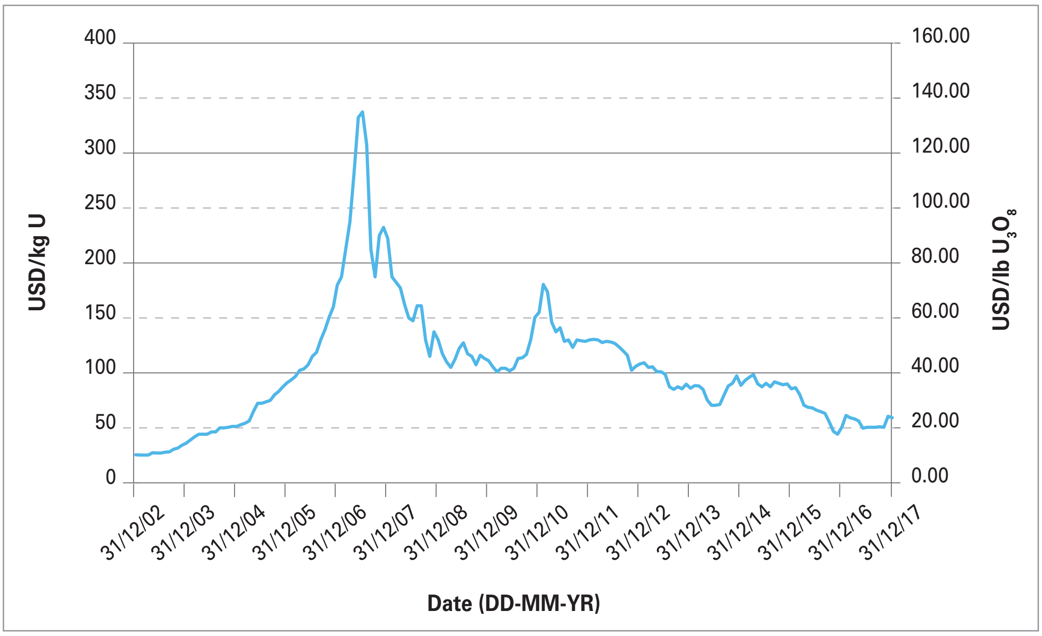
In addition to information provided by governments and international sources, the industry trade press – TradeTech and the Ux Consulting Company LLC (UxC) – also provides spot price indicators for immediate or near-term delivery (i.e. for less than one year), which typically amounts to 15% to 25% of all annual uranium transactions. While the trend of increasing prices outlined above is evident in spot market transactions since 2002, and in particular after 2004, spot prices have shown more volatility than long-term price indicators since 2006 (see Figure 2). In June 2007, the spot market price reached as high as USD 136/lb U_3O_8 (USD 354/kgU) before declining to USD 40.50/lb U_3O_8 (USD 105/kgU) in February 2010. It then recovered to USD 72.25/lb U_3O_8 (USD 188/kgU) at the end of January 2011, before declining once again to USD 24/lb U_3O_8 (USD 62/kgU) at the end of 2017 (see Figure 2).

Different explanations have been advanced to account for the spot price dynamics between 2003 and 2017, including problems experienced in nuclear fuel cycle production centres that highlighted a dependence on a few critical facilities in the supply chain, changes in the value of the currency used in uranium transactions – i.e. the US dollar – and the after-effects of the Fukushima Daiichi accident in 2011. The expected expansion of nuclear power generation in countries such as China, India and Russia, combined with the recognition by many governments of the important role that nuclear energy can play in enhancing security of energy supply, contributed to a strengthening of the uranium market until 2007. The influence of speculators in the market also helped to accelerate upward price movement at the time. The downturn in the spot price, which began in June 2007, has been attributed to a reluctance of traditional buyers to buy at such high prices, as well as to the global financial crisis that stimulated sales by distressed sellers needing to raise capital.

In late 2007, the uranium spot price began a gradual decline that settled between the USD 40/lb U_3O_8 (USD 104/kgU) and USD 50/lb U_3O_8 (USD 130/kgU) range in 2009. Proposed US government inventory sales appeared to offset rising demand as Chinese and Indian government programmes designed to increase nuclear generating capacity began to be implemented. In the second half of 2010, the spot price began to rally once again after news that China was active in the long-term market, stimulating speculative activity on perceptions of tightening supply and demand. However, the Fukushima Daiichi accident in 2011 precipitated an initial rapid decline in prices that continued more gradually through to the end of 2017. Reactor requirements dropped considerably as a result of reactors being shut down in Germany, Japan and the United States. Projects that had been implemented before the accident to increase uranium production, led to an increase in production even as demand weakened, and the market became saturated, putting further downward pressure on prices through to the end of 2017. The excess uranium inventories and the decline in uranium needs as a result of the substitution of enrichment (underfeeding) also contributed to a downward trend in uranium prices.

Macroeconomic movements have also had an impact on the uranium market. The strengthening of the US dollar in recent years, for example, particularly in relation to the currencies of major uranium producers (e.g. Canadian dollar, Kazakh tenge, Russian rouble and South African rand) has contributed to uranium price volatility. Mining companies outside of the United States have benefited from the USD appreciation against other currencies, as most of their operating costs, including labour-related costs, are in domestic currencies. These companies have thus been able to continue operating the mines despite falling uranium market prices that are expressed in US dollars.

Figure 2: Uranium spot-price dynamics
(TradeTech exchange value[1] trend, 2002-2017)



Source: Trade Tech (www.uranium.info).

1. The exchange value is Trade Tech's judgement of the price at which spot and near-term transactions for significant quantities of natural uranium concentrates could be conducted as of the last day of the month.

Aerial view of the McArthur River uranium mine, Canada.

In both established and potential markets, nuclear power is facing increasingly competitive challenges from other modes of generation, especially in deregulated markets, while continuing to confront regulatory and political hurdles following the Fukushima Daiichi accident. With the continuing decline of uranium market prices leading up to 2017, many delays in planned mine developments have been announced and more could follow should prices decline further.

Announcements of significant reductions in uranium production began and ended 2017. These reductions could potentially realign the supply-demand balance in the uranium market. The most significant of these announcements were those to suspend mine production at McArthur River/ Key Lake in Canada, to cut production in Kazakhstan, the world's leading producer, and to cease development of new wellfields at many in situ leach mines in the United States (e.g. Nichols Ranch and Lost Creek). A return of more favourable market conditions could see at least some of the delayed projects reactivated, which would ensure the supply of a growing global nuclear park. Since several of these projects have advanced through regulatory and other development steps, the time required to bring the facilities into production could be reduced, and production could likely respond more rapidly to increasing demand.

Evolutions in the uranium market may continue to be further driven by developments on both the demand and supply side. On the demand side, global new build and operating lifetime extensions for existing nuclear plants, together with the restart of additional Japanese reactors, could affect the uranium market. On the supply side, the levelling off of uranium production in the short term, as well as possible limitations on secondary uranium supplies (e.g. inventories) have been viewed as critical factors that should be taken into account.

As a low-carbon energy source, nuclear energy enables countries to ensure security of electricity supply, to maintain a stable price for energy and to move towards global climate objectives. With nuclear power projected to increase in Asia and the Middle East, the two regions are being seen as critical markets with a potentially high demand for new uranium production to provision new reactors in the coming decades. The right price signals will however be crucial for producers to make the necessary decisions to invest in new uranium supply capacity.

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Progress towards an all-hazards approach to emergency preparedness and response

"An all-hazards approach to emergency management is the most efficient use of available resources, including stakeholders". (*Practices and Experience in Stakeholder Involvement for Post-nuclear Emergency Management* – NEA, 2011).

by O. Guzmán

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Webinar of 12 January 2018 with William D. Magwood, IV, Director-General, Nuclear Energy Agency (NEA); Thierry Schneider, Director of the French Nuclear Protection Evaluation Centre and Vice Chair of the NEA Committee on Radiological Protection and Public Health; Anthony Cox, Acting Director of the OECD Environment Directorate; and Jack Radisch, Senior Project Manager at the OECD Directorate for Public Governance.

An emergency situation, whether natural or human-made, is a challenge for both political leaders and for those in society who are responsible for managing the related crises. Governments must be able to rely on a structurally robust system to effectively cope with the complexity, novelty and uncertainty that characterise societal expectations in relation to modern crises.

In its efforts to improve emergency preparedness and response (EPR), the NEA has long made emergency management a priority, as reflected in the *Strategic Plan of the Nuclear Energy Agency: 2017-2022.* A key aspect of these efforts has centred on preparing, conducting and evaluating the International Nuclear Emergency Exercise (INEX) series, which first began in 1993. Experiences and lessons learnt from these exercises have provided a substantial base for the development of recommendations to improve emergency management systems both nationally and internationally. While the NEA and other international organisations in the nuclear field have understandably focused their work on nuclear emergency preparedness, it is clear that emergency management is not an area specific to the nuclear field. It is a broad, complex and dynamic field that, in the post-Fukushima context, has become part of a much broader discussion.

Nuclear power plant accidents are extremely rare, but industrial non-nuclear events and natural disasters occur more frequently and can have a potentially wide-ranging impact on populations over a large geographical area. As a result of such events, populations may be required to take part in protective actions such as sheltering, evacuation and the restriction of food supplies. Research on these types of non-nuclear events and natural disasters has been extensive and has led to an understanding of factors that support the effectiveness of response activities, as well as those that may degrade the response.

Such information is useful for an "all-hazards" framework in its capacity to enhance existing preparedness efforts not only for nuclear power plants, but also more generally for industrial facilities and for natural disasters. In 2015, the OECD Council issued a Recommendation on the governance of critical risks, advocating that its "members establish and promote a comprehensive, all-hazards and transboundary approach to country risk governance to serve as the foundation for enhancing national resilience and responsiveness".

It is in this context that the NEA has presented evidence for the inclusion of nuclear and radiological emergency preparedness into the more comprehensive domain of "all-hazards emergency planning".

Establishing such a comprehensive, all-hazards, transboundary approach to country risk governance is not an easy endeavour and will be a long-term process that implies the involvement of multiple actors, both at national and international levels. It also means approaching the process from a multidisciplinary perspective.

A new NEA report on all-hazards approach to emergency preparedness and response

Guided by the logic of building an all-hazards approach from a multidisciplinary perspective, the NEA joined forces with the OECD Public Governance and Territorial Development Directorate's High Level Risk Forum (HLRF), the OECD Environment Directorate and the European Commission's Joint Research Centre (JRC) – which operates the Major Accident Reporting System (eMARS) database – to gather lessons from non-nuclear events. This collaboration resulted in the NEA report, *Towards an All-Hazards Approach to Emergency Preparedness and Response: Lessons Learnt from Non-Nuclear Events.* Experts from a wide range of fields outside of the nuclear energy and radiological protection fields participated in this NEA report, analysing databases and drawing on published materials. These expert contributions were enriched with national experiences from countries such as the United States and Japan in an effort to learn from non-nuclear events and move towards an all-hazards approach to emergency preparedness and response.

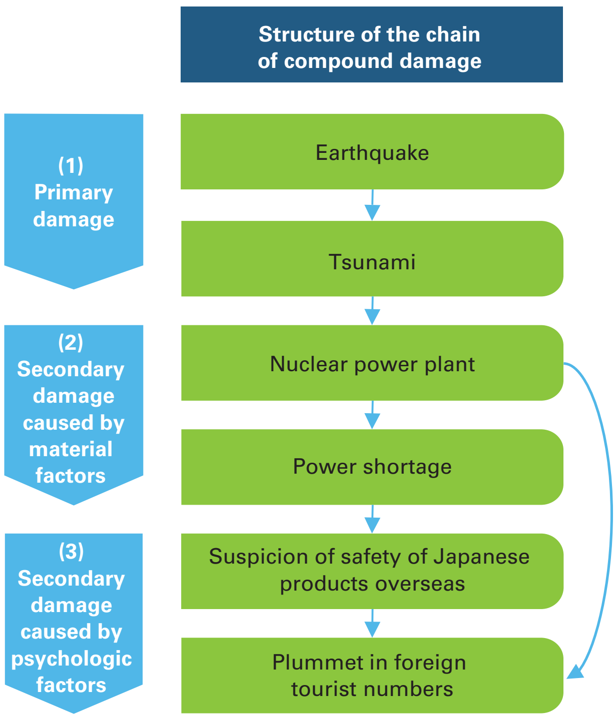
The Fukushima Daiichi accident clearly showed the importance of an integrated, "all-hazards" approach when faced with a global event such as the 2011 Great East Japan Earthquake and related tsunami.

NEA member countries have over the years built robust emergency management systems, which are regularly tested and enhanced through lessons learnt. Nevertheless, it is the nature of nuclear operations and regulation, including emergency management, to learn from all experiences – both those arising from exercises and from real accidents. The lessons gathered in this NEA report can ultimately be used by countries to enhance already existing nuclear emergency preparedness and response systems. Countries implementing the OECD Council Recommendation on the Governance of Critical Risk may also benefit from such lessons.

Insights from a cross-disciplinary approach

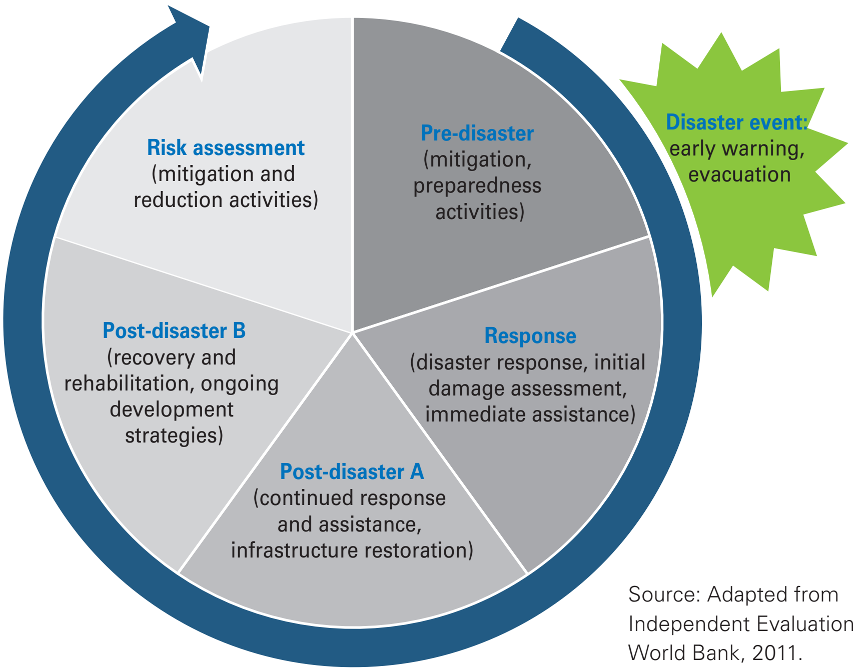
The diverse contributions to the report demonstrate similarities in emergency planning and preparedness across sectors and identify lessons learnt and good practices. One example of how a cross-disciplinary approach may provide new insights is that of mental health in the aftermath of an emergency situation. Mental health issues were revealed to be a significant, long-term public health problem ensuing from nuclear accidents at Three Mile Island and Chernobyl. Such issues remain a pressing public health concern in the aftermath of the Fukushima Daiichi nuclear power plant accident. To raise awareness of the mental health side of emergencies, the report includes a chapter on public health lessons from accidents involving exposure to toxic substances, based on the work of experts in this field.[1]

Figure 1: Cascading effects of the Great East Japan Earthquake and related tsunami



Source: Adapted from Kaji, 2012.

Figure 2: The risk management cycle



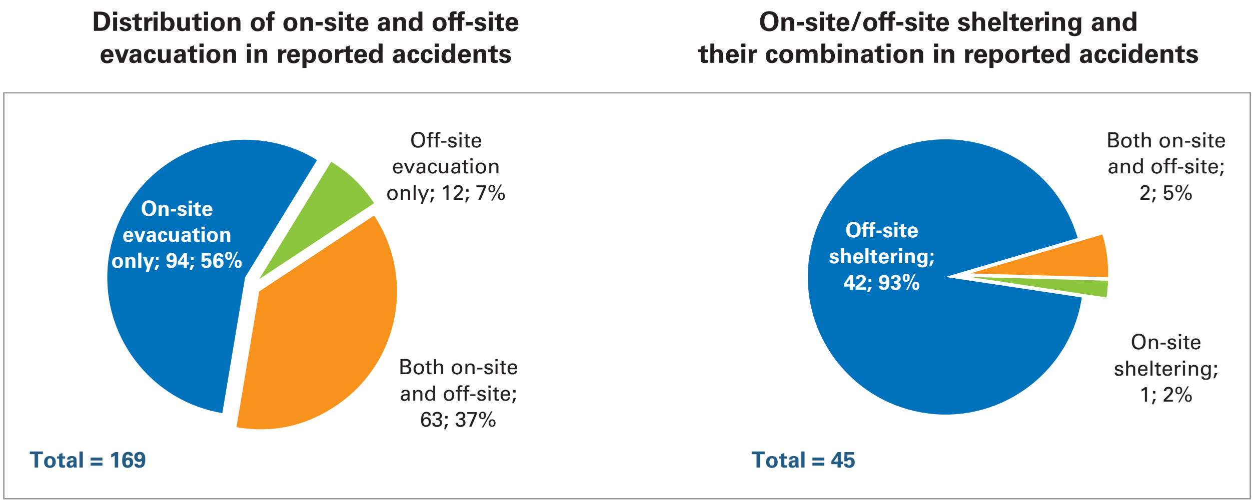
Source: Adapted from Independent Evaluation Group, World Bank, 2011.

Health, as defined by the World Health Organization (WHO), encompasses physical, mental and social well-being. The NEA, on the basis of its mandate in relation to public health matters that concern radiation, has initiated collaboration with the WHO to assist decision makers with implementing the practical tools necessary to ensure that future interventions fully embrace all three features of the WHO definition of health.

Other examples of important lessons learnt from experiences outside the nuclear field are outlined in the report:

- New crisis governance frameworks are needed for "black swan" events. Governments must develop robust crisis-management frameworks to cope with the complexity, novelty, ambiguity and uncertainty that characterise many modern crises.
- Engaging the private sector in crisis-management is essential as the scale and complexity of major crisis requires a "whole-of-society" approach. Governments should set up the right incentives for co-operation with the private sector in times of crisis.
- Taking into account the key messages related to lessons learnt from chemical and Natech[2] accidents is also important, for example that preparedness can make the difference between success and failure in limiting the damages and long-term impacts of a disaster. Lessons learnt are an enormous reference, useful for identifying gaps in emergency preparedness and innovative ways to manage both expected and unexpected aspects of any response.

Figure 3: Evacuation and sheltering in reported accidents



Source: The European Commission Joint Research Centre Major Accident Reporting System (eMARS).

- Natech accidents are an important reference because they pose specific challenges to emergency management since several accidents can take place simultaneously and have an impact on large areas, affecting people and the environment, as well as neighbouring industry and infrastructures. On-site and off-site emergency plans for accidents involving hazardous materials should take natural hazard risks into account, and on-site emergency plans should assume that off-site response resources are unavailable under natural disaster conditions.
- Social media presents opportunities to enhance crisis communication, but it also comes with new challenges. Governments should therefore develop dedicated crisis communication strategies for the use of social media in crisis management.

Conclusions

Achieving a comprehensive, all-hazards, transboundary approach to country risk governance is not an easy endeavour and will be a long-term process that implies the involvement of multiple actors, both at national and international levels. It will also be crucial to continue approaching the process from a multidisciplinary perspective. For the NEA, a major step in this process has been, and will be, taking into account experiences from the emergency management of hazards other than those that may emanate from the nuclear sector.

The lessons learnt in this report, originating from the multidisciplinary perspectives of fields outside the nuclear sector, can be used by political leaders and those in society who are responsible for managing crisis and emergency situations.

The NEA continues to assist its member countries to build "all-hazards" preparedness and response approaches. It will also continue to foster its long-term relations with the International Atomic Energy Agency (IAEA), the European Commission (EC) and the World Health Organization (WHO), while strengthening the fruitful collaboration with the OECD Public Governance and Territorial Development Directorate's High Level Risk Forum, the OECD Environment Directorate and the EC Joint Research Centre.

The NEA has already initiated the next step in continuously improving already robust emergency management systems by organising an international joint workshop in 2020. The joint workshop will bring together EPR experts from different sectors to address different types of hazards – either natural or human-made – to share experiences, identify best practices and issue recommendations in an effort to move even further towards an all-hazards approach to emergency management.

Notes

1. This chapter was produced based on publications by J.M. Havenaar and E.J. Bromet.
2. NATECH accident = natural hazard-triggered technological accident.

Reference

NEA (2018), *Towards an All-Hazards Approach to Emergency Preparedness and Response: Lessons Learnt from Non-Nuclear Events*, OECD, Paris, oe.cd/nea-all-hazards-epr-2018. View the webinar at www.oecd-nea.org/rp/epr/2018/webinar/.

The Nuclear Energy Agency at sixty

by A. Duncan

Ms Aleshia Duncan (aleshia.duncan@oecd.org) is Senior Advisor for Multilateral Co-ordination and Secretary to the Steering Committee for Nuclear Energy.

From left to right: Yoshiaki Oka, Chairman, Japan Atomic Energy Commission (JAEC), Daniel Verwaerde, Chairman and Chief Executive Officer, French Alternative Energies and Atomic Energy Commission (CEA), Gerassimos Thomas, Deputy Director-General for Energy, European Commission (EC), Marta Žiaková, Chair, NEA Steering Committee for Nuclear Energy, Kristine L. Svinicki, Chairman, US Nuclear Regulatory Commission (NRC), William D. Magwood, IV, Director-General, Nuclear Energy Agency (NEA), Agneta Rising, Director General, World Nuclear Association (WNA), Alexey Likhachev, Director General, State Atomic Energy Corporation "Rosatom", Russia and Bertrand de L'Épinois, Chairman, World Association of Nuclear Operators (WANO) Paris Centre.

The mission and membership of the Nuclear Energy Agency have expanded considerably since its beginnings in 1958, when 17 European countries gathered to form a specialised nuclear agency within the Organisation for Economic Co-operation and Development (OECD). Today, the NEA is made up of 33 member countries from the Americas, Europe and the Asia-Pacific region, and is collaborating with key partners from around the world.

Celebrations of the 60th anniversary at the NEA began in early 2018 and have included a high-level session and reception on 19 April 2018, hosted by the NEA Director-General William D. Magwood IV (see comments on p.3). Dignitaries from 31 countries joined in the festivities at NEA Headquarters in the OECD Boulogne Building, where Director-General Magwood opened the high-level session with a congratulatory video from the OECD Secretary-General Ángel Gurría. Secretary-General Gurría praised the scientific and technical expertise of the NEA, its contribution to the international nuclear sector and the important role that it has played in multilateral co-operation.

Dr Marta Žiaková, Chair of the NEA Steering Committee for Nuclear Energy, then took the stage to commend the Agency's "significant role in promoting international co-operation in the further development of innovative nuclear energy technologies and systems, as well as in assisting its 33 member countries [...] in addressing emerging concerns related to nuclear technology and radioactive material management." She outlined the extensive work of the Agency in nuclear safety, scientific research and decommissioning, as well as in supporting regulatory authorities. As Chair of the Nuclear Regulatory Authority in the Slovak Republic since 2002, she has first-hand knowledge of co-operation in this regard.

The Chairman of the United States Nuclear Regulatory Commission (NRC), Ms Kristine Svinicki, spoke about the collective wisdom and experience of the NEA, saying that the NRC had benefited greatly from discussions with other member country experts on complex technical issues, shared research and lessons learnt. Mr Daniel Verwaerde, Chairman and Chief Executive Officer of the French

Alternative Energies and Atomic Energy Commission (CEA), emphasised the NEA's "singular and essential place in the landscape of international organisations dedicated to nuclear energy", which is made evident by its capacity to "quickly structure communities at the highest level of experts around emerging issues."

Mr Alexey Lichachev, Director General of the State Atomic Energy Cooperation, Rosatom, said that the event was especially symbolic for Russia as it had been five years since the country had joined the NEA. He indicated that Russia's "engagement in NEA projects and programmes has helped to enhance nuclear safety and streamline the Russian legal and regulatory framework." Dr Yoshiaki Oka, Chairman of the Japan Atomic Energy Commission (JAEC), underlined the NEA's sustained ability to maintain the key features of homogeneity in its membership, flexible working methods, a depth and quality of technical work, and a small size that has contributed to cost-effectiveness. He thanked the NEA in particular for its supportive activities following the Fukushima Daiichi nuclear power plant accident in 2011.

Mr Bertrand de L'Epinois, Chairman of the World Association of Nuclear Operators (WANO) said that WANO was proud to be a part of this international consort and particularly happy about the Memorandum of Understanding signed last year with the NEA. He highlighted specific initiatives already underway in relation to safety culture and support to newcomer countries in nuclear energy, all of which will contribute to a "collective responsibility to improve safety together".

Ms Agneta Rising, Director General of the World Nuclear Association (WNA), referred specifically to the NEA Nuclear Innovation 2050 initiative, saying "we need the NEA to continue to promote collaborative approaches to nuclear innovation" with continued emphasis on safety, health, regulatory matters and the environment. And finally, Mr Gerassimo Thomas, Deputy Director-General for Energy at the European Commission (EC), drew attention to the importance of reflecting on a "new dynamism" at the occasion of this sixty-year anniversary celebration, saying that looking at both achievements and failings will help the international nuclear energy sector to learn from its mistakes in this post-Fukushima period.

All of the speakers at the session echoed the common themes of working together globally towards a low-carbon energy future and of developing technologies that focus both on safety and cost efficiency. As Director-General Magwood concluded in his remarks, the NEA is here to support its member countries as the evolution of nuclear energy proceeds, and "today, with the 21st century well underway, we must now look to the future." In the words of Director-General Lichachev, this future will consist of "the sun, the wind, water and the atom – supplementing and reinforcing one another – [...as] the basis of the future world carbon-free balance."

All of the session's participants were invited to attend the celebratory reception that followed with guests and partners from around the world. A new NEA video was premiered at the event (see www.oecd-nea.org/general/about), allowing nearly 200 NEA collaborators and stakeholders to enjoy the opportunity of reflecting on progress made at the NEA over the past six decades. The reception served as a small token of thanks from the NEA to all of those who have shared in building the frameworks that ensure the peaceful and safe uses of nuclear energy.

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

by E. Lazo

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Since shortly after the discovery of X-rays and natural radiation, experts in both national and international fora have worked towards establishing an international radiological protection (RP) system. International organisations have contributed to the evolution of this RP system by sharing state-of-the-art scientific knowledge and experience accumulated over many decades, all of which have continued to refine the principles of the RP system – principles that have largely been accepted worldwide, and have served as a basis for national regulations and guidelines.

While guidance and standards describe the technical facts in relation to the RP system, the body of understanding that they reflect, including how the different elements have evolved, is not well documented. To appropriately and effectively apply the RP system to existing and emerging situations, the "spirit" of the RP system – its nuances and history – need to be fully understood by tomorrow's leaders.

It was to respond to this challenge that the Nuclear Energy Agency decided to establish the International Radiological Protection School (IRPS), to provide a clear understanding of the RP system and how it is intended to be interpreted for application in diverse and emerging circumstances.

Objectives and key topics of the IRPS

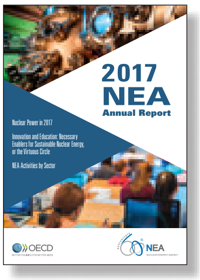
The first session of the IRPS will take place on 20-24 August 2018 in Sweden, hosted by the Stockholm University Centre for Radiation Protection (CRPR) with the support of the Swedish Radiation Safety Authority (SSM). During the session, experts who contributed to the creation of the RP system will provide an historical overview of how and why the RP system evolved, while transmitting an understanding of what the system is intended to mean. The programme will include sessions built on a mix of presentations and illustrative case studies. The objectives and topics to be covered include:

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

The programme is aimed at mid-career experts in the field of radiological protection. Participants should hold positions providing policy and practical level advice in government ministries, regulatory authorities, research institutions, nuclear fuel cycle industries or in other industrial sectors. Lecturers will build on participants' own experiences to ensure that discussions are, to the extent possible, relevant to their situation and concerns. Applications from non-NEA member countries are welcome.

For more information about the 2018 programme and the application process, please visit www.oecd-nea.org/rp/irps or send an email to irps@oecd-nea.org.

General Interest



Annual Report 2017

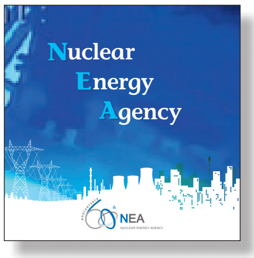
NEA No. 7404. 72 pages.

Available online at:
http://oe.cd/nea-2017-en

Rapport annuel 2017

AEN n° 7405. 72 pages.

Available online at:
http://oe.cd/nea-2017-fr



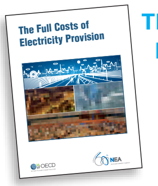
The Nuclear Energy Agency brochure

NEA No. 7398. 28 pages.

Also available in French.

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

Nuclear technology development and economics



The Full Costs of Electricity Provision

NEA No. 7298. 212 pages.

Available online at:
http://oe.cd/nea-full-costs-2018

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

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

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

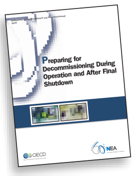
Radioactive waste management

Microbial Influence on the Performance of Subsurface, Salt-Based Radioactive Waste Repositories

NEA No. 7387. 68 pages.

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

For the past several decades, the Nuclear Energy Agency Salt Club has been supporting and overseeing the characterisation of rock salt as a potential host rock for deep geological repositories. This extensive evaluation of deep geological settings is aimed at determining – through a multidisciplinary approach – whether specific sites are suitable for radioactive waste disposal. Studying the microbiology of granite, basalt, tuff and clay formations in both Europe and the United States has been an important part of this investigation, and much has been learnt about the potential influence of microorganisms on repository performance, as well as about deep subsurface microbiology in general. Some uncertainty remains, however, around the effects of microorganisms on salt-based repository performance. Using available information on the microbial ecology of hypersaline environments, the bioenergetics of survival under high ionic strength conditions and studies related to repository microbiology, this report summarises the potential role of microorganisms in salt-based radioactive waste repositories.



Preparing for Decommissioning During Operation and after Final Shutdown

NEA No. 7374. 160 pages.

Available online at:
http://oe.cd/2i0

The transition from an operating nuclear facility to the decommissioning phase is critical in the life cycle of every facility. A number of organisational and technical modifications are needed in order for the facility to meet new objectives and requirements, and a certain number of activities must be initiated to support the transition and preparation for the dismantling of the facility. Thorough preparation and planning is key for the success of global decommissioning and dismantling projects, both to minimise delays and undue costs and to ensure a safe and efficient decommissioning process. The aim of this report is to inform regulatory bodies, policy makers and planners about the relevant aspects and activities that should begin during the last years of operation and following the end of operation. Compiling lessons learnt from experiences and good practices in NEA member countries, the report supports the further optimisation of transition strategies, activities and measures that will ensure adequate preparation for decommissioning and dismantling.

Radiological Protection

Towards an All-Hazards Approach to Emergency Preparedness and Response

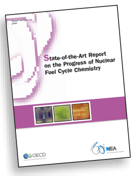
NEA No. 7308. 100 pages.

Available online at:
http://oe.cd/nea-all-hazards-pub-2018

The field of emergency management is broad, complex and dynamic. In the post-Fukushima context, emergency preparedness and response (EPR) in the nuclear sector is more than ever being seen as part of a broader framework. The OECD has recommended that its members "establish and promote a comprehensive, all-hazards and transboundary approach to country risk governance to serve as the foundation for enhancing national resilience and responsiveness". In order to achieve such an all-hazards approach to emergency management, a major step in the process will be to consider experiences from the emergency management of hazards emanating from a variety of sectors.

The NEA Working Party on Nuclear Emergency Matters (WPNEM) joined forces with the OECD Working Group on Chemical Accidents (WGCA), the OECD Public Governance and Territorial Development Directorate's High-Level Risk Forum (HLRF) and the European Commission's Joint Research Centre (JRC) to collaborate on this report, which demonstrates similarities between emergency planning and preparedness across sectors, and identifies lessons learnt and good practices in diverse areas for the benefit of the international community. A set of expert contributions, enriched with a broad range of national experiences, are presented in the report to take into account expertise gathered from the emergency management of hazards other than those emanating from the nuclear sector in an effort to support and foster an all-hazards approach to EPR.

Nuclear science and the Data Bank



State-of-the-art Report on the Progress of Nuclear Fuel Cycle Chemistry

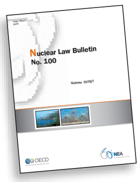
NEA No. 7267. 300 pages.

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

The implementation of advanced nuclear systems requires that new technologies associated with the back end of the fuel cycle are developed. The separation of minor actinides from other fuel components is one of the advanced concepts being studied to help close the nuclear fuel cycle and to improve the long-term effects on the performance of geological repositories. Separating spent fuel elements and subsequently converting them through transmutation into short lived nuclides should considerably reduce the long-term risks associated with nuclear power generation.

R&D programmes worldwide are attempting to address such challenges, and many processes for advanced reprocessing and partitioning minor actinides are being developed. This report provides a comprehensive overview of progress on separation chemistry processes, and in particular on the technologies associated with the separation and recovery of minor actinides for recycling so as to help move towards the implementation of advanced fuel cycles. The report examines both aqueous and pyro processes, as well as the status of current and proposed technologies described according to the hierarchy of separations targeting different fuel components. The process criteria that will affect technology down selection are also reviewed, as are non proliferation requirements. The maturity of different reprocessing techniques are assessed using a scale based on the technology readiness level, and perspectives for future R&D are reviewed.

Nuclear law



Nuclear Law Bulletin No. 100

Volume 2018/1

NEA No. 7367. 148 pages.

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

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: "Legal challenges to the operation of nuclear reactors in Japan"; "Inside nuclear baseball: Reflections on the development of the safety conventions"; and "The Peaceful Nuclear Energy Programme in the United Arab Emirates: Background and history".

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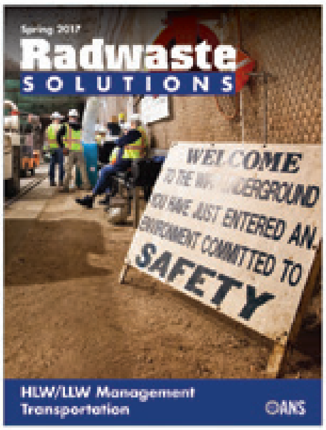
The American Nuclear Society (ANS) publishes two trade magazines, *Nuclear News* and *Radwaste Solutions*, which cover all aspects of the nuclear energy industry, from new plant construction to decommissioning. See why over 10,000 readers throughout 58 countries rely on our magazines to stay informed.



Nuclear News

ans.org/nn

Published since 1959, *Nuclear News* is the monthly membership magazine of the American Nuclear Society. The magazine reports on the latest developments in the nuclear field, a large part of which concerns nuclear energy – in particular, the 540 units that are in operation or forthcoming throughout 35 countries. News reports cover plant operations, maintenance, security, international developments, waste management, fuel, and industry. Also covered are nonpower uses of nuclear science and technology, including nuclear medicine, food irradiation, and space nuclear applications.

49th Annual Buyers Guide

Published as a special 13th issue, the *Nuclear News* Buyers Guide is an annual directory listing nearly 800 suppliers (by country) throughout more than 470 categories of products and services utilized by the nuclear industry.

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Radwaste Solutions

ans.org/rs

Created by the American Nuclear Society in 1994, this specialty magazine provides dedicated coverage of the fastest growing segment of the nuclear industry – worldwide waste management services. Editorial is focused on the generation, handling, treatment, transportation, storage, and disposal of radioactive waste. Articles are contributed by people working with utilities and those involved in U.S. DOE site work, in the medical, legal, university, consulting, and commercial areas, and from all levels of government.

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

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

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