

NEA News



Special issue:

Why the climate needs nuclear energy

A clean environment approach to uranium mining

The growing interrelationship between nuclear law
and environmental law

Radioactive waste management solutions

Nuclear regulatory organisations: Learning from
stakeholders to enhance communication

and more...

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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 friendly 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 31 member countries: 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, 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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Climate change and nuclear energy

In late 2015, nearly 200 countries came together to agree on a regime aimed at addressing climate change. The outcome of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change, more commonly known as “COP21”, codified the world community’s aspiration to reduce emissions of greenhouse gases in order to limit increases in mean global temperatures to below 2 degrees Celsius above pre-industrial levels. While proponents of this process hail the success of COP21, most also recognise that much remains to be decided – and implemented – if these goals are to be achieved.

The most pertinent questions remain to be answered. For example, how are these goals to be accomplished? Can the modern and mature economies of NEA member countries pursue healthy economic growth while slashing CO₂ emissions? Can emerging economies meet these global targets while still improving the lives of the more than 1.5 billion people who currently lack access to electricity? If the goals reflected in the agreement emerging from COP21 are to be met, providing clear, substantive answers to these questions will be one of the most challenging tasks facing the world in this century.

Our partners at the International Energy Agency (IEA) have developed analyses to consider an economic approach that would meet the less ambitious 2°C target, and have produced the “2°C scenario” (2DS) to describe the transformations necessary in the energy sector. The scenario, discussed in this issue’s lead article authored by Senior Economist Dr Jan Horst Keppler and Senior Nuclear Energy Analyst Dr Henri Paillère, requires the use of a very broad range of energy technologies to replace traditional fossil fuel-based energy production by 2050, including massive increases in wind and solar power and significant deployment of carbon sequestration – while calling for extensive improvements in efficiency (such that 25% of all reductions would be achieved using energy efficiency measures).

In this scenario, nuclear power would provide the single largest contribution of any technology in meeting the CO₂ emissions reduction target. However, in order to reach this goal, the world would need roughly 500 new, large commercial power reactors beyond those currently in operation.

This by no means implies that individual countries setting policies to eschew nuclear power cannot succeed in meeting their environmental goals. But the task of achieving the 2°C target – or the more challenging 1.5°C target – becomes vastly more difficult if the largest carbon-free source of electric power in NEA countries is not included as part of the solution. Further, the risk of failure grows as any future option is removed.

For many countries, an inclusive approach evaluating all energy technologies presents the most practical path towards realising the vision set by COP21. As such, it is vital that any existing barriers to the nuclear energy option be addressed in the coming years. Such work is central to the NEA’s basic mission and purpose and our efforts will support our member’s needs and policies in this area.

It is commendable that so many countries were able to find a means to reach agreement in Paris last year. It will be even more commendable if these countries find the means to fully implement this accord. We must continue the work ahead to ensure that safe, emission-free nuclear energy technologies can be called upon to serve in this cause, both today and in the long-term future.

William D. Magwood, IV
NEA Director-General

Why the climate needs nuclear energy

by J.H. Keppler and H. Paillère*

The global response to climate change is a key policy concern of the 21st century. Many governments around the world have agreed that action should be taken to achieve large cuts in greenhouse gas (GHG) emissions over the coming decades, to adapt to the impacts of climate change and to ensure the necessary financial and technical support for developing countries to take action. Indeed, a historic international agreement has been reached to help achieve these goals at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) held in Paris in December 2015.

This Paris agreement reflects the broad consensus that global annual GHG emissions will need to be reduced by at least 50% from today's levels by 2050 if the world is to limit the average temperature increase to below 2° Celsius by the end of the century in order to avoid the worst consequences of global warming.

The NEA recently published a brochure on *Nuclear Energy: Combating Climate Change* describing the role that nuclear energy can play in helping to mitigate climate change, and setting that role in the context of all low-carbon electricity sources, with specific references to renewables. The brochure looks more specifically at the electricity sector, at how CO₂ emissions from the nuclear fuel cycle compare with other energy sources and at the future contribution of nuclear power in a 2°C scenario.

The role of the electricity sector

Electricity plays a particularly important role in this context as it is responsible for over 40% of global carbon emissions (42% in 2013) from the energy sector, and this share is rising. While this amounts to slightly less than 30% of total anthropogenic greenhouse gas emissions, the electricity sector is nevertheless the focus of much attention, mainly because it is the one sector where measures to cut GHG emissions have the greatest chance to succeed, at least in the short to medium term.

There are three reasons for this. First, the electricity supply system comprises a relatively small number of well-known facilities. Second, established low-carbon alternatives for electricity generation do exist. Nuclear energy, hydropower and renewables – in particular onshore wind and solar photovoltaics (PV) – might each have their own challenges but they have been technologically proven and are available for immediate deployment. Third,

switching to low-carbon electricity production could initiate a broad wave of electrification, which will help decarbonise other sectors as well. Switching to electric cars powered by low-carbon electricity in transport is the most high-profile example of electricity-driven decarbonisation in other sectors.

Currently, the electricity sector is far from being low-carbon as it continues to be dominated by coal and gas. In 2013, the share of electricity produced from coal was 41% at the global level, 33% in OECD countries and 49% in non-OECD countries (see Figure 1). Gas produced 22% of global electricity, 26% in OECD countries and 19% in non-OECD countries.

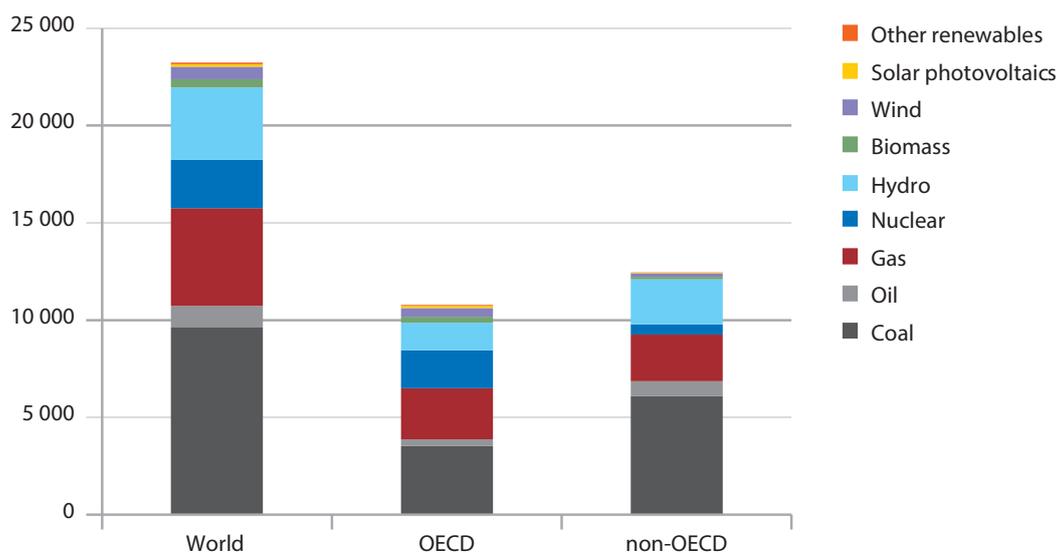
The largest low-carbon source of electricity at the world level is hydropower, with a 16% share of electricity production, 13% in OECD countries and 19% in non-OECD countries. Nuclear energy, for its part, produced 11% of global electricity supply in 2013. This corresponds to 18% of electricity supply in OECD countries and slightly more than 4% in non-OECD countries. Non-hydro renewables were far behind with less than 6% share of electricity production.

Much hope has been placed in the production of electricity from renewable energies in recent years, in particular from wind and solar PV. While their absolute contribution remains small, their average annual growth rates between 1990 and 2013 have reached around 20%. These impressive figures are the result of both very low initial levels that have amplified growth rates (which have come down somewhat in recent years), as well as of extensive government-sponsored subsidies administered mainly through guaranteed feed-in tariffs.

However, producing low-carbon electricity with wind and solar PV gives rise to problems for the electrical system because of their variability over the day and during the year, and because of their unpredictability. Additional investment into transmission and distribution networks, as well as the increased cost of the residual generation systems that need to guarantee continuous security of supply, add “system costs” over and above the

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Figure 1: Electricity production by technology
(Terawatt hours [TWh] in 2013)



Source: Based on IEA (2015a).

plant-level costs of electricity production (see NEA, 2012b). Other elements include declining load factors with increasing capacities and auto correlation continuing to lead to production when it is least valuable, as well as the growing rarity of the best sites in terms of meteorological conditions. Because of questions of variability of production, wind and solar PV cannot, in the absence of a breakthrough in cheap and abundant storage, provide round-the-clock electricity supply.

Other renewable sources such as biomass, biogas, geothermal or marine resources are too limited to make a significant contribution to low-carbon electricity generation in the coming decades. Dispatchable low-carbon sources of electricity will thus always be needed. As hydropower resources can no longer be increased significantly in OECD countries, the only remaining option for dispatchable low-carbon electricity is nuclear power, which is a critical element in many decarbonisation strategies of the electricity sector.

How CO₂ emissions from the nuclear fuel cycle compare with other energy sources

Unlike the combustion of fossil fuels, the process of nuclear fission does not produce any CO₂ or other greenhouse gases, and thus nuclear power plants do not emit GHGs directly during operation. There are some indirect emissions that can be attributed to nuclear energy, mainly through the use of fossil-based energy sources in the various steps of the nuclear fuel cycle (see Figure 2 for a comparison of the direct and indirect CO₂ emissions of different technologies).

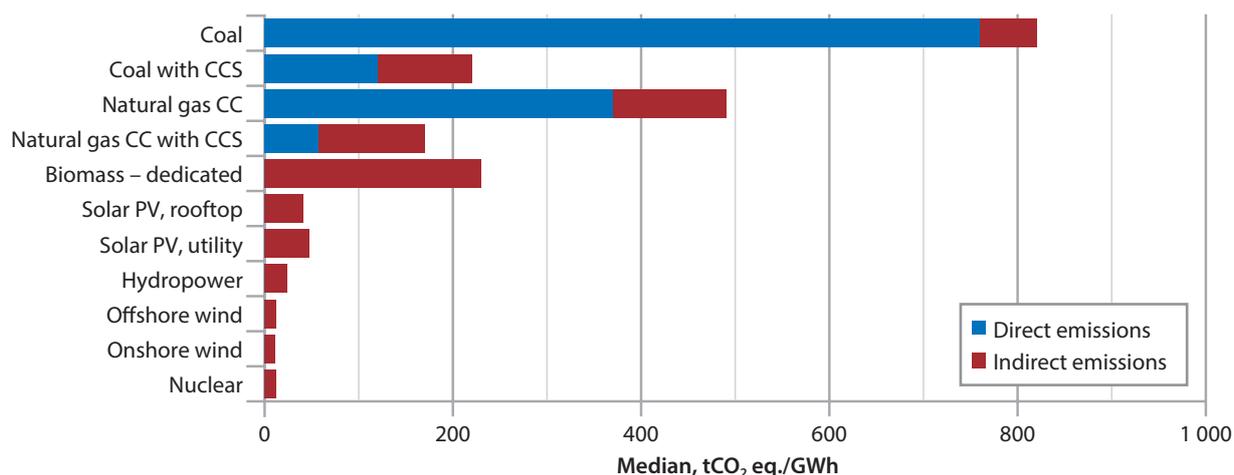
The reduction of CO₂ emissions resulting from the use of nuclear power has added benefits in terms of reducing air pollution, which is also a major environmental issue that has severe impacts on human health and economic development. In developing countries with air pollution problems, the development of nuclear power is driven

Table 1: Life cycle emissions from different power generation sources
(mg/kWh)

	Coal		Natural gas		Bioenergy	Nuclear
	Hard coal	Lignite	Combined cycle	Steam turbine		
SO₂	530-7 680	425-27 250	1-324	0-5 830	40-490	11-157
NO_x	540-4 230	790-2 130	100-1 400	340-1 020	290-820	9-240
PM	17-9 780	113-947	18-133	Insufficient data	29-79	0-7

Source: Masanet et al. (2013).

Figure 2: Direct and indirect GHG emissions for different sources of electricity



Note: Lifecycle emissions from dedicated energy crops are relatively high due to the N₂O emissions from agricultural soils. N₂O has a global warming factor that is 298 times that of CO₂ (IPCC [2014], Chapter 11, p. 880).

CC = combined cycle; CCS = carbon capture and storage; GWh = Gigawatt-hour.

Source: Data from IPCC (2014).

more by the need for clean air technologies rather than by its contribution to the reduction of CO₂ emissions. The most important local and regional pollutants from fossil fuel combustion are particulate matter of varying diameter (PM), sulphur dioxide (SO₂), nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The latter two are precursors for ground-level ozone (O₃). Other pollutants include an array of heavy metals, as well as radionuclides. Above certain thresholds, all of them are considered major public health concerns (see Table 1).

The contribution of nuclear power to reducing carbon emissions

The contribution of nuclear power to electricity generation grew rapidly in the 1970s and 1980s, but has fallen since as electricity demand growth has outpaced nuclear expansion since 1990. Nuclear power is nevertheless one of the largest sources of low-carbon electricity. Globally, it avoids each year between 1.2 and 2.4 Gigatonnes (Gt or billion tonnes) of CO₂ emissions, assuming this power would otherwise be produced by burning either gas or coal.

A simple and straightforward assumption to estimate the contribution of nuclear power to global GHG abatement is to substitute nuclear power production with the residual global fuel mix. World electricity generation in 2012 amounted to 22 752 TWh, 2 461 TWh of which was produced by nuclear power and 20 291 TWh by other sources. Global CO₂ emissions from the electricity sector were 13 346 million tCO₂. Producing the 2 461 TWh

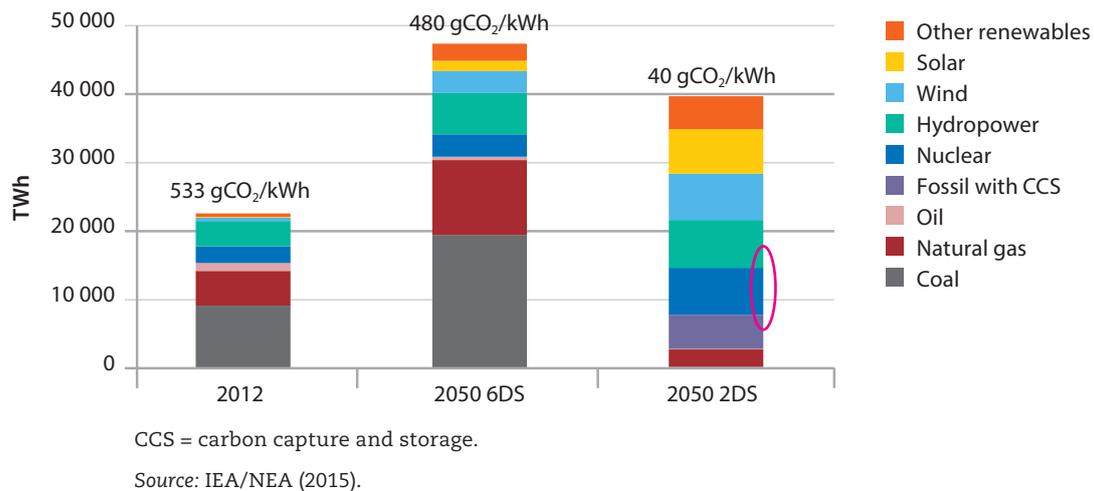
equivalent to nuclear power production by a proportional increase of all other sources would amount to an additional 1.6 Gt of CO₂. Cumulatively, nearly 60 Gt of CO₂ have thus been avoided globally since 1971, thanks to nuclear power.

Looking towards the future, the contribution of nuclear power in limiting global GHG emissions could be even more important than in the past. The recently released IEA/NEA *Technology Roadmap: Nuclear Energy – 2015 Edition* (IEA/NEA, 2015) takes into account a number of factors that have had a significant impact on the global energy sector since the 2010 edition. Many of these factors have not been favourable to nuclear power, including the Fukushima Daiichi accident in March 2011, the global financial and economic crisis, shortcomings in electricity markets and the failure to set up functioning CO₂ markets. Cheap shale gas in the United States has also reduced the cost of an important competing fuel.

Despite these additional challenges, nuclear energy remains a proven low-carbon source of baseload electricity that is essential to the IEA/NEA long-term vision of a sustainable energy scenario. The 2°C scenario (2DS) developed in the IEA *Energy Technology Perspectives 2015*, exemplifies this vision, in calling for a virtual decarbonisation of the power sector by 2050.

A mix of technologies including nuclear energy, carbon capture and storage and renewables will be needed to achieve this decarbonisation. Figure 3 shows how the contribution of nuclear power to emission reductions would play out in terms of total global electricity production under the 2DS.

Figure 3: Shares of different technologies in global electricity production until 2050 in the 2DS



Under the 2DS, gross nuclear capacity is projected to increase from 390 Gigawatts (GW) to 930 GW by 2050. This growth in nuclear capacity will essentially be driven by non-OECD countries. Currently, OECD countries and Russia account for over 85% of total global capacity. In 2050, these countries combined will see only a modest increase in capacity from 350 GW to 400 GW.

Growth in nuclear capacity will primarily be led by China, which could surpass the United States by 2030 and, with 250 GW of nuclear, would have more than twice the currently installed capacity of the United States in 2050. India, which is forecast to be the second fastest growing market for nuclear, would have about 100 GW of capacity in 2050, making it the third largest market for nuclear after the United States. In terms of contributing to the reduction of CO₂ emissions, an IEA analysis (IEA, 2015a) shows that in order to steer the global power sector from

a “business-as-usual” 6DS to a 2DS, nuclear could contribute up to 15% of CO₂ reductions cumulatively to 2050 (see Figure 5). With its current large base of generation, nuclear power would therefore provide the largest individual contribution, alongside wind, of any single technology to emission-free energy.

Can nuclear power be expanded rapidly enough?

The 2°C scenario projects more than a doubling of the current nuclear capacity of 390 GW today to 930 GW by 2050. This would require annual grid connection rates of over 12 GW in the present decade, rising to well above 20 GW in the following decade. A comparison with the major expansion of nuclear power in the 1970s and 1980s indicates that, given strong policy support, nuclear power could expand in a sufficiently rapid manner. During the 1970s, nuclear

Figure 4: Projected nuclear capacity with regional split and share of electricity generation in the IEA’s Energy Technology Perspective 2015 2DS

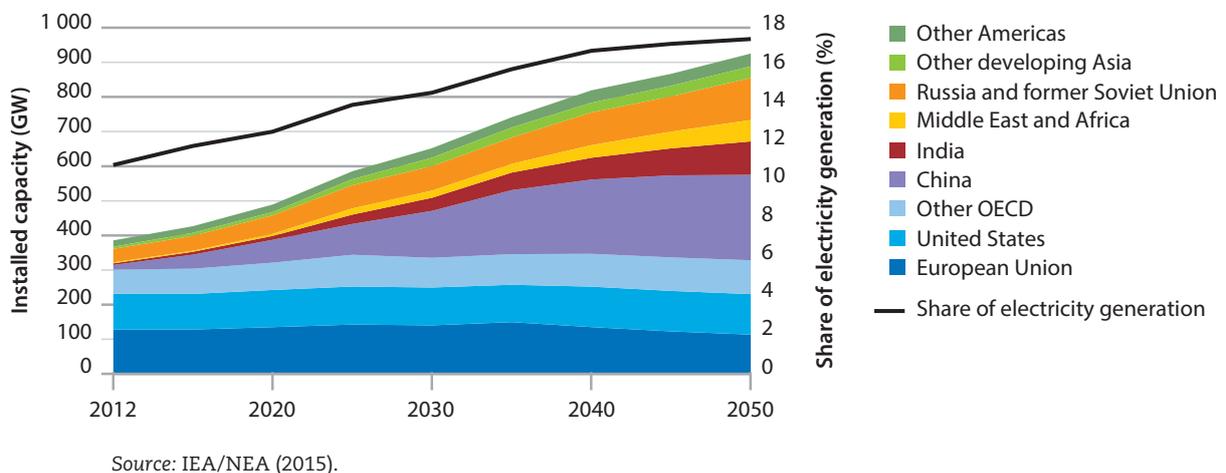
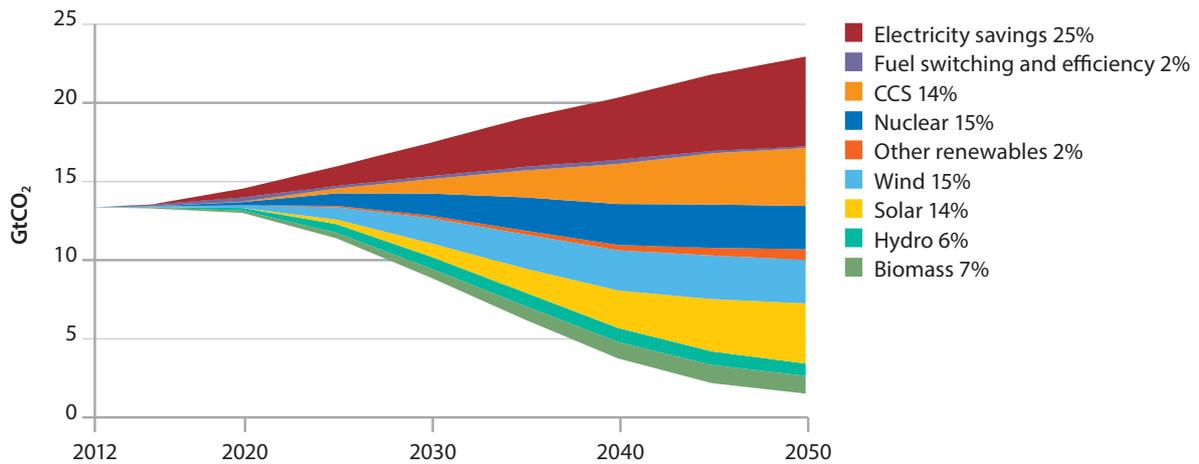


Figure 5: Emissions reductions required in the power sector by 2050 to move from the 6°C scenario (6DS) to the 2DS



Note: Percentage numbers refer to the contribution of the technology area to the cumulative CO₂ reduction between the 6DS and 2DS over the period 2012-2050.

Source: IEA (2015c).

reactor construction projects typically reached 30 per year, peaking at above 40. This was translated later to annual grid connection rates from 15 and 30 GW between 1980 and 1987, which are much higher than today's rates.

The two most important challenges of building a new nuclear power plant today are assembling the conditions for successful financing and managing a highly complex construction process. Because of their high fixed costs, nuclear power plants fare better with stable long-term prices. High fixed costs of investment are common to all low-carbon technologies such as nuclear power, but also hydropower, wind or solar PV. In markets with price risks, nuclear power is at a competitive disadvantage with fossil fuel-based technologies such as gas or coal, even though it scores as well or better on traditional measures of competitiveness such as the levelised costs of electricity (LCOE).

While a robust carbon price would certainly be helpful to decarbonise electricity systems, measures ensuring price stability such as long-term contracts, regulated tariffs, feed-in tariffs (FITs) or contracts for difference (CfD) remain important for all low-carbon generating projects including nuclear power. All successful projects rely on long-term financing. However, for the time being such long-term financing is still based on individual, ad hoc measures. In order to enable nuclear's full contribution, more general financing frameworks need to be put into place.

In construction, where the emergence of a competitive, global supply chain is not yet ensured, the convergence of nuclear engineering codes and

quality standards remains a key step to promote both competition and public confidence. In parallel, a number of smaller technological and managerial improvements have kept the industry moving forward. During a time of major technological, structural and geographical shifts, it is important that the global nuclear industry maintain a dynamic of continuous technological, logistical and managerial improvement.

Nuclear energy and adaptation to climate change

There is increasing concern that if GHG emissions cannot be reduced quickly enough, climate change will occur on a scale such that ecosystems, economies and industry will be significantly affected. The IEA, for instance, has repeatedly warned that the "door is closing" on the possibility of maintaining global warming under 2°C. Increased use of renewable technologies (wind, solar and hydro) is at the same time likely to make electricity production and distribution systems more dependent on climatic conditions. However, thermal power plants, such as fossil fuel and nuclear power plants, will also be affected by the reduction of water availability and the increased likelihood of heat waves, both of which would have an impact on the cooling capabilities of the plants and on their power output.

Regions and countries will not be affected by climate change in the same way. Some countries will benefit, others will be negatively affected in terms of electricity production, generation costs and security of supply. According to the latest

Intergovernmental Panel on Climate Change report (IPCC, 2014), the world is ill-prepared for risks from a changing climate. This includes the energy sector. The IPCC makes the case that these risks can be partly mitigated through adaptation measures.

Given the long operating lives of nuclear power reactors – 60 years for generation III designs – the possible impact of climate change on the operation and safety of these plants needs to be studied and addressed at design and siting stages to limit costly adaptation measures during operation. A study carried out by the NEA provides an assessment of the potential vulnerability of nuclear power plants to climate change (NEA, forthcoming). The availability of water for cooling will certainly become one of the major criteria for siting new nuclear plants. Existing reactors, on the other hand, may require more significant investments to deal with variations in climatic and hydrological conditions that exceed initial design values at the sites where they are located, especially if long-term operation is under consideration. In addition, more severe environmental and regulatory constraints are also being implemented in many countries. This in turn may impose operational limitations on the use of thermoelectric plants and add considerable costs to power plant retrofits, which will ultimately have an impact on the electricity generation cost of such plants.

Climate change projections such as those of the IPCC see increased frequencies of intense heat waves and droughts in some regions. In addition to the impact on water quality and availability, climate change may also lead to extreme climatic events that can undermine the operation of nuclear power plants, for instance, floods, frazil ice and forest fires. Severe storms may be another matter of concern, as they undermine the integrity of the transmission network or contribute to the flooding and transport of debris, challenging the operation of the cooling systems and leading in some cases to the shutdown of the nuclear power plant.

According to the IPCC, floods are expected to occur with greater frequency and severity, as a result of the increased intensity of precipitation events, greater storm wind speeds and rising sea levels. Reactors located on shorelines of oceans and large lakes are more vulnerable to this type of event.

There are different ways in which the resilience of nuclear power plants can be improved in the face of climate change. Protection against extreme floods can be achieved through elevated dykes and water tight access ports into buildings, or rooms housing safety equipment. Technological improvements can be made to existing plants, through minor engineering changes or retrofits of cooling systems. Lowering the water intake at the source, for example, can decrease the temperature sensitivity of the cooling water in the case of a heat wave. Changing the cooling system from a once-through cooling system to a closed-cycle or hybrid system

is another possible improvement, and represents a more ambitious retrofit effort.

To guarantee the safety functions of nuclear plants' cooling systems and ensure that threshold temperatures are not reached in the buildings, more efficient heat exchangers or equipment able to operate at higher temperatures than the initial design, and more powerful air conditioning units, can also be installed.

Constructing a new nuclear power plant offers more possibilities to effectively address the issue of cooling water availability, at the stage of design and siting. Because nuclear power plants situated along the coasts are less vulnerable to temperature-related phenomena (though they can be more vulnerable to flooding), coastal sites should be preferred over river sites, if the country has access to the sea. Otherwise, use of closed-cycle cooling reduces the water intake, though not the overall water consumption as a fraction is evaporated. Use of non-traditional water resources, for example municipal water, reclaimed water, brackish water or mine water, can be considered for cooling thermoelectric plants.

Nuclear power plants are thus to some extent as vulnerable to changes in the climate as are other thermoelectric plants, but adaptation measures and innovations in the design can help improve the resilience of these plants, and ensure that they remain a robust source of low-carbon electricity in all conditions.

Conclusion

Global electricity demand is expected to increase strongly over the coming decades. Meeting this demand while drastically reducing CO₂ emissions from the electricity sector will be a major challenge.

Given that the once-significant expectations placed on carbon capture and storage are rapidly diminishing and that hydropower resources are in limited supply, there are essentially only two options to decarbonise an ever increasing electricity sector: nuclear power and renewable energy sources such as wind and solar PV. Of these two options, only nuclear energy provides firmly dispatchable baseload electricity, since the variability of wind and solar PV requires flexible back-up that is frequently provided by carbon-intensive peak-load plants.

Nuclear power plants do, however, face challenges due to their large up-front capital costs, complex project management requirements and difficulties in siting. As technologies with high fixed costs, both nuclear power and renewables must respond to the challenge of acquiring long-term financing, as investments in capital-intensive low-carbon technologies are unlikely to be forthcoming in liberalised wholesale markets. In order to substantially decarbonise the electricity systems of OECD countries, policymakers must understand the similarities, differences and complementarities

The NEA at COP21



The NEA officially launched its new brochure on *Nuclear Energy: Combating Climate Change* at the 21st Conference of the Parties (COP21) of the UN Framework Convention on Climate Change (UNFCCC). In co-operation with the International Atomic Energy Agency (IAEA), the NEA also held two side-events on “Why the Climate Needs Nuclear Energy” on 10-11 December 2015. The purpose of the events was to highlight the role of nuclear power in helping to achieve the target of limiting the rise in global mean temperatures to 2°C above pre-industrial levels.

To avoid exceeding this critical threshold, the electricity sector, which currently emits over 40% of global carbon emissions for the energy sector, will need to be virtually decarbonised by 2050. Speakers at the events underlined that nuclear power would remain the biggest contributor to low-carbon energy after hydro as the only low-carbon source of dispatchable and scalable power. In addition to the future role of nuclear power in reducing greenhouse gas emissions, presenters highlighted other contributions of nuclear power, for example, to economic development more generally and to the security of energy supply. The side-events benefitted not only from co-operation among the NEA, the OECD and the IAEA, but also from a lively exchange with an interested audience. NEA representatives were present throughout the conference at the OECD pavilion and the exhibition booth. Side-event presentations are available for download from the NEA website at oe.cd/1aX.

between nuclear and renewables in the design of future low-carbon electricity systems. The value of dispatchable low-carbon technologies, such as hydro and nuclear, for the safe and reliable functioning of electricity systems must also be recognised.

Should the decarbonisation of electricity sectors in the wake of COP21 become a reality, nuclear power might well be the single most important source of electricity by 2050, mainly because of the contribution of non-OECD countries. The Paris agreement is neutral in terms of the means that countries can use to achieve their declared emission reduction targets, and nuclear energy may be employed to that end by all countries that wish to do so. Making the option of nuclear power generation viable and attractive requires two conditions. First, it is important to understand the current and potential future contribution of nuclear power in reducing greenhouse gas emissions. Second, measures to address the outstanding social, institutional and financial issues would be needed in order for the expansion of nuclear generating capacity to be in line with making the limitation of the rise in global mean temperatures below 2°C a reality.

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A clean environment approach to uranium mining

by L. Grancea*

A global and multi-faceted response to climate change is essential if meaningful and cost-effective progress is to be made in reducing the effects of climate change around the world. There is no doubt that the uranium mining sector has an important role to play in such a goal. Uranium is the raw material used to produce fuel for long-lived nuclear facilities, necessary for the generation of significant amounts of baseload low-carbon electricity for decades to come. Given expectations of growth in nuclear generating capacity and the associated uranium demand, enhancing awareness of leading practices in uranium mining is indispensable.

Actors in the uranium mining sector operate in a complex world, throughout different geographies, and involving global supply chains. They manage climate-sensitive water, land and energy resources and balance the interests of various stakeholders. Managed well, uranium mining delivers sustainable value for economic growth, employment and infrastructure, with specific attention given to the preservation of the environment. In the early phases of the industry, however, downside risks existed, which created legacy environmental and health issues that still can be recalled today.

This article addresses key aspects of modern uranium mining operations that have been introduced as regulations and practices have evolved in response to societal attitudes about health, safety and environmental protection. Such aspects of mine management were seldom,

if ever, respected in the early stages of uranium mining. With the implementation of modern mine lifecycle parameters and regulatory requirements, uranium mining has become a leader in safety and environmental management. Today, uranium mining is conducted under significantly different circumstances and is now the most regulated and one of the safest forms of mining in the world.

Public consultation

Public participation is an important parameter that must be an integral part of planning and approval processes for uranium mining, along with an emphasis on the transparency of performance throughout the entire life cycle of the mine. An effective public consultation process facilitates dialogue with the public and other stakeholders so as to take into account questions and concerns. This is a two-way process – not just an outward-flowing information programme – which actively encourages questions and answers that arise throughout stakeholder involvement. Improving public information and consultation with stakeholders thus allows the industry to better respond to concerns or fears about the regulation and management of radiation and its impact on workers, the public

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Uranium mine in the Limousin region of France, before and after remediation.

and the environment. Public consultation and stakeholder involvement are crucial components in obtaining and maintaining a social licence to conduct uranium mining.

Environmental impact assessment

Past experience with environmental legacies has underlined the need to plan projects carefully through an environmental impact assessment (EIA) process that provides opportunities for stakeholder participation. The interested public and special interest groups, including indigenous populations, should be involved in this assessment process.

An EIA is a mechanism used to predict and minimise the environmental effects of proposed initiatives before they are fully planned or undertaken. It is a planning, decision-making and public consultation tool. Overall, the objectives of an EIA are to incorporate environmental factors into decision making and to identify the potential environmental impacts of a proposed project. The EIA provides stakeholders with an overview of the project, and it details specific measures proposed to mitigate or minimise potential environmental effects that could arise if the mining project were to proceed.

Environmental monitoring

The general purpose of environmental monitoring is to check whether uranium mining operations are impacting the environment beyond limits established by the regulator. After decommissioning, the objective is to verify that rehabilitation work is being performed as planned. In its early history, all types of mining facilities had little or no environmental monitoring and the result was often widespread contamination that required challenging and costly remediation efforts.

Since environmental monitoring is an essential safety and environmental protection function of any uranium mining facility today, the collection of sufficient baseline environmental data is a vital first step in designing and carrying out a proper environmental monitoring programme. It is important to begin collecting baseline information in the exploration phase, before the site undergoes any significant physical disturbance. Monitoring programmes should be reviewed regularly to ensure that they remain relevant in relation to the parameters being monitored, the location of monitoring stations and the frequency of the monitoring activities. Reports must be submitted to regulators and preferably made available to the public. Upstream and downstream water quality monitoring around the site must include all adjacent streams, even intermittent, as well as rivers and lakes, and must be performed seasonally during dry periods, winter conditions, spring runoff or during the rainy season in tropical climates.

Socio-economic impacts and benefits

The mining industry is a major force in the world economy, occupying a primary position at the start of the resource supply chain in the field of nuclear energy. The benefits of mining include direct foreign investment, national investment in the local economy and the creation of exports that can be significant economic drivers. Uranium mining can provide increased employment, training and salaries. It can also be an economic stimulus to the local and broader economy, allowing for the development of secondary industries such as retail and service sectors that supply the mine and the mine's employees. Mining requirements for infrastructure such as roads, airports, electricity and water can lead to longer-term regional development.

Mine lifetimes vary considerably and although some can continue operating for decades, eventually either local resources will be depleted or the economics of the operation will change, leading to mine closure and decommissioning. The direct economic benefits from the activity will then come to an end, and trained and experienced workers may have to seek employment elsewhere.

All socio-economic aspects of mining should be carefully evaluated by stakeholders prior to the development of a mine. While uranium mining can provide important socio-economic benefits to local populations, the industry alone cannot be expected to resolve all regional socio-economic and development issues, nor local issues. During the operating lifetime of a mine, potentially negative influences must be taken into account, such as the disruption of traditional lifestyles and potential social pressures created by the influx of workers.

An analysis of socio-economic impacts and benefits to evaluate the impacts of mining on the local community is undertaken in leading practice jurisdictions prior to decisions to begin mining, often as part of an EIA. If mining is approved, arrangements with governments are typically established to ensure that local inhabitants benefit from the extraction of the resource, even after the mine closes, since businesses and skills developed during operations are transferable to regional mining and other activities.

Financial assurance

Past uranium mining legacies from the early strategic era have largely been left to governments to remediate, often at a high cost. To provide assurance that mining companies, and not governments, are fully responsible for funding decommissioning and remediation activities, leading practice jurisdictions require uranium mining companies to post financial assurance. This means that companies must produce an approved remediation plan prior to beginning production and must post appropriate financial

guarantees for the expected cost of closure and remediation that could arise at any stage of the mining life cycle.

Mine reclamation and potential long-term care costs must be forecast in order to determine the value of the financial assurance required. In many mining jurisdictions, requirements have evolved to call for the development of mine reclamation plans at the time of initial permitting, including cost forecasts for future remediation work and the corresponding financial assurances. As mine activities develop, reforecasting is periodically required (e.g. every one to five years). To account for limitations encountered when forecasting the costs of activities in the distinct future, including reasonably foreseeable uncertainties, the value of financial assurances can be substantial. Future rehabilitation costs, as well as the cost of the financial assurances needed to address them, have thus proven to be effective motivators to minimise environmental liabilities during the operating period.

Transport of uranium ore concentrates

The safe transport of uranium ore concentrates (UOC) is a necessary component of production. With expectations that increasing uranium demand will drive the development of new mining operations in various jurisdictions, often located outside uranium-consuming countries, safe transport continues to be a high priority.

The transport of various hazardous materials – including operating materials such as acid, alkali, fuels and explosives, as well as the final or interim product – is often required during operations. Movements of dangerous goods by road, rail and/or sea are regulated by the competent national and/or regional authorities. Due to its low activity per unit mass, UOC is considered a low hazard and can therefore be transported as an industrial package with appropriate placarding and labels. The shipment of UOC is currently carried out in sealed, reusable steel drums that are loaded in ISO containers (i.e. containers certified by the International Organisation for Standardization). To ensure safe and efficient transport, good industry practices have been defined and implemented, including recommendations for drum design, size, materials and labelling. Although UOC consists mainly of uranium, its radioactivity per mass is well below the activity of the ore. Therefore, the main health concern from UOC is related to its chemical toxicity as a heavy metal, rather than its radioactivity.

In the late 1990s, the World Nuclear Transport Institute was founded by industry to represent the collective interests of the radioactive materials transport sector. International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material have become an internationally



AREVA

Safe uranium concentrates transport. Ship sailing through the Panama Canal.

accepted standard for governments and the industry. It is incumbent upon governments to adopt these regulations, and approximately 60 countries have already done so. The transport of nuclear materials has an excellent safety record, which is especially noteworthy due to the great distances involved and the large number of shipments that have been successfully made. Although UOC has been transported around the world for decades to a few existing conversion and enrichment facilities, no accidents resulting in serious harm to people or the environment have been recorded to date.

Emergency planning

Because of the radioactivity of uranium deposits and the strategic importance of uranium, governments and operators are required to implement emergency planning measures to deal with potential on-site accidents.

Emergency preparedness is related to the type of mining undertaken (underground, open-pit or *in situ* leaching [ISL]), since different emergency scenarios have to be considered for each type of mining. Although off-site consequences (radiological or otherwise) are unlikely in the context of uranium mining operations, off-site contamination requiring intervention could occur, for example, through leakages from tailings management facilities.

The requirements for emergency preparedness are defined in national regulations and are therefore country-specific. In general, national authorities and operators are expected to regularly conduct assessments of threats posed by facilities. A very important point when dealing with incidents related to radioactive material is keeping the public informed, which ultimately helps to avoid criticism for a lack of transparency or public outcry resulting from a breach of faith. To this end, it is recommended that protocols be established that outline specific means of communicating incidents to the public.

Nuclear security and safeguards

Mine operators are required to take measures that make unauthorised access to radioactive materials as difficult as possible. These measures are based on feasible risk and threat scenarios, and entail the establishment of limited access areas, the installation of detection systems against unauthorised intrusion, the development of contingency plans to counter malicious acts and the familiarisation of state response forces with the sites. The use of established measurement and record systems, automated data entry and clearly defined responsibilities are all part of an effective management system. However, because of the non-fissile nature of uranium ore concentrates, it is of limited safeguard concern, and as such, security requirements are generally comparatively low.

The establishment and maintenance of a good physical protection regime for nuclear materials lies in the hands of the state. It is responsible for creating the legislative and regulatory framework, designating competent authorities, providing education and training, setting responsibilities and evaluating national threats. IAEA safeguards also provide a basis for nuclear security, since confirming that relevant material is only used for its intended purpose contributes to the prevention of illegal acts. The IAEA monitors and verifies all sources and special fissionable materials in countries under safeguards. Under the Additional Protocol, a state is required to provide the IAEA with broader information covering all aspects of its nuclear fuel cycle activities, including uranium mining.

Handover

The final stage of a mine's life cycle is the return of the land to the landowner following completion of mining closure and remediation activities. Once the results of environmental monitoring have shown that the remediated facility has performed as designed, mining companies can proceed to the handover stage.

After the operator has completed the approved decommissioning and reclamation activities, the site enters a period of transition-phase monitoring, during which the operator is required to continue monitoring and maintaining the site. During the transition-phase monitoring period, regulators continue to conduct periodic inspections and review monitoring results, and the operator continues to remain fully liable for any impacts the site may have on the environment, surrounding communities and public safety.

If the site performs in accordance with the decommissioning and reclamation plan, and it achieves the predicted stability during transition-phase monitoring, the operator may make an application to obtain a release from further monitoring and maintenance responsibilities, as well as the obligation to maintain financial assurance.

Knowledge transfer

Knowledge transfer is a key final step for the operator who hands over the site to the long-term care and maintenance programme. The long-term objective of modern uranium mining is to ensure that the site where mining activities have taken place, once decommissioned and remediated, remains stable and safe over the long term. To ensure this long-term safety and stability, future generations must be fully aware of what is located there, why it is there and what must be protected or maintained. The key documents that summarise the operation and remediation of the site, as well as the engineered close-out design and monitoring verification programme, must be readily available in a secure location. All of this detailed information must be archived in an information management system that is preferably government-controlled. Such archiving occurs after long-term stability has been achieved and confirmed by the post-remediation monitoring programme, and after regulatory approval has been obtained following a final phase of public consultation.

Conclusions

Experiences from modern uranium mines show that successful companies develop innovative strategies to manage all the potential impacts of uranium mining on workers, communities and the environment. An ongoing dialogue among the main stakeholders has proven critical in this regard.

Trust between uranium mining companies and communities depends on what companies do, not on what they say. Work with indigenous populations, on water, air, land, health risks, closure, chemicals management and the transport of uranium concentrates all have an impact on uranium industry performance.

Today, uranium mining operations are performed in co-operation with concerned stakeholders, respecting the local and global environment. The industry adopts best practices, complies with regulatory requirements and even moves beyond these practices and requirements where possible. Environmental leadership is today integrated into all aspects of uranium mining.

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The growing interrelationship between nuclear law and environmental law

by P. Bourdon*

With the recent United Nations Climate Change Conference (COP21) in Paris, a great deal of attention is being given to low-carbon energy technologies and policies that could help the world limit the global temperature increase to 2° Celsius. Among these technologies, nuclear energy, which remains the largest source of low-carbon electricity in OECD countries and the second largest source of electricity at the global level after hydropower, can play a key role (IEA/NEA, 2015: 5).

The 2011 Fukushima Daiichi accident heightened public concern over the safety of nuclear energy in many countries. Because of the potentially far-reaching consequences of the use of nuclear energy on the environment in the case of an accident, it is commonly thought that nuclear law and environmental law are not entirely compatible or do not necessarily share the same objectives. Nuclear law may be defined as “the body of special legal norms created to regulate the conduct of legal or natural persons engaged in activities related to fissionable materials, ionizing radiation and exposure to natural sources of radiation” (Stoiber et al., 2003: 4), while environmental law can be defined as “the body of law that contains elements to control the human impact on the Earth and on public health” (Kurukulasuriya et al., 2003: 15).

These two areas of law were considered independently in the past, since the initial focus of nuclear law, which was developed before environmental law, was to protect people and property, without explicitly referring to the environment. However, the 1986 Chernobyl accident and increasing environmental concerns during that same decade led to a growing emphasis on environmental protection in the field of nuclear activities (Emmereichs, 2008: 91-109). On the one hand, nuclear law, as *lex specialis*, aims to ensure that nuclear activities are carried out in a manner that is safe for both the public and the environment. On the other hand, the expansion of

the realm of environmental law has given rise to the application of environmentally focused international instruments to those same nuclear activities. This article illustrates the growing interrelationship between these two areas of law.

The inclusion of environmental law concepts into international nuclear law instruments

Taking the environment into account in the prevention and mitigation of nuclear incidents

Since the beginning of the first civil nuclear programmes, it has been acknowledged that “the production and use of atomic energy involves hazards of a special character and potentially far-reaching consequences”.¹ Following the 1986 Chernobyl accident, international legal frameworks have been developed to prevent and mitigate any potential damage resulting from the production and use of atomic energy.

The 1994 Convention on Nuclear Safety (CNS) perfectly illustrates the trend of including the protection of the environment into nuclear law instruments. By setting international benchmarks, the CNS aims to legally commit participating states operating land-based nuclear power plants to maintain a high level of safety (Rautenbach et al., 2006). In the Preamble to the CNS, contracting parties declare their awareness of the “importance to the international community of ensuring that the use of nuclear energy is safe, well regulated and environmentally sound”. Accordingly, Article 1(ii) of the CNS states that one of its objectives is “to establish and maintain effective defences in nuclear installations against potential radiological hazards in order to protect individuals, society and the environment from harmful effects of ionizing radiation from such installations”. The convention obliges states to take appropriate steps, in particular, to ensure that procedures are established and implemented “for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment” (IAEA, 1994).

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TEPCO, Japan

Fukushima Daiichi nuclear power plant.

Another, earlier example of this trend can be found in the 1986 Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency (“Assistance Convention”).² The Assistance Convention establishes an international framework for co-operation among states parties, and with the International Atomic Energy Agency (IAEA) to facilitate prompt assistance and support in the event of a nuclear accident or radiological emergency. Article 1 of the Assistance Convention sets out two additional objectives: to minimise the effects of a nuclear accident or radiological emergency and to protect life, property and the environment from the effects of radioactive releases.

More recently, the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (“Joint Convention”) aims to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management through the enhancement of national measures and international co-operation including, where appropriate, safety-related co-operation. It includes in its objectives the protection of individuals, society and the environment from the harmful effects of ionising radiation – now and in the future – during all stages of the management of spent fuel and radioactive waste.³ The Joint Convention accordingly provides for contracting parties to carry out an environmental assessment before the construction of either a spent fuel management facility or a radioactive waste management facility.⁴

Compensation for environmental damage caused by nuclear incidents

Notwithstanding the best efforts to achieve a high level of safety, the possibility remains that an accident may occur in a nuclear installation or during the transportation of nuclear substances to or from a nuclear installation. It is therefore necessary to be prepared to deal with the legal consequences of such an accident in a timely and financially adequate manner. Two specific international legal frameworks for third party nuclear liability were established as early as the 1960s to ensure adequate compensation for damage to persons and property resulting from a nuclear accident: first, the “Paris-Brussels Regime” rests on the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy (“Paris Convention”) and the 1963 Brussels Convention Supplementary to the Paris Convention (“Brussels Supplementary Convention”); and second, the “Vienna Regime” stands on the 1963 Vienna Convention on Civil Liability for Nuclear Damage (“Vienna Convention”) and the 1997 Protocol to amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage (“1997 Protocol”). A third, more recent regime is that established by the 1997 Convention on Supplementary Compensation for Nuclear Damage (CSC).

Under both the 1960 Paris Convention and the 1963 Vienna Convention, the notion of “nuclear damage” only covers personal injury and damage to

property, without the environment being explicitly addressed.⁵ The Paris Convention gives considerable latitude to national legislators to determine the scope of “property damage” which could, if desired, include environmental damage (Emmerechts, 2008: 91-109). The Vienna Convention goes further by allowing states to provide for the compensation of environmental damage either under the scope of “property damage” or under the heading “any other loss or damage so arising or resulting if and to the extent that the law of the competent court so provides”.⁶ Yet neither the Paris Convention nor the Vienna Convention *obliges* their contracting parties to cover environmental damage in their national laws.

Just as the 1986 Chernobyl accident provided the catalyst for the adoption of the aforementioned international instruments focusing on nuclear safety, waste and spent fuel management, emergency response and assistance, the accident also provided the impetus to improve international nuclear liability frameworks by modernising the Paris-Brussels and Vienna Regimes, and by establishing the CSC. One of the main enhancements arising out of the revision or establishment of these regimes concerns compensation for environmental damage. The 1997 Protocol was the first to expand the definition of nuclear damage to encompass the “costs of measures of reinstatement of impaired environment” as well as the “loss of income deriving from an economic interest in any use or enjoyment of the environment, incurred as a result of a significant impairment of that environment”. These new heads of damage were also included in the CSC and later in the 2004 Protocol to amend the Paris Convention (“2004 Protocol”), which has not yet entered into force.

The inclusion of new heads of damage introduces into nuclear third party liability law the “polluter-pays” principle, one of the founding principles of international environmental law. The revised and newly adopted conventions provide guidance for determining the “costs of measures of reinstatement of impaired environment” by defining “measures of reinstatement” as “any reasonable measures which have been approved by the competent authorities of the state where the measures were taken, and which aim to reinstate or restore damaged or destroyed components of the environment, or to introduce, where reasonable, the equivalent of these components into the environment”.⁷ The revised and newly adopted conventions also leave broad discretion to national legislators to determine which measure of reinstatement is deemed to be reasonable, based on the nature and extent of the damage, the effectiveness of such measure and relevant scientific and technical expertise.⁸ When making such determination, national legislators may also refer to similar existing legal frameworks, such as the EU Environmental Liability Directive (2004)⁹ or the Civil Liability Convention for Oil Pollution Damage (1992).¹⁰

The effect of international environmental law instruments on nuclear activities

Access to information regarding nuclear matters

The concepts of transparency and stakeholder involvement are relatively recent in the nuclear field and are examples of the effect that the development of international environmental law has had on nuclear law and nuclear activities.

The notion of public participation in international environmental law can be traced back to the 1972 United Nations Stockholm Declaration on the Human Environment and to the 1992 Rio Declaration on Environment and Development.¹¹ Although they have no legally binding status, both the Stockholm Declaration and the Rio Declaration highlight the importance of procedural environmental law – including the public's right to access environmental information – as part of a global effort to protect the environment in the present and the future.

The Joint Convention was the first international nuclear law instrument that requires contracting parties to make available to the public information about the safety of spent nuclear fuel facilities and radioactive waste management facilities.¹² The main international instrument that grants the public the right to access environmental information is the 1998 Aarhus Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters ("Aarhus Convention"). The provisions of the Aarhus Convention are broken down into three pillars: access to information, public participation in decision making and access to justice.

The Aarhus Convention grants the public the right to request access to any environmental information held by public authorities, in whatever form. Information on nuclear energy projects is generally defined as "environmental", and so covered by the Aarhus Convention, given the potential environmental consequences of such projects in the case of a nuclear accident.¹³ Accordingly, the public may request that public authorities provide detailed information regarding the safety of a nuclear installation, the radiation levels in a given area or potential effects on biodiversity due to the construction of a nuclear power plant at a given location.

Some information may be exempt from release by public authorities, when, for example, the disclosure would adversely affect the confidentiality of the proceedings of public authorities, national defence, public security or the confidentiality of commercial and industrial information to protect a legitimate economic interest. The Aarhus Convention specifies that such grounds for refusal shall be interpreted in a restrictive way, taking into account the public interest as well as whether the information requested relates to emissions into the environment.

Public participation and environmental impact assessments in a transboundary context

In most countries, the public's right to participate in decision making on activities that are likely to cause a significant adverse impact on the environment, including in the nuclear field, is considered of paramount importance. Public participation significantly contributes to building public trust and confidence in nuclear activities.

The primary international instrument regarding public participation in environmental impact assessments (EIAs) is the 1991 Espoo Convention on Environmental Impact Assessment in a Transboundary Context ("Espoo Convention"). The purpose of the Espoo Convention is to enhance international co-operation and allow environmentally sound decisions to be made, paying careful attention to minimising significant adverse impacts, particularly in a transboundary context. To accomplish this, the Espoo Convention requires that an EIA be carried out for certain types of activities that are planned by a contracting party and are likely to have a significant environmental impact within an area under the jurisdiction of another contracting party. The Espoo Convention specifies what has to be considered at an early stage of the decision-making process, and it obliges countries to notify and consult each other, as well as the public. It also requires that all comments received from the public and authorities, as well as the findings of the assessment, be taken into account when the final decision is made on the planned activity. Because of the potential transboundary consequences of a nuclear accident, the Espoo Convention applies to all activities related to a nuclear installation.¹⁴

The Parties to the Espoo Convention have led several initiatives over the last five years to promote implementation of the convention in the field of nuclear energy. The United Nations Economic Commission for Europe (UNECE), which acts as the Secretariat to the Aarhus and Espoo Conventions, prepared a background note in 2011 on the application of the Convention to nuclear energy related activities. This note reflects the diverse and sometimes conflicting views expressed by the Parties to the Espoo Convention on its application in this area. In June 2014, the Meeting of the Parties to the Convention adopted Decision VI/7 on the application of the convention to nuclear energy related activities.¹⁵ This decision proposes the preparation of good practice recommendations to support the application of the Espoo Convention to nuclear energy related activities, which are expected to be presented in 2017.

In addition, the 2003 Kyiv Protocol on Strategic Environmental Assessment ("Protocol on SEA") requires that a strategic environmental assessment (SEA) be carried out for certain plans and programmes, and possibly for policies and legislation that are likely to have significant environmental effects, including in relation to health. Contracting

parties therefore have to integrate environmental assessments into the development of plans and programmes at the earliest stages, irrespective of whether such plans or programmes are likely to have an impact on the territory of another state. The scope of application of the Protocol on SEA is identical to that of the Espoo Convention, and therefore extends to all activities related to a nuclear installation.

Finally, the Aarhus Convention also includes provisions on public participation in the decision-making process. The public concerned has the right to participate in environmental decision making, including all activities related to a nuclear installation, from construction and operation to decommissioning.¹⁶

It should be noted that the Espoo Convention, the Protocol on SEA and the Aarhus Convention together provide for a comprehensive framework on EIAs and public participation that reaches much further than the obligations found in specific international nuclear law instruments. Both the Joint Convention and the Nuclear Safety Convention require that a contracting party consult other contracting parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation.¹⁷ However, these instruments do not directly address consultation with the public.

Conclusion

Remarkable advances have been made over the past thirty years to take into account international environmental law principles and instruments in the field of nuclear law. Parties to international instruments dedicated to the field of nuclear activities have increasingly recognised the necessity to set high targets in relation to environmental protection. In parallel, international environmental law conventions have extended their reach to all major nuclear activities for peaceful purposes. The strong interrelationship between environmental law and nuclear law results in a complementary framework, where one body of law covers the weaknesses of the other. It can be reasonably expected that this trend will continue in the future.

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Notes

1. See Exposé des Motifs of the Paris Convention on Third Party Liability in the Field of Nuclear Energy, paragraph 1.
2. The full text and latest status of the Assistance Convention can be consulted at the following address: www.iaea.org/publications/documents/treaties/convention-assistance-case-nuclear-accident-or-radiological-emergency.
3. See Article 1(ii) of the Joint Convention.
4. See Article 8 and Article 15 of the Joint Convention.
5. See Article 3 of the Paris Convention and Article 1(k) of the Vienna Convention.
6. See Article 1(k)(ii) of the Vienna Convention.
7. See Article 1(a)(viii) of the Paris Convention as amended by the 2004 Protocol, Article I.1(m) of the Vienna Convention as amended by the 1997 Protocol and Article 1(g) of the CSC.
8. See Article 1(a)(x) of the Paris Convention as amended by the 2004 Protocol, Article I.1(o) of the Vienna Convention as amended by the 1997 Protocol and Article 1(l) of the CSC.
9. Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage. The full text of the directive can be consulted at the following address: www.eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02004L0035-20130718&from=EN.
10. More information on the Civil Liability Convention for Oil Pollution Damage can be accessed at the following address: [www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Civil-Liability-for-Oil-Pollution-Damage-\(CLC\).aspx](http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Civil-Liability-for-Oil-Pollution-Damage-(CLC).aspx).
11. Principle 1 of the Stockholm Declaration states: "Man has the fundamental right to... an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generations (...)". Principle 10 of the Rio Declaration states: "Environmental issues are best handled with participation of all concerned citizens (...). At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities... and the opportunity to participate in decision-making processes (...). Effective access to judicial and administrative proceedings... shall be provided."
12. See Article 6 and Article 13 of the Joint Convention.
13. Article 2 of the Aarhus Convention defines the notion of "environmental information" as including, notably, "[f]actors, such as substances, energy, noise and radiation, and activities or measures, including administrative measures, environmental agreements, policies, legislation, plans and programmes, affecting or likely to affect the elements of the environment (...) and cost-benefit and other economic analyses and assumptions used in environmental decision-making".
14. The list of the activities covered by the Espoo Convention is provided in its Appendix I. Pursuant to Article 1 of the Espoo Convention, any major change to an activity listed under Appendix I of the convention also falls within its scope of application. Appendix I to the convention provides for an exemption concerning research installations for the production and conversion of fissionable and fertile materials whose maximum power does not exceed 1 kilowatt (KW) continuous thermal load.
15. Decision VI/7 is part of the decisions adopted by the Meeting of the Parties to the Espoo Convention at its sixth session (2-5 June 2014). The full text of these decisions can be consulted at the following address: www.unece.org/fileadmin/DAM/env/documents/2014/EIA/MOP/ECE_MP.EIA_20_Add.1%E2%88%92ECE_MP.EIA_SEA_4_Add.1_e.pdf.
16. The list of the activities covered by the Aarhus Convention is provided in its Annex I, which also indicates that "any change to or extension of activities, where such a change or extension in itself meets the criteria/thresholds set out in this annex" shall be subject to the public participation requirements laid out in the convention. Annex I also provides for an exemption concerning research installations for the production and conversion of fissionable and fertile materials whose maximum power does not exceed 1 kW continuous thermal load.
17. Article 17 of the Nuclear Safety Convention and Articles 6 and 13 of the Joint Convention.

Radioactive waste management solutions

by M. Siemann*

One of the more frequent questions that arise when discussing nuclear energy's potential contribution to mitigating climate change concerns that of how to manage radioactive waste. Radioactive waste is produced through nuclear power generation, but also – although to a significantly lesser extent – in a variety of other sectors including medicine, agriculture, research, industry and education. The amount, type and physical form of radioactive waste varies considerably. Some forms of radioactive waste, for example, need only be stored for a relatively short period while their radioactivity naturally decays to safe levels. Others remain radioactive for hundreds or even hundreds of thousands of years.

Public concerns surrounding radioactive waste are largely related to long-lived high-level radioactive waste. Countries around the world with existing nuclear programmes are developing longer-term plans for final disposal of such waste, with an international consensus developing that the geological disposal of high-level waste (HLW) is the most technically feasible and safe solution. This article provides a brief overview of the different forms of radioactive waste, examines storage and disposal solutions, and briefly explores fuel recycling and stakeholder involvement in radioactive waste management decision making.

Different types of radioactive waste

Broadly speaking, there are three types of radioactive waste: low-level waste (LLW), intermediate-level waste (ILW) and HLW. The distinction is made depending on the level of radioactivity and the length of time the waste remains hazardous. LLW and ILW may be further subdivided into categories according to the half-lives of the radionuclides they contain (the half-life of a radioactive isotope is the time it takes for half of any given number of atoms to decay). “Short-lived” waste decays in less than 30 years and “long-lived” waste takes more than 30 years to decay.

Definitions of what constitutes LLW and ILW vary from country to country, but typically LLW comprises such materials as shoe covers, lab coats, cleaning cloths or towels that have been used in an area where radioactive material is present. LLW can normally be handled using rubber gloves and without particular shielding. This type of waste can be either

short-lived or long-lived; however, short-lived waste accounts for most of the volume of LLW. Much of the waste generated during the decommissioning of a nuclear power plant is managed as LLW or even “very low-level waste”. About 90% of the volume of radioactive waste generated in the world each year is LLW, although it contains only about 1% of the total radioactivity.

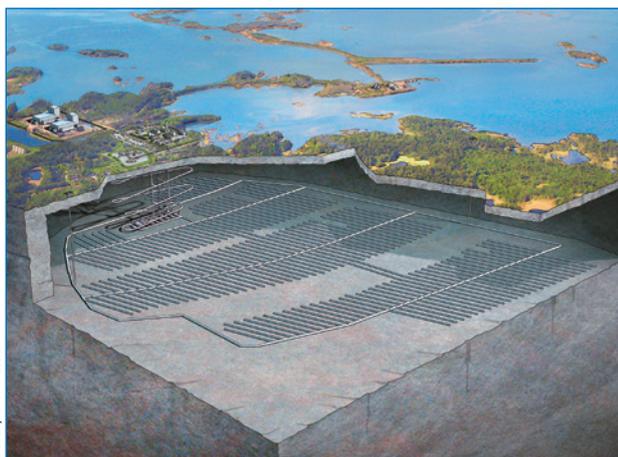
Typical examples of intermediate-level waste are spent ion-exchange resins (used in the clean-up of radioactive liquids), incinerator ash and fuel cladding. ILW usually requires special precautions during handling to limit radiation exposures. Some forms of ILW need long-term isolation because of the long-lived radionuclides that they contain.

High-level waste refers to the highly radioactive waste requiring shielding and permanent isolation from the biosphere. Typically this is the spent nuclear fuel produced by nuclear power plants, or the waste that is produced during the reprocessing of spent fuel. Most of these materials also need a longer period of cooling.

Although the relative amount of HLW is small with respect to the total volume of radioactive waste produced in nuclear power programmes, it contains up to 99% of the radioactivity. The half-lives required for the radioactivity of HLW to decay to a level that would have been generated by the original ore from which the nuclear fuel was produced may be up to 100 000 years.

Current global waste production is 8 000 to 10 000 million tonnes per year (excluding overburden from mining and mineral extraction wastes), of which about 400 million tonnes per year is hazardous waste and about 0.4 million tonnes per year is radioactive waste from nuclear power plants and their fuel cycle support facilities (excluding mining and extraction wastes). Compared with industrial toxic and hazardous waste, the volume of radioactive waste from nuclear power generation is therefore relatively small.

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Planned area for the spent nuclear fuel repository in Östhammar.

Radioactive waste must be safely stored pending shipment, processing or disposal. “Short-term storage” is provided at many facilities before the waste is shipped off-site for treatment or disposal. In other cases, radioactive waste may be placed in “long-term storage” to allow the level of radioactivity in the waste to decay. If it is intended to retrieve the waste at a later date, it is considered stored rather than in final disposal. Waste storage is not an alternative to disposal; rather it is a step in the management strategy leading to final disposal.

When a disposal site is available, ILW and LLW can be sent there directly at regular intervals. If not, interim storage in a structure above ground is necessary. For HLW and spent nuclear fuel, it has always been recognised that interim storage to permit decay of radiation and heat generation is necessary.

Because of the low volume (compared with other industrial processes) of waste produced and the special processing and disposal methods required, it is often more economical to transport radioactive waste to central processing, storage or disposal facilities. All such transport must be carried out in accordance with the relevant national and international model regulations (the ADR for road transport, the ADN for inland waterways, the RID for rail transport, the IMO dangerous goods code for sea transport and the ICAO technical instructions for air transport).¹ The transboundary movements of radioactive waste in Europe are also subject to European Union regulations.

Disposal of radioactive waste

Disposal is the final step in radioactive waste management. Usually it is understood to mean putting waste away without any intention of retrieving it, and without the need for long-term surveillance or monitoring.

Many countries are already disposing low-level and short-lived intermediate-level waste in repositories. On a volumetric basis, some three-quarters of all the radioactive waste created since the start of the nuclear industry has already been sent for disposal. In the case of some LLW from nuclear reactors, medical applications and research, the half-lives of the radioactive substances in the waste are short enough that effective disposal is achievable by deposition in supervised near-surface vaults, while decay takes place.

The current preferred option for the eventual disposal of HLW is emplacement in repositories deep underground in well-chosen geological conditions. In general, the geological disposal concept involves treating the waste in order to achieve a suitable physical and chemical form, packaging it inside long-lived engineered barriers emplaced deep underground, and sealing these facilities with appropriate materials. In these underground surroundings, as opposed to the surface environment, conditions remain stable over the long periods needed to allow the radioactivity to decay to a sufficiently low level.

Deep geological disposal

“Geological disposal... represents an ethically correct approach (taking responsibility within the generation producing the waste) and it should be pursued now proportionately with each country’s situation.” – NEA Radioactive Waste Management Committee, 2008.

Three deep geological disposal facilities – in Finland, France and Sweden – are scheduled to start operating between 2020 and 2025. These projects are currently the most advanced disposal programmes in the world.

In Finland, construction is underway on the ONKALO facility in the municipality of Eurajoki. The Underground Rock Characterisation Facility is being built for the final disposal of spent nuclear fuel. Posiva Oy started construction in 2004, and the facility is scheduled to begin accepting spent fuel in 2020.

Located in the Meuse/Haute-Marne region in the east of France, the Industrial Geological Storage Centre (Centre industriel de stockage géologique, or Cigéo) is scheduled to start operating in 2025. The facility will accept HLW and long-lived ILW.

The final repository for Sweden’s spent nuclear fuel is set to be built in Forsmark, in the municipality of Östhammar. The site was selected in 2009 and applications have been submitted to build the final repository. The project is managed by the Swedish nuclear fuel and waste management company, SKB, and the facility is due to be completed in 2025.

Recycling of nuclear fuel

In the longer term, nuclear fuel also offers important possibilities for recycling, since with current water-cooled reactors, only a small fraction of the uranium is usually consumed in the reactor. This could vastly increase the energy potential of existing uranium stocks and known resources, from a few hundred to several thousand years of nuclear fuel demand. It could also greatly reduce the radiotoxicity of the resulting HLW. Present recycling techniques use sensitive technologies, and are unlikely to expand significantly in the short to medium term. However, the expansion of recycling in the longer term could be facilitated by further technological development of recycling technologies, and the deployment of fast neutron reactors, one of the generation IV reactor technologies currently being developed. Such deployment of advanced technologies would have important implications for the long-term sustainability of nuclear energy, as it could multiply by between 30 to 60 times, and perhaps more, the amount of energy extracted from each tonne of uranium, thereby making available uranium resources sufficient to power fast neutron reactors for several thousands of years.

Stakeholder involvement

The NEA Forum on Stakeholder Involvement (FSC) facilitates the sharing of experience in addressing the societal dimension of radioactive waste management. It explores means of ensuring an effective partnership with the public with a view to strengthening confidence in decision-making processes. The time when exchanges between waste management institutions and civil society were confined to rigid mechanisms is coming to an end. A more complex interaction now involves players at national, regional and local levels, with a broader, more realistic view of decision making taking shape. The FSC is contributing to such trends. It has agreed, for example, on eight action goals that should be pursued in order to identify waste management solutions widely regarded as legitimate.

FSC action goals:

- to have an open debate on the national policy regarding energy production and the future of nuclear energy, including waste management;
- to reach a common understanding that the status quo is unacceptable and that an important problem needs to be solved;
- to define clearly the actors and goals of the waste management programme, including the source, type and volume of waste;
- to define an iterative approach that will match a suitable waste management method with a technically acceptable site;
- to agree and apply a fair and open methodology so as to identify one or more site(s) that are both technically and politically acceptable;

- to provide forums that will enable communities to express their issues and concerns so that these can be addressed;
- to negotiate tailor-made benefit packages and community oversight schemes with both host and neighbouring communities in order to enhance their well-being and socio-economic situation, and to design facilities so that they will bring added value to the community;
- to fully respect agreements when implementing decisions.

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Note

1. ADR – European Agreement concerning the International Carriage of Dangerous Goods by Road; ADN – European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways; RID – Regulations concerning the International Carriage of Dangerous Goods by Rail; IMO – International Maritime Organisation; ICAO – International Civil Aviation Organization.

Nuclear regulatory organisations: Learning from stakeholders to enhance communication

by A. Lorin*

Since its creation 15 years ago, the NEA Committee on Nuclear Regulatory Activities (CNRA) Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC) has been addressing a broad range of communication issues, with two reports recently issued on *Nuclear Regulatory Organisations, the Internet and Social Media: The What, How and Why of Their Use as Communication Tools* and on *Nuclear Regulatory Organisations and Communication Strategies*.

After the Fukushima Daiichi nuclear power plant accident in 2011, nuclear regulatory organisations around the world reaffirmed the need to strengthen stakeholder outreach and communication, and to create more robust avenues for stakeholder involvement in regulatory matters. The WGPC proposed a means for stakeholders to play a more active role in the group by holding one-day workshops in conjunction with regular meetings. These workshops offer a platform for stakeholder exchange with communication experts from nuclear regulatory organisations (NROs). The objective is to stimulate co-operation and improve communication by better understanding stakeholder perceptions, needs and expectations, and by discussing how to use traditional and social media more effectively.

The first two pilot workshops in Europe and North America

The first stakeholder communication workshop was held in April 2014 in Europe, and the second in April 2015 in North America. Nearly 50 participants from 18 countries attended the first workshop at the French Nuclear Safety Authority (ASN) headquarters in Paris. Participants included a wide range of European stakeholders representing the media, communications experts, local information committees and non-governmental organisations from Belgium, France, the Slovak Republic, Spain and Sweden.

A total of 45 participants from 12 countries shared their views at the second workshop held at the United States Nuclear Regulatory Commission (NRC) headquarters in Washington, DC. Elected officials and stakeholders from local information committees and non-governmental organisations attended from both Canada and the United States.

The first two pilot workshops have proven that a continuous and close interaction between regulators and stakeholders is an important element in helping

to build public confidence in nuclear regulatory organisations. WGPC membership is largely made up of NRO representatives from member countries, and so the workshops were considered highly valuable with practical elements that would allow for real improvements in the communication practices of regulators.

Some of the key lessons learnt which were highlighted during the workshops included reputation and trustworthiness; needs, constraints and knowledge building; transparency and emotional aspects; traditional and social media; public involvement and risk culture.

Reputation and trustworthiness

In order to build trust and credibility, nuclear regulatory organisations must inform the public about nuclear safety and other related issues. It is a constant challenge for a nuclear regulatory organisation to strengthen its reputation and to be perceived as trustworthy. For this reason, credibility should be built before an event happens and maintained even during a crisis.

In many countries, the nuclear regulatory organisation is not well-known, partially because of a tendency to change names as a result of administrative reorganisation, which ultimately creates confusion. Nuclear regulatory organisations should avoid such changes and work on improving their overall image with regard to the public. The reputation of an NRO can be challenged during a crisis, making it essential that the regulator ensure a rapid and adequate response. It is also important for the NRO to be perceived as an independent body without any connection to the nuclear industry.

Ultimately, nuclear regulatory organisations must keep in mind that if they do not communicate with the public, the latter will often turn to other sources of information. Sometimes, these sources

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The NEA WGPC European workshop with French Nuclear Safety Authority Director-General and CNRA Chairman Jean-Christophe Niel, along with participants in the workshop, April 2014, Paris.

lack independence and the information they provide is not as objective as the information that might have been provided by the regulator.

Needs, constraints and knowledge building

The need to establish a positive relationship between nuclear regulatory organisations and stakeholders based on openness, rapid responses and proactive communication was one of the most important factors that was underlined at workshops in Europe and North America. Because of budget cuts that have reduced the number of journalists and put them under considerable pressure, the media also needs to be provided with accurate, clear and timely information from regulators. It needs up-to-date information and not, for example, information from an annual report that was already covered in the previous year.

The role of the NRO communication officer is crucial in this regard, as he or she needs to develop a stable relationship with journalists. Technical information that explains and gives sense to benefits in terms of nuclear safety, radiation protection and environmental protection is often highly appreciated by the public. A glossary of technical terms, graphics and videos to explain technical material can also be useful in this regard. Steps should also be taken to work towards an educational approach based on plant tours, training and webinars for reporters.

Transparency and emotional aspects

Another key lesson for nuclear regulatory organisations concerns transparency, which can be particularly demanding during emergency situations. In order to emphasise its independence and trustworthiness on a regular basis, the NRO

needs to make its position clear in the debate among pro- and anti-nuclear factions.

Since nuclear topics are complex and can be misunderstood or even instill fear in some people, nuclear regulatory organisations must provide reliable, accurate and balanced information, particularly during emergency events. Timeliness is important during emergencies, as reporters can sometimes point to gaps between what the nuclear regulatory organisation knew and what was made available to the media. Nuclear regulatory organisations must ensure that technical expertise remains available even in the midst of an event.

While the media does not necessarily expect empathy from regulators, it does expect the NRO to be capable of making decisions while recognising the emotional aspects involved in a situation. Infographics or other data are effective ways to explain an incident. Transparency in relation to board and other discussions is also appreciated by the media.

Nuclear regulatory organisations should take the time to listen to the public before incidents happen in order to identify the real concerns of the public. This could serve to anticipate what kinds of emotions the regulators will likely be dealing with in the case of an accident.

Traditional and social media

The Fukushima Daiichi nuclear power plant accident underlined a strong need to provide clear messages that are delivered in a timely manner and can be understood by non-experts. National regulators must ensure the consistency of these messages, because the globalisation of information and the use of new technologies such as social media has allowed for information to be disseminated instantly, anywhere in the world.



The NEA WGPC North American workshop with NEA Director-General William D. Magwood, IV, United States Nuclear Regulatory Agency Chairman Steven Burns and participants, April 2015, Washington, DC.



Social media is more than a new channel of communication. It is a mass communication tool that puts a certain degree of pressure on the nuclear regulatory organisation, but it can also contribute to fulfilling the NRO mission: informing, educating and preventing accidents. Social media can help NROs to reach a larger audience. It can also be a means to build the regulator’s e-reputation and to have the NRO perceived as credible, transparent and independent.

While social media can help to share expertise and deliver accurate information, it can also have constraints. For instance, because people can directly reach organisations to express their opinions and dissatisfaction, or to ask a wide range of questions, the increased inflow of information creates an enormous amount of work for an NRO. Moreover, when people ask questions about nuclear safety, they expect immediate feedback. Not receiving a timely response can cause anxiety or increase suspicion that something is being hidden. At the same time, it is difficult for an NRO to provide a rapid answer in a crisis because it needs the time to assess the situation before offering feedback.

Using social media platforms and monitoring e-reputations is thus time consuming, and requires online communication and community management expertise. Depending on the size of the organisation and the audience, several employees may be required to manage related activities, which could involve content production and publishing, monitoring, community development and moderation.

Nuclear regulatory organisations should also keep in mind that journalists generally prefer to be informed first by “traditional tools” (e.g. e-mail or press releases) rather than having to learn about an incident through a social media platform.

Public involvement and risk culture

Enhancing knowledge about nuclear issues and the safety culture can be an arduous task, particularly during emergency situations when nuclear regulatory organisations must find a good balance between denial and panic, providing reliable and objective information and offering the correct assessment of the seriousness of an event.

The goal is to make citizens responsible for their own protection, for instance by enhancing their awareness of countermeasures in the case of an emergency situation. It is a long-term goal that needs to be conducted both in routine and in emergency situations. An important part of this work is proposing public debates, which can be very challenging both in terms of organisation and follow-up.

Conclusion

While nuclear regulatory organisations may have a common willingness to improve their communication methods and to build constructive relationships with stakeholders, every country has its own practices and cultural background, and thus its own challenges. Following the first workshop in Paris, which brought together European stakeholders, and the second in North America, the NEA is now organising a third workshop in Asia (Japan) to be held in April 2016. This third workshop will enable the NEA to gather stakeholder views from a third continent. A report on the workshops’ findings will be issued after the completion of this third workshop, thus giving a broader idea of how to improve the overall communication methods of nuclear regulatory organisations around the world.

Towards the renewal of the NEA Thermochemical Database

by M.E. Ragoussi, D. Costa and M. Bossant*

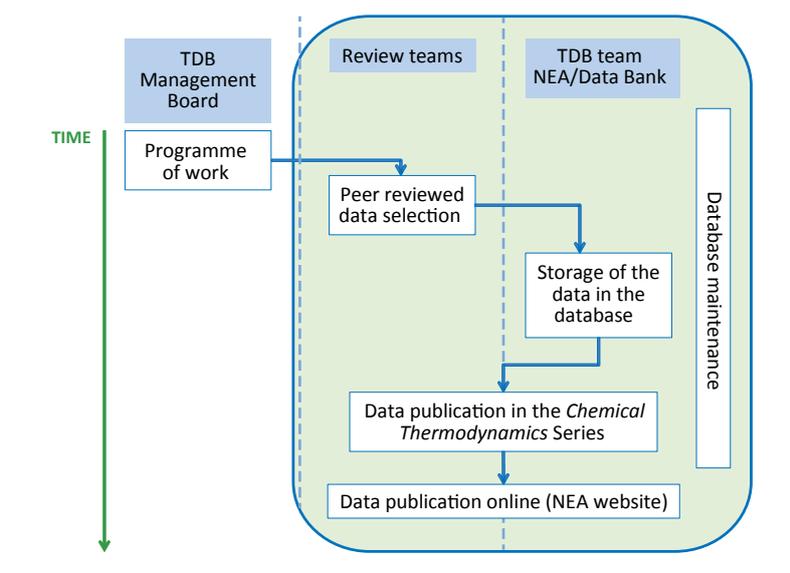
The Thermochemical Database (TDB) Project was created three decades ago as a joint undertaking of the NEA Radioactive Waste Management Committee and the NEA Data Bank.¹ The project involves the collection of high-quality and traceable thermochemical data for a set of elements (mainly minor actinides and fission products) relevant to geo-physical modelling of deep geological repositories. Funding comes from 15 participating organisations, primarily national nuclear waste authorities and research institutions.

The quantities that are stored in the TDB database are: the standard molar Gibbs energy ($\Delta_f G_m^\circ$) and enthalpy of formation ($\Delta_f H_m^\circ$), the standard molar entropy (S_m°) and, when available, the heat capacity at constant pressure ($C_{p,m}^\circ$), together with their uncertainty intervals. Reaction data are also provided: $\log_{10} K_r^\circ$ (equilibrium constant of reaction), $\Delta_r G_m^\circ$ (molar Gibbs energy of reaction), $\Delta_r H_m^\circ$ (molar enthalpy of reaction) and $\Delta_r S_m^\circ$ (molar entropy of

reaction). Data assessment is carried out by teams of expert reviewers through an in-depth analysis of the available scientific literature, following strict guidelines defined by the NEA to ensure the accuracy and self-consistency of the adopted datasets.² Thermochemical data that has been evaluated and selected over the years have been published in the 13 volumes of the *Chemical Thermodynamics* series.³ They are also stored in a database that is updated each time the study of a new element is completed (see Figure 1).⁴ The TDB selected data are made available to external third parties through the NEA website where data extracted from the database can be displayed and downloaded as plain text files.

Following recent recommendations of the Task Force on the Future Programme of the NEA Data Bank to enhance scientific expertise and user services, a renewal of the software managing the TDB database is being undertaken. The software currently used was designed 20 years ago and is becoming

Figure 1: TDB project workflow for the production of one volume of the *Chemical Thermodynamics* series



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obsolete. Redesigning the application will provide an opportunity to correct current shortcomings and to develop new functionalities that will greatly improve the quality of the tool, both on the technical and conceptual levels. The main goal of the renewal is to meet the technological standards of modern thermochemical databases, including the preparation of a thorough documentation of the technical and functional features of the tool, and to envisage greater flexibility and options for end users, accompanied by a more robust and reliable management of the data to facilitate its maintenance. The upgrading work that will be performed involves redesigning both the Oracle database (back end) and the web interface (front end).

The main axes of improvement are detailed below.

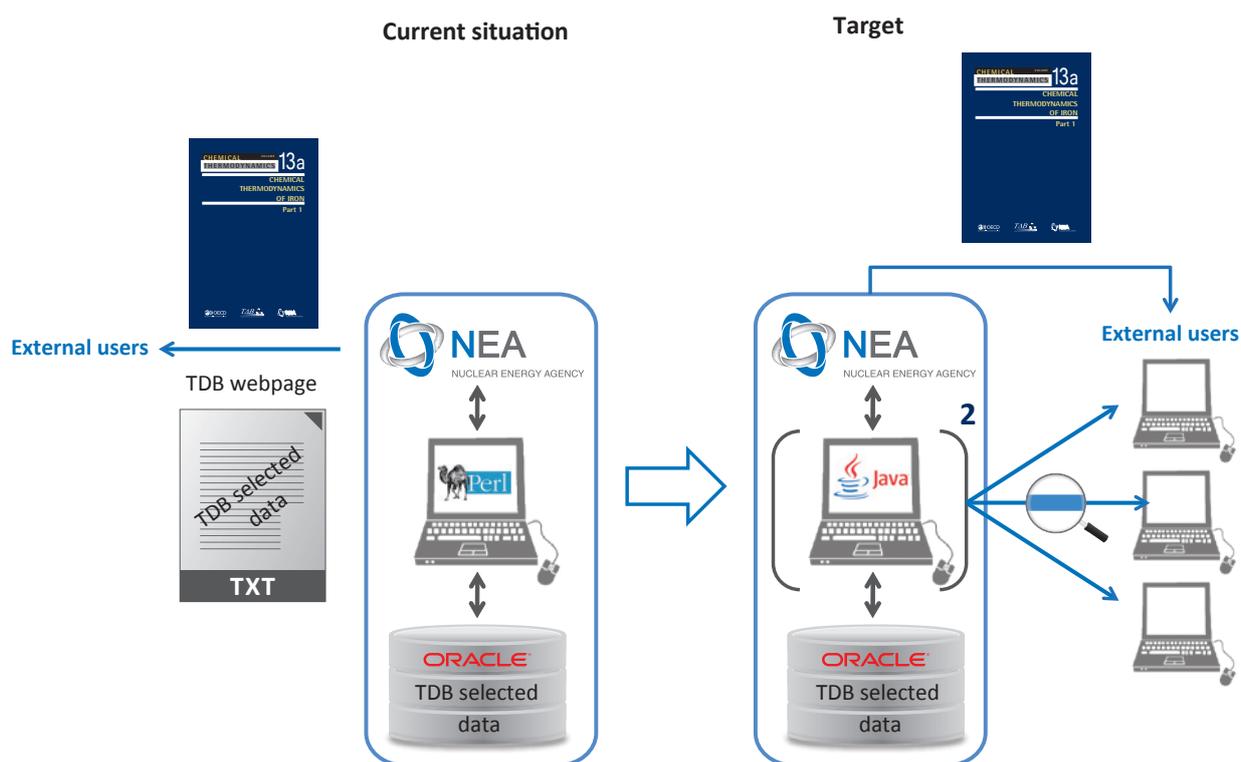
Improving TDB functionalities

- **Access to the database and advanced search capabilities for external users:** In the current approach, TDB data users do not have direct access to the database, and they can only retrieve selected values through the published *Chemical Thermodynamics* volumes or the TDB webpage, where the data is exported from the actual database. This prevents them from performing advanced searches. The possibility for external users to access the database in a read-only manner will be implemented in the

new software (see Figure 2). A search interface will be developed, allowing external users to select data by combining multiple criteria, and then to export matching data.

- **Data file format:** TDB data are not provided in a suitable input file format for most geochemical modelling software available. Within the scope of the new system, a functionality is envisaged that will allow for the exporting of TDB data, as subsets or as a whole, in a format compatible with PHREEQC,⁵ which is one of the most popular geochemical modelling tools. Formats for other common modelling tools may also be considered in the future. This aspect of the update is particularly important as data will be more easily usable for modelling, and thus the range of users can become broader.
- **Thermodynamic consistency checks:** Internal consistency of the published data is a primary concern. Consistency checks are implemented to some extent in the current software and involve calculations that link formation and reaction data. The new system will be enriched with a set of additional automatic checks that will enable a more robust verification of the internal thermodynamic consistency of stored data, hence improving the scientific quality of the database. Moreover, control of the overall integrity and numerical consistency of the data will be reinforced by implementing explicit constraints in the Oracle database layer of the application.

Figure 2: Change of concept of the TDB database



Improving TDB management aspects

- **Technical and functional documentation:** Several adjustments have been carried out since the original development of the web interface employed to manage data. These adjustments were not always documented and were not implemented in an entirely controlled manner, which has created a number of bugs in the system. The technical maintenance has thus become challenging and time-consuming. For the new system, the technical and functional framework will be documented in detail, allowing for higher quality and more efficient maintenance, as well as easier transferability across staff over time.
- **Programming language:** The web interface will be programmed in Java, which is one of the most commonly used enterprise-oriented languages adapted to the implementation of web applications. Java programming is also part of the core competencies of Data Bank IT staff, which should facilitate maintenance of the application.
- **Bibliographic archive:** The TDB project possesses an ample archive of scientific publications, which is used for the preparation of the *Chemical Thermodynamics* series. Storage, as well as export of bibliographic data for publication is a separate function, presently unrelated to the TDB database. Bibliographic data are in fact stored in a bibtex file,⁶ following an outdated approach that is prone to errors. The renewal of the database will provide an opportunity to merge the two functions, implementing a new reference management software within the database.

A proposal including the scope, tasks, milestones, schedule and budget for the renewal of the database was approved by the TDB Management Board in June 2015. The project will be led by the TDB team with the technical assistance of the Data Bank IT team, and under the supervision and scientific guidance of the TDB Executive Group.

Conclusion

As an international reference within the radioactive waste management community, it has proven vital to introduce certain improvements to the TDB database in order to maintain the high quality and reliability that have always characterised the distributed data. The renewal of the database is therefore being undertaken to meet the current standards for high-quality thermochemical databases and to broaden the possibilities offered to end users.

Notes

1. Ragoussi, M.-E. and S. Brassinnes (2015), "The NEA Thermochemical Database Project: 30 Years of Accomplishments", *Radiochim. Acta*, Vol. 103, Issue 10, Pages 679-685.
2. To consult TDB project guidelines (1999) see www.oecd-nea.org/dbtdb/guidelines/.
3. TDB publications are available at www.oecd-nea.org/dbtdb/info/publications/.
4. The TDB electronic data can be accessed at www.oecd-nea.org/dbtdb/tdbdata/tdbdata.html.
5. For more information on PHREEQC, see http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/.
6. For more information on bibtex files, see www.bibtex.org.

NEA joint projects: nuclear safety, nuclear science, radioactive waste management, radiological protection

Project	Participants	Budget
<p>Advanced Thermal-hydraulic Test Loop for Accident Simulation (ATLAS) Project Contact: neil.blundell@oecd.org Current mandate: April 2014-March 2017</p>	Belgium, China, Finland, France, Germany, Hungary, India, Japan, Korea, Russia, Spain, Sweden, Switzerland, United Arab Emirates, United States.	EUR 2.5 million
<p>Behaviour of Iodine Project (BIP) Contact: axel.breest@oecd.org Current mandate: January 2016-December 2018</p>	Belgium, Canada, Finland, France, Germany, Japan, Korea, Spain, Sweden, United Kingdom, United States.	EUR 1 million
<p>Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant (BSAF) Contact: andrew.white@oecd.org Current mandate: April 2015-March 2018</p>	Canada, China, Finland, France, Germany, Japan, Korea, Russia, Spain, Switzerland, United States.	EUR 270 K
<p>Cable Ageing Data and Knowledge (CADAK) Project Contact: olli.nevander@oecd.org Current mandate: January 2015-December 2017</p>	Canada, France, Japan, Korea, Norway, Slovak Republic, Spain, Switzerland and United States.	EUR 360 K
<p>Cabri Water Loop Project Contact: martin.kissane@oecd.org Current mandate: January 2016-March 2018</p>	Czech Republic, Finland, France, Germany, Japan, Korea, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States.	≈ EUR 74 million
<p>Component Operational Experience, Degradation and Ageing Programme (CODAP) Contact: olli.nevander@oecd.org Current mandate: February 2015-December 2017</p>	Canada, Chinese Taipei, Czech Republic, Finland, France, Germany, Japan, Korea, Slovak Republic, Spain, Sweden, Switzerland, United States.	EUR 130 K /year
<p>Co-operative Programme on Decommissioning (CPD) Contact: inge.weber@oecd.org Current mandate: January 2014-December 2018</p>	Belgium, Canada, Chinese Taipei, Denmark, European Commission, France, Germany, Italy, Japan, Korea, Slovak Republic, Spain, Sweden, United Kingdom, United States.	≈ EUR 75 K /year

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

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

Objectives

- Provide experimental data for resolving key light water reactor (LWR) thermal-hydraulics safety issues related to multiple, high-risk failures, notably those highlighted by the Fukushima Daiichi nuclear power plant (NPP) accident.
- Focus in particular on the validation of simulation models and methods for complex phenomena of high safety relevance to thermal-hydraulic transients in design basis accidents and design extension conditions.

- Obtain a more detailed and mechanistic understanding of iodine adsorption/desorption on containment surfaces by means of new experiments with well characterised containment paints and paint constituents, and novel instrumentation (spectroscopic methods).
- Obtain a more detailed and mechanistic understanding of organic iodide formation by means of new experiments with well characterised containment paints and paint constituents, and novel instrumentation (chromatographic methods).
- Develop a common understanding of how to extrapolate with confidence from small-scale studies to reactor-scale conditions.

- Analyse the accident progression of the Fukushima Daiichi NPP accident utilising the common information database.
- Improve the understanding of the severe accident (SA) phenomena which occurred during the accident, through comparison with participants' analysis results and with measured plant data.
- Contribute the above results to the improvement of methods and models of the SA codes applied in each participating organisation in order to reduce uncertainties in SA analysis and to validate the SA analysis codes by using data measured through the decommissioning process.
- Contribute results of the analysis on accident progression, the status in the reactor pressure vessels (RPVs) and the primary containment vessels (PCVs), and the status of debris distribution to a future debris removal plan.

- Establish the technical basis for assessing the qualified life of electrical cables in light of the uncertainties identified following the initial (early) qualification testing. This research will investigate the adequacy of the margins and their ability to address the uncertainties.
- Enter for a number of member countries cable data and information in the system, e.g. technical standards being applied in the qualification of cables and inspection methods being used regularly.
- Estimate the remaining qualified lifetime of cables used in NPPs. The cable condition-monitoring techniques shared by the participants within CADAK will become an up-to-date encyclopaedic source to monitor and predict the performance of numerous unique applications of cables.
- Analyse the information collected to develop topical reports in co-ordination with the CSNI Working Group on Integrity and Ageing of Components and Structures (WGIAGE).

- Extend the database for high burn-up fuel performance in reactivity-induced accident (RIA) conditions.
- Perform relevant tests under coolant conditions representative of pressurised water reactors (PWRs).
- Extend the database to include tests done in the Nuclear Safety Research Reactor (Japan) on boiling water reactor (BWR) and PWR fuel.

- Collect information on passive metallic component degradation and failures of the primary system, reactor pressure vessel internals, main process and standby safety systems, and support systems (i.e. ASME Code Class 1, 2 and 3 or equivalent), as well as non-safety-related (non-code) components with significant operational impact.
- Establish a knowledge base for general information on component and degradation mechanisms such as applicable regulations, codes and standards, bibliography and references, R&D programmes and pro-active actions, information on key parameters, models, thresholds and kinetics, fitness for service criteria, and information on mitigation, monitoring, surveillance, diagnostics, repair and replacement.
- Develop topical reports on degradation mechanisms in close co-ordination with the WGIAGE.

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

NEA joint projects

Project	Participants	Budget
<p>Fire Incidents Records Exchange (FIRE) Project Contact: neil.blundell@oecd.org Current mandate: January 2016-December 2019</p>	Canada, Czech Republic, Finland, France, Germany, Japan, Netherlands, Korea, Spain, Sweden, Switzerland, United States.	≈EUR 336 K
<p>Fire Propagation in Elementary, Multi-room Scenarios (PRISME) Project Contact: neil.blundell@oecd.org Current mandate: July 2011-June 2016</p>	Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden, United Kingdom.	EUR 7 million
<p>Halden Reactor Project Contact: axel.breest@oecd.org Current mandate: January 2015-December 2017</p>	Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Japan, Kazakhstan, Norway, Korea, Russia, Slovak Republic, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States.	≈EUR 55 million
<p>High Energy Arcing Fault Events (HEAF) Project Contact: neil.blundell@oecd.org Current mandate: July 2012-December 2016</p>	Canada, France, Germany, Japan, Korea, Spain, United States.	Costs covered by the US NRC and in-kind contributions.
<p>Hydrogen Mitigation Experiments for Reactor Safety (HYMERES) Project Contact: axel.breest@oecd.org Current mandate: January 2013-December 2016</p>	Canada, China, Czech Republic, Finland, France, Germany, India, Japan, Korea, Russia, Spain, Sweden, Switzerland.	EUR 4 million
<p>Information System on Occupational Exposure (ISOE) Contact: edward.lazo@oecd.org Current mandate: January 2016-December 2019</p>	Armenia, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Lithuania, Mexico, Netherlands, Korea, Pakistan, Romania, Russia, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States.	≈EUR 400 K /year
<p>International Common-cause Failure Data Exchange (ICDE) Project Contact: axel.breest@oecd.org Current mandate: January 2015-December 2018</p>	Canada, Czech Republic, Finland, France, Germany, Japan, Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	EUR 330 K

Objectives

- Collect fire event experience (by international exchange) in the appropriate format and in a quality-assured and consistent database.
- Collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention.
- Generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences.
- Establish a mechanism for the efficient feedback of experience gained in connection with fire, including the development of defences against their occurrence, such as indicators for risk informed and performance based inspections.
- Record the characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies.

- Answer questions concerning smoke, fire and heat propagation inside a plant, by means of experiments tailored for code validation purposes for fire modelling computer codes.
- Undertake experiments related to smoke and hot gas propagation, through a horizontal opening between two superimposed compartments.
- Provide information on heat transfer to cables and on cable damage.
- Provide information on the effectiveness of fire extinguishing systems.

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

- extended fuel utilisation: basic data on how the fuel performs, both under normal operation and transient conditions, with emphasis on extended fuel utilisation in commercial reactors;
- degradation of core materials: knowledge of plant materials behaviour under the combined deteriorating effects of water chemistry and nuclear environment, also relevant for plant lifetime assessments;
- man-machine systems: advances in computerised surveillance systems, virtual reality, digital information, human factors and man-machine interaction in support of control room upgradings.

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

- use data from the experiments and past events to develop a mechanistic model to account for the failure modes and consequence portions of HEAFs;
- improve the state of knowledge and provide better characterisation of HEAFs in fire probabilistic risk assessment (PRA) and US National Fire Protection Association NFPA 805 license amendment request applications;
- examine the initial impact of the arc to primary equipment and the subsequent damage created by the initiation of an arc (e.g. secondary fires).
- use international collaboration to expand on the pool of available test data and acquire authorship involvement in the development of a new US NUREG that consequently has international standing and applicability.

Improve the understanding of hydrogen risk phenomenology in containment in order to enhance modelling in support of safety assessments that will be performed for current and new NPPs. With respect to previous projects related to hydrogen risk, HYMERES introduces three new elements:

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

- Collect, analyse and exchange occupational exposure data and occupational exposure management experience at NPPs.
- Provide broad and regularly updated information on methods to improve the protection of workers and on occupational exposure in NPPs.
- Provide a mechanism for dissemination of information on these issues, including evaluation and analysis of the data assembled and experience exchanged, as a contribution to the optimisation of radiation protection.

- Provide a framework for multinational co-operation.
- Collect and analyse common-cause failure (CCF) events over the long term so as to better understand such events, their causes and their prevention.
- Generate qualitative insights into the root causes of CCF events which can then be used to derive approaches or mechanisms for their prevention or mitigation of their consequences.
- Establish a mechanism for the efficient feedback of experience gained in connection with CCF phenomena, including the development of defences against their occurrence, such as indicators for risk-based inspections.
- Generate quantitative insights and record event attributes to facilitate the quantification of CCF frequencies in member countries. Use the ICDE data to estimate CCF parameters.

NEA joint projects

Project	Participants	Budget
<p>Loss of Forced Coolant (LOFC) Project Contact: neil.blundell@oecd.org Current mandate: March 2011-March 2016</p>	Czech Republic, France, Germany, Hungary, Japan, Korea, United States.	EUR 3 million
<p>Primary Coolant Loop Test Facility (PKL) Project Contact: neil.blundell@oecd.org Current mandate: April 2012-April 2016</p>	Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	EUR 3.9 million
<p>Source Term Evaluation and Mitigation (STEM) Project Contact: axel.breest@oecd.org Current mandate: January 2016-December 2019</p>	Canada, Czech Republic, Finland, France, Germany, United States.	EUR 3.5 million
<p>Studsvik Cladding Integrity Project (SCIP) Contact: axel.breest@oecd.org Current mandate: July 2014-June 2019</p>	Czech Republic, Finland, France, Germany, Japan, Norway, Korea, Russia, Spain, Sweden, Switzerland, United Kingdom, United States.	≈EUR 12 million
<p>Thermochemical Database (TDB) Project Contact: maria-eleni.ragoussi@oecd.org Current mandate: April 2014-March 2018</p>	Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, United Kingdom, United States.	EUR 1.5 million
<p>Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project Contact: simone.massara@oecd.org Current mandate: January 2013-December 2016</p>	Canada, France, Japan, Netherlands, Korea, United States.	≈EUR 380 K
<p>Thermal-hydraulics, Hydrogen, Aerosols, Iodine (THAI) Project Contact: neil.blundell@oecd.org Current mandate: February 2016-July 2019</p>	Canada, Czech Republic, Finland, France, Germany, Hungary, Japan, Netherlands, Korea, Sweden, United Kingdom.	≈EUR 3.6 million

Objectives

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

- provide experimental data to clarify the anticipated transient without scram (ATWS) in the case of an LOFC with occurrence of reactor re-criticality;
- provide experimental data to validate the key assumptions in computer codes predicting the behaviour of reactor kinetics, core physics and thermal-hydraulics related to protective measures for safety;
- provide experimental data to verify the capabilities of these codes regarding the simulation of phenomena coupled between reactor core physics and thermal-hydraulics.

- Investigate safety issues relevant for current PWR plants as well as for new PWR design concepts.
- Focus on complex heat transfer mechanisms in the steam generators and boron precipitation processes under postulated accident situations.

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

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

- Generate high-quality experimental data to improve the understanding of the dominant failure mechanisms for water reactor fuels and devise means for reducing fuel failures.
- Achieve results of general applicability (i.e. not restricted to a particular fuel design, fabrication specification or operating condition).
- Achieve experimental efficiency through the judicious use of a combination of experimental and theoretical techniques and approaches.

Produce a database that:

- contains data for elements of interest in radioactive waste disposal systems;
- documents why and how the data were selected;
- gives recommendations based on original experimental data, rather than on compilations and estimates;
- documents the sources of experimental data used;
- is internally consistent;
- treats all solids and aqueous species of the elements of interest for nuclear waste storage performance assessment calculations.

Make available a comprehensive, internationally recognised thermodynamic database and associated phase diagrams on nuclear fuel materials for the existing and future generation of nuclear reactors. Specific technical objectives this project intends to achieve are:

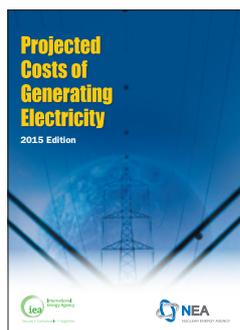
- predict the solid, liquid and/or gas phases formed during fuel/cladding chemical interaction under normal and accident conditions;
- improve the control of the experimental conditions during the fabrication of the fuel materials at high temperature;
- predict the evolution of the chemical composition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

Address remaining questions and examine experimental data relevant to nuclear reactor containments under severe accident conditions concerning:

- release of gaseous iodine from a flashing jet;
- deposition of molecular iodine on aerosol particles;
- hydrogen combustion during spray operation;
- onset of passive autocatalytic recombiner (PAR) operation under extremely low oxygen conditions.

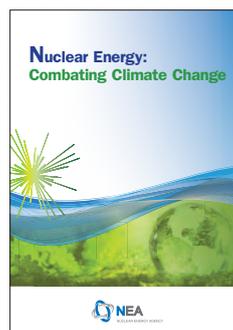
New publications

General interest



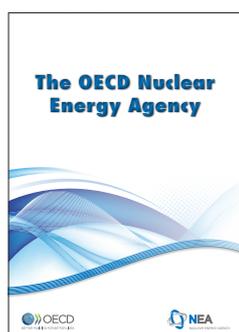
Projected Costs of Generating Electricity 2015 Edition

NEA No. 7057.
212 pages.



Nuclear Energy: Combating Climate Change

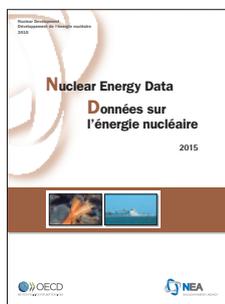
NEA No. 7208.
16 pages.



The OECD Nuclear Energy Agency

8 pages.
Also available in French.

Nuclear development and the fuel cycle

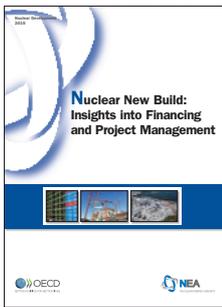


Nuclear Energy Data 2015 Données sur l'énergie nucléaire 2015

NEA No. 7195. 244 pages.

Nuclear Energy Data is the OECD Nuclear Energy Agency's annual compilation of statistics and country reports documenting nuclear power status in the OECD area. Information provided by member country governments includes statistics on installed generating capacity, total electricity produced by all sources and by nuclear power, nuclear energy policies and fuel cycle developments, as well as projected generating capacity and electricity production to 2035, where available. Total electricity generation at nuclear power plants and the share of electricity production from nuclear power plants increased slightly in 2014, by 1.4% and 0.3% respectively, despite Japan's nuclear fleet remaining offline throughout the year. No new reactor was connected to the grid in OECD countries and one, in the United States, was permanently shut down.

Governments committed to having nuclear power in the energy mix advanced plans for developing or increasing nuclear generating capacity, with the preparation of new build projects making progress in Finland, Hungary, Turkey and the United Kingdom. Further details on these and other developments are provided in the publication's numerous tables, graphs and country reports.



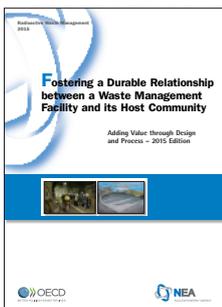
Nuclear New Build: Insights into Financing and Project Management

NEA No. 7195. 244 pages.

Nuclear new build has been progressing steadily since the year 2000, with the construction of 94 new reactors initiated and 56 completed reactors connected to the grid. Among these new reactors are some of the first generation III/III+ reactors of their kind. Drawing on a combination of conceptual analysis, expert opinion and seven in-depth case studies, this report provides policy makers and stakeholders with an overview of the principal challenges facing nuclear new build today, as well as ways to address and overcome them.

It focuses on the most important challenges of building a new nuclear power plant, namely assembling the conditions necessary to successfully finance and manage highly complex construction processes and their supply chains. Different projects have chosen different paths, but they nonetheless share a number of features. Financing capital-intensive nuclear new build projects requires, for example, the long-term stabilisation of electricity prices whether through tariffs, power purchase agreements or contracts for difference. In construction, the global convergence of engineering codes and quality standards would also promote both competition and public confidence. In addition, change management, early supply chain planning and “soft issues” such as leadership, team building and trust have emerged over and over again as key factors in the new build construction process. This report looks at ongoing trends in these areas and possible ways forward.

Radioactive waste management



Fostering a Durable Relationship between a Waste Management Facility and its Host Community

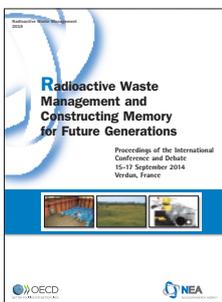
Adding Value through Design and Process – 2015 Edition

NEA No. 7264. 66 pages.

In the field of long-term radioactive waste management, repository projects can take many years to complete. Such projects will inevitably have an effect on the host community from the planning stage to the end of construction and beyond. The key to a long-lasting and positive relationship between a facility and its host community is ensuring that solutions are reached together throughout the entire process. The sustainability of radioactive waste management solutions can potentially be achieved through design and implementation of a facility that provides added cultural and amenity value, as well as economic opportunities, to the local community.

This edition of *Fostering a Durable Relationship between a Waste Management Facility and its Host Community: Adding Value through Design and Process* highlights new innovations in siting processes and in facility design – functional, cultural and physical – from different countries, which could be of added value to host communities and their sites in the short to long term. These new features are examined from the perspective of sustainability, with a focus on increasing the likelihood that people will both understand the facility and its functions, and remember over very long timescales what is located at the site.

This 2015 update by the NEA Forum on Stakeholder Confidence will be beneficial in designing paths forward for local or regional communities, as well as for national radioactive waste management programmes.



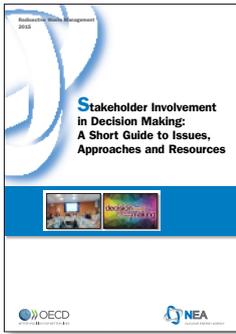
Radioactive Waste Management and Constructing Memory for Future Generations

Proceedings of the International Conference and Debate, 15-17 September 2014
Verdun, France

NEA No. 7259. 177 pages.

The Preservation of Records, Knowledge and Memory (RK&M) across Generations initiative was launched by the Nuclear Energy Agency in 2011 to foster international reflection and progress towards this goal and to meet increasing demands by waste management specialists and other interested parties for viable and shared strategies. The RK&M initiative is now in its second phase, which is to last until 2017. Phase I culminated on 15-17 September 2014 with the organisation of an international conference and debate on “Constructing Memory” held in Verdun, France.

The conference was attended by approximately 200 participants from 17 countries and 3 international organisations. Participants included specialists from the radioactive waste management area and beyond, academics in the fields of archaeology, communications, cultural heritage, geography and history, as well as artists, archivists and representatives from local heritage societies and from communities that could host a radioactive waste repository.

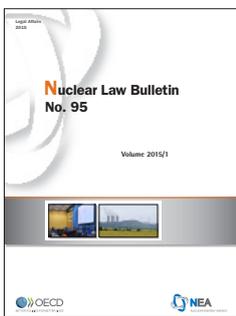


Stakeholder Involvement in Decision Making: A Short Guide to Issues, Approaches and Resources

NEA No. 7189. 60 pages.

Radioactive waste management is embedded in broader societal issues such as the environment, risk management, energy, health policy and sustainability. In all these fields, there is an increasing demand for public involvement and engagement. This 2015 update of *Stakeholder Involvement Techniques: Short Guide and Annotated Bibliography*, assists practitioners and non-specialists by outlining the steps and issues associated with stakeholder involvement in decision making and by facilitating access to useful online resources (handbooks, toolboxes and case studies). The updated guide has been considerably enriched with experiences since 2004 and includes extensive references to the literature. It is published alongside the release of an online annotated bibliography that will be updated regularly.

Nuclear law



Nuclear Law Bulletin No. 95

Volume 2015/1

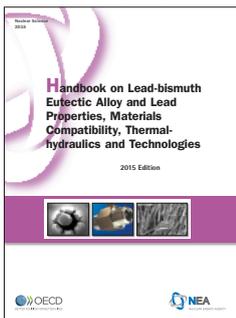
NEA No. 7252. 157 pages.

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

Feature articles in this issue include “Entry into force of the Convention on Supplementary Compensation for Nuclear Damage: Opening the umbrella”; “Towards a new international

framework for nuclear safety: Developments from Fukushima to Vienna”; “Nuclear arbitration: Interpreting non-proliferation agreements”.

Nuclear science and the Data Bank



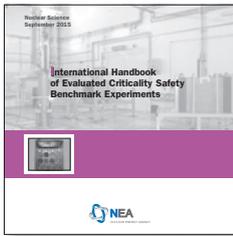
Handbook on Lead-bismuth Eutectic Alloy and Lead Properties, Materials Compatibility, Thermal-hydraulics and Technologies 2015 Edition

NEA No. 7268. 948 pages.

Heavy liquid metals such as lead or lead-bismuth have been proposed and investigated as coolants for fast reactors since the 1950s. More recently, there has been renewed interest worldwide in the use of these materials to support the development of systems for the transmutation of radioactive waste. Heavy liquid metals are also under evaluation as a reactor core coolant and accelerator-driven system neutron spallation source. Several national and international R&D programmes are ongoing for the development of liquid lead-alloy technology and the design of liquid lead-alloy-cooled reactor systems.

In 2007, a first edition of the handbook was published to provide deeper insight into the properties and experimental results in relation to lead and lead-bismuth eutectic technology and to establish a common database. This handbook remains a reference in the field and is a valuable tool for designers and researchers with an interest in heavy liquid metals.

The 2015 edition includes updated data resulting from various national and international R&D programmes and contains new experimental data to help understand some important phenomena such as liquid metal embrittlement and turbulent heat transfer in a fuel bundle. The handbook provides an overview of liquid lead and lead-bismuth eutectic properties, materials compatibility and testing issues, key aspects of thermal-hydraulics and existing facilities, as well as perspectives for future R&D.



International Handbook of Evaluated Criticality Safety Benchmark Experiments

September 2015

NEA No. 7281. DVD (limited distribution).

The Criticality Safety Benchmark Evaluation Project (CSBEP) was initiated in October of 1992 by the United States Department of Energy (DOE). The project quickly became an international effort as scientists from other interested countries became involved. The International Criticality Safety Benchmark Evaluation Project (ICSBEP) became an official activity of the

Nuclear Energy Agency (NEA) in 1995.

This handbook contains criticality safety benchmark specifications that have been derived from experiments performed at various critical facilities around the world. The benchmark specifications are intended for use by criticality safety engineers to validate calculation techniques used to establish minimum subcritical margins for operations with fissile material and to determine criticality alarm requirements and placement. Many of the specifications are also useful for nuclear data testing. Example calculations are presented; however, these calculations do not constitute a validation of the codes or cross-section data.

The evaluated criticality safety benchmark data are given in nine volumes. These volumes span approximately 69 000 pages and contain 567 evaluations with benchmark specifications for 4 874 critical, near-critical or subcritical configurations, 31 criticality alarm placement/shielding configurations with multiple dose points for each, and 207 configurations that have been categorised as fundamental physics measurements that are relevant to criticality safety applications.

New to the handbook are benchmark specifications for neutron activation foil and thermoluminescent dosimeter measurements performed at the SILENE critical assembly in Valduc, France as part of a joint venture in 2010 between the US DOE and the French Alternative Energies and Atomic Energy Commission (CEA). A photograph of this experiment is shown on the front cover.

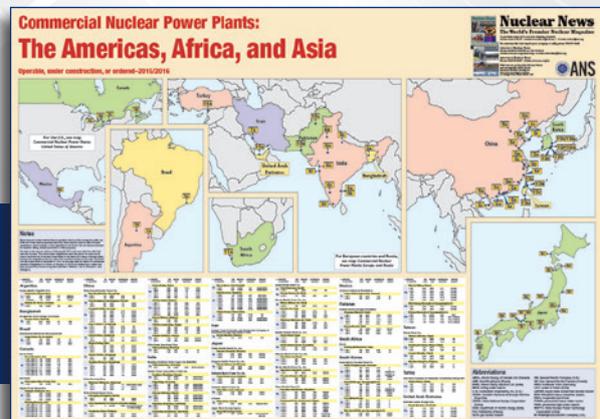


2015/2016 Wall Maps of Commercial Nuclear Power Plants

Updated **Nuclear News** wall maps show the location of each commercial power reactor that is operable, under construction, or ordered as of February 28, 2015. Tabular information includes each reactor's generating capacity (in Net MWe), design type, date of commercial operation (actual or expected), and reactor supplier.

Three updated versions are now available:

- Europe and Russia
- United States
- The Americas, Africa and Asia (which includes Canada, Mexico, South America, Africa, and Asia)



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Europe and Russia map & The Americas,* Africa, and Asia map

*The Americas include Canada, Mexico, and South America, but not the United States.

Actual map dimensions: 99.7 x 67.9cm, the data in these maps is valid as of 2/28/15.
Note: U.S. nuclear power plants are shown on the U.S. map only, not on either of the worldwide maps.

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