

NEA News is published twice yearly in English and French by the OECD Nuclear Energy Agency. The opinions expressed herein are those of the contributors and do not necessarily reflect the views of the Organisation or of its member countries. The material in NEA News may be freely used provided the source is acknowledged. All correspondence should be addressed to:

The Editor, NEA News  
OECD Nuclear Energy Agency  
12, boulevard des Îles  
92130 Issy-les-Moulineaux  
France  
Tel.: +33 (0)1 45 24 10 12  
Fax: +33 (0)1 45 24 11 10

The OECD Nuclear Energy Agency (NEA) is an intergovernmental organisation 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 29 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, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the NEA. A co-operation agreement is in force with the International Atomic Energy Agency.

For more information about the NEA, see:  
[www.oecd-nea.org](http://www.oecd-nea.org)

**Editorial board:**  
Janice Dunn Lee  
Cynthia Gannon-Picot  
Serge Gas

**Production and marketing:**  
Cynthia Gannon-Picot  
Andrée Pham Van  
Solange Quarneau

**Design and layout:**  
Fabienne Vuillaume

Cover page photo credits: Olkiluoto-3, Finland (P. Bourdon, AREVA); Superphénix, France (Y. Forget); Radioactive waste containers, Nogent NPP, France (H. Cazin, EDF Photo Library); Laser ablation, France (CEA). Page 3 photo credit of Luis Echávarri (M. Lemelle, France).

## Contents

### Facts and opinions

---

Security of energy supply and the contribution of nuclear energy 4

Regulatory issues for new nuclear build and new entrants 9

### NEA updates

---

Transition from thermal to fast neutron nuclear systems 12

Explaining the shortage of medical radioisotopes 16

New nuclear build and evolving radiological protection challenges 20

The Forum on Stakeholder Confidence celebrates a decade of work 24

Decontamination and dismantling of radioactive concrete structures 27

### News briefs

---

The Blue Ribbon Commission and siting radioactive waste disposal facilities 30

NEA joint projects 32

New publications 38



## New build, new entrants and new members



As we begin preparations for the 50<sup>th</sup> anniversary celebrations of the Organisation for Economic Co-operation and Development (OECD), we also have the pleasure in welcoming four new OECD member countries and one new NEA member. Chile acceded to the OECD on 7 May 2010, Slovenia on 21 July 2010, Israel on 7 September 2010 and Estonia on 9 December 2010. The NEA's most recent member – Poland – officially joined on 18 November 2010. Slovenia has applied for NEA membership and a decision on its application will be taken in the second quarter of 2011. This active evolution in membership reflects the dynamic environment in which OECD and NEA work is being carried out.

It is also a particularly dynamic time for the nuclear energy sector in general. As several of the articles in this issue show, nuclear energy is increasingly being viewed as a pragmatic solution to the issues of security of supply, cost stability and climate change, and this is having effects in nearly all areas of development, deployment and follow-up.

The NEA has recently completed a study on the *Security of Energy Supply and the Contribution of Nuclear Energy*. It is the first time that the security of energy supply has been quantitatively verified with a set of coherent indicators, thus placing the study at the centre of the current energy debate (see page 4 for further details). The role of the Agency in examining these questions was also recognised when I was appointed in September to the World Economic Forum's Council for Global Dialogue on Energy Security.

With this increasing interest in nuclear energy, many questions evidently arise in terms of new build and new entrants. A first article looks at this issue from the regulatory perspective, highlighting the main challenges and considerations that need to be addressed by regulators in the current context, and placing special emphasis on the needs of new entrants. The article on new nuclear build and radiological protection stresses *inter alia* the importance of incorporating operational lessons learnt into new designs (see page 20).

As new build progresses, whether in countries with mature nuclear energy programmes or entirely new ones, stakeholder consultation and involvement will remain an essential element throughout the process. Site selection, nuclear safety, radiological protection of workers and the environment, and radioactive waste management are among the most common topics of public concern. As shown in many studies, including those of the NEA Forum on Stakeholder Confidence which has recently celebrated its 10<sup>th</sup> anniversary (see page 24), collaborative decision-making is the most effective means for adopting measures that are more broadly accepted and thereby more sustainable over the long run. Nuclear energy is a long-term investment which, handled with care, can reap clear benefits.

A handwritten signature in black ink, which appears to read 'Luis E. Echávarri'. The signature is fluid and cursive, written over a light background.

Luis E. Echávarri  
NEA Director-General

# Security of energy supply and the contribution of nuclear energy

by R. Cameron and J.H. Keppler\*

The continuous availability and affordability of energy and, in particular, electricity has become an indispensable condition for the working of modern society. This is especially true for advanced industrial or post-industrial societies, where electricity provides the services essential for production, communication and exchange. Unsurprisingly, governments of OECD countries are thus concerned with understanding the factors influencing the security of energy and electricity supplies and seek to develop policy frameworks and strategies to enhance them.

As a domestically produced, largely carbon-free source of electricity, nuclear energy is, in principle, well-placed to play a constructive role in this context. This is why the NEA launched a comprehensive study on “The Security of Energy Supply and the Contribution of Nuclear Energy”, seeking to empirically assess the contribution of nuclear energy to the energy supply security of OECD countries over the past four decades. It is the first time that quantitative indicators for energy supply security have been developed and applied to a coherent set of data over such a long time frame. The results are telling. While not the only factor, nuclear energy has been a significant contributor to the notable improvement in the security of energy supplies of many OECD countries.

However, before considering quantitative indicators, the concept of “security of energy supply” must be defined and understood as it applies to the formulation of government policy. This is less straightforward than it may seem. Energy supply security can mean very different things to different people. A foreign policy expert will look at the issue from another angle than a network engineer or an economist. Definitions of what is security of energy supply by various experts abound, but they are often too abstract to address the concrete issues intrinsically linked to geopolitical preferences, strategic technology choices and fundamental orientations of social policy. Definitions also change from one country to another. For example, a country with limited access to cross-border energy infrastructures but a broad domestic resource base will think differently about the security of its energy supplies than a small, open economy closely interconnected with its neighbours but with few resources of its own. Not unlike the notion of “sustainability”, another key dimension of energy policy in OECD countries, the notion of security of energy supply is often being applied in diverse ways to support different policy objectives.

A general starting point is the following consensus definition: “Security of energy supply is the resilience of the energy system to unique and unforeseeable events that threaten the physical integrity of energy flows or that lead to discontinuous energy price rises, independent of economic fundamentals.” It can be shown that “import dependency and diversification”, “resource and carbon intensity” as well as “infrastructure adequacy” are three key verifiable parameters that are encapsulated in this general definition. It is important, however, to keep in mind that these three parameters are not identical with energy supply security, but their qualification and contextualisation are important in each individual case.

## Two key dimensions of energy supply security

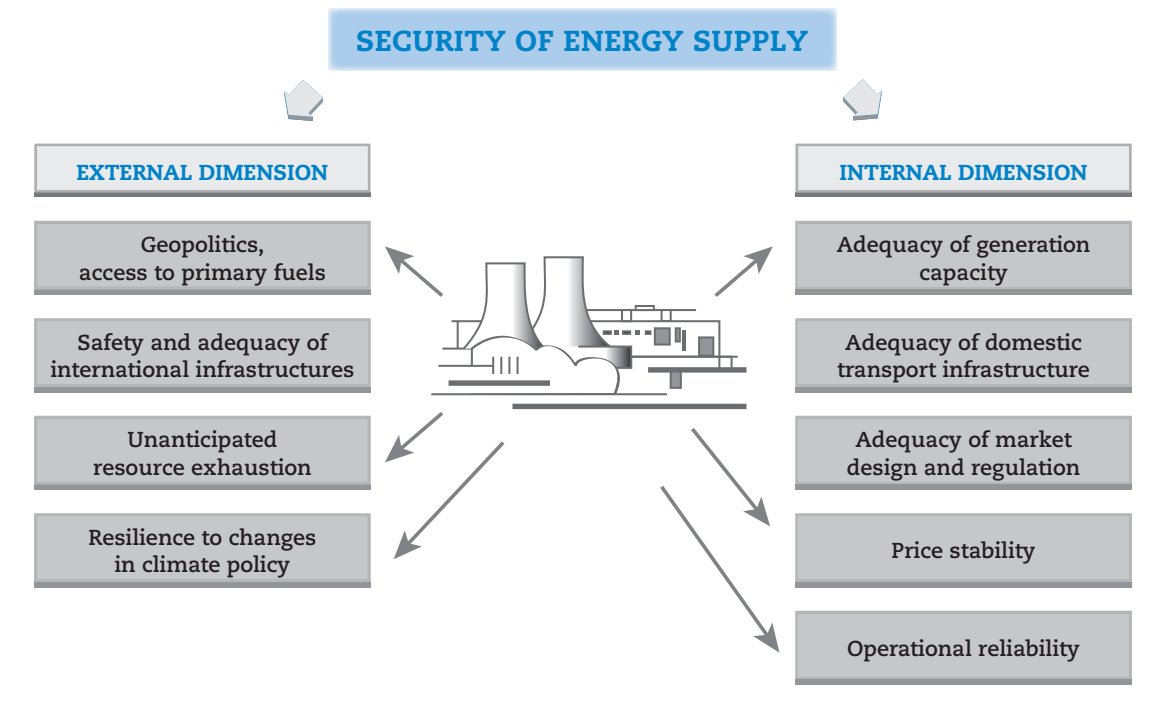
Energy supply security is a classic example of an externality, i.e. of an impact on the well-being of individuals and society generated by an economic activity, but which is not already priced in the marketplace. Being a negative externality, energy supply risk constitutes a policy issue. This means that private individuals cannot cover themselves for such risks due to their complexity and unquantifiable nature. This is where governments need to step in. Energy supply risks can be considered in terms of two main dimensions: the external or geopolitical dimension, and the internal dimension that includes technical, financial and economic issues. Nuclear energy can play a constructive role in both of them (see Figure 1).

### Import dependence, resource exhaustion and carbon policy: the external dimension

Geopolitical risk almost always refers to primary energy carriers (oil, gas, coal, uranium or renewables) since their location depends on the vagaries of geology and climate. Production and consumption are

\* Dr. Ron Cameron ([ron.cameron@oecd.org](mailto:ron.cameron@oecd.org)) is Head of, and Dr. Jan Horst Keppler ([jan-horst.keppler@oecd.org](mailto:jan-horst.keppler@oecd.org)) Principal Administrator in, the NEA Nuclear Development Division.

Figure 1: Dimensions of energy security and potential contributions of nuclear energy



thus often physically located far apart, in countries and regions with different histories, cultures and values. Apart from exploration and production, all other steps of the energy chain such as refinement or enrichment, conversion and distribution can be moved physically closer to the final customer or are, like consumption, directly under the latter's control.

Given that a fundamental cause of geopolitical supply risks is the physical separation of the centres of primary energy production and consumption, it is tempting to address the issue by striving to bring production home ("energy independence"). Whether this is a good approach depends on a country's geographical position, its own energy endowment, the state of its physical infrastructures for transport and storage, the diversification of its supplies, the willingness of its population to accept higher, average long-term prices for lower volatility and a host of other issues.

In an ideal world, security of energy supply would not be equated to energy independence or self-sufficiency. Free and global energy trade through smoothly functioning competitive markets would guarantee timely delivery of all necessary energy resources. Most countries are relying at least partially on the international trade of energy and will continue to do so. However, the issue of self-sufficiency does assume a particular significance in electricity markets since, due to the technical and economic challenges associated with its storage, electricity is only transported over relatively

short distances. In island countries such as Japan and Australia, or *de facto* isolated countries such as the Republic of Korea, national electricity generation must be able to cover national demand.

#### *Economic, financial and technical conditions for energy security: the internal dimension*

Energy security begins at home. The most important responsibility for OECD governments is to establish appropriate framework conditions for providing incentives to private actors to install domestically an adequate level of facilities for the production, transport, conversion and consumption of energy. Important elements in this strategy are regulatory stability, market organisation, fiscal coherence and predictability of environmental policy. The challenge in the electricity sector is the creation of framework conditions that:

- do not discriminate against domestically produced, low-carbon energy sources such as nuclear and renewables; and
- allow for the construction of adequate transport, production and conversion capacity with appropriate long-term financial arrangements.

OECD governments thus have a responsibility to create market conditions that allow low-carbon technologies with lower supply risks to compete on a level playing field. Governments also have a role to play with regard to the provision of adequate levels of transport, distribution and conversion capacity.

Such capacity can partly be provided by markets themselves, but in other cases, it requires regulation and supervision. First, regulation must provide sufficiently attractive financial conditions for investment in transport and conversion infrastructure. Second, projects must have political backing at the national level against excessive delays, through appropriate regulatory processes and zoning laws, as well as effective mechanisms for consultation, mediation and compensation.

## Empirical evidence

Indicators for energy security of supply thus need to include information on:

- import dependency and diversification of fuel and energy supply;
- resource and carbon intensity;
- system and infrastructure adequacy.

The NEA study applied the Simplified Supply and Demand Index (SSDI) that is capable of working with the only available, consistent data set on OECD countries' energy sectors over the past 40 years, the IEA Energy Statistics. The SSDI is composed of three weighted contributions: demand, infrastructure and supply. These contributions take into

account the degree of diversity and supply origin of different energy carriers, the efficiency of energy consumption and the state of the electricity generation infrastructure.

The evolution of the SSDI throughout the period (1970-2007) was analysed for several OECD countries: Australia, Austria, Canada, Finland, France, Italy, Japan, the Netherlands, the Republic of Korea, Sweden, the United Kingdom and the United States (see Figure 2). It identifies changes in the trend when important policy changes have been implemented, such as the United Kingdom's switch from coal to gas or the introduction of nuclear power programmes in France and the United States.

Figure 2 shows that the value of the SSDI has significantly increased between 1970 and 2007 in the case of most countries under study: Canada, Finland, France, Japan, the Netherlands, Sweden, the United Kingdom and the United States. The improvement in the SSDI in the first set of OECD countries is due to three different factors:

- the introduction of nuclear power for electricity generation;
- the decrease in energy intensity;
- the increase in the diversification of primary energy sources.

Figure 2: Evolution of the SSDI for selected OECD countries

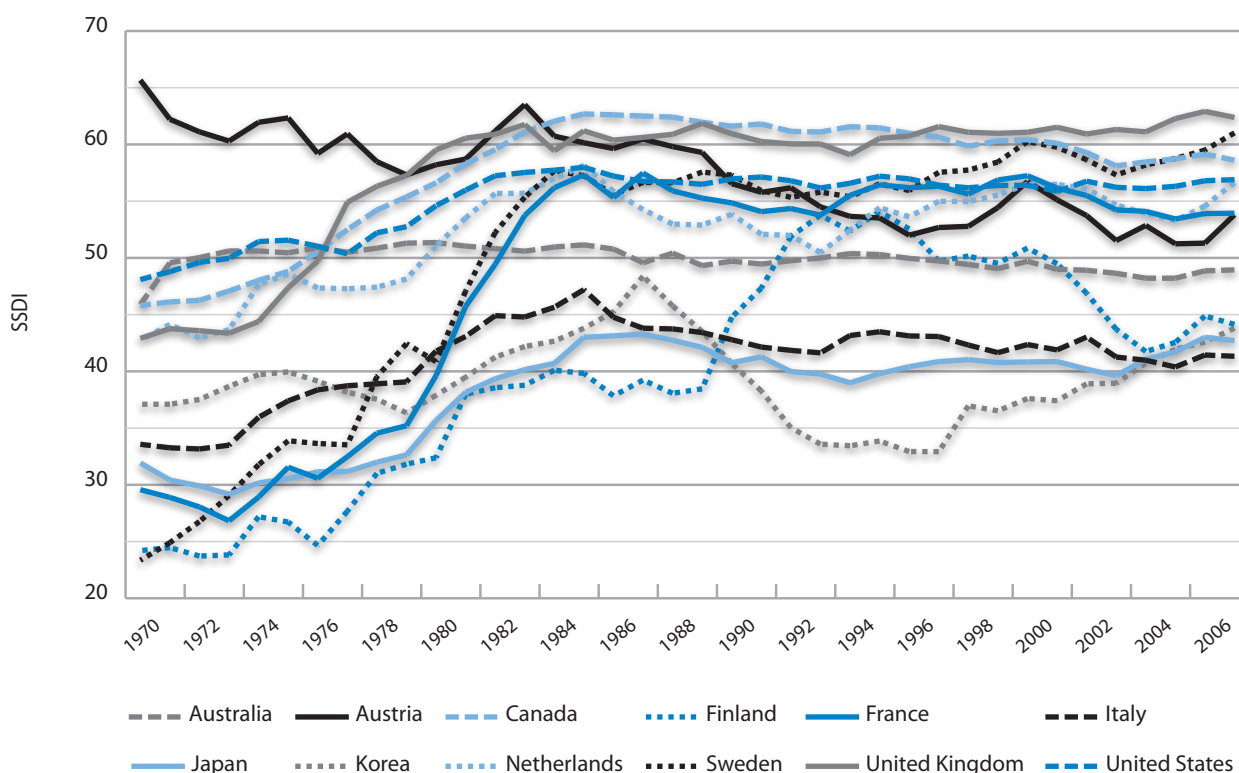
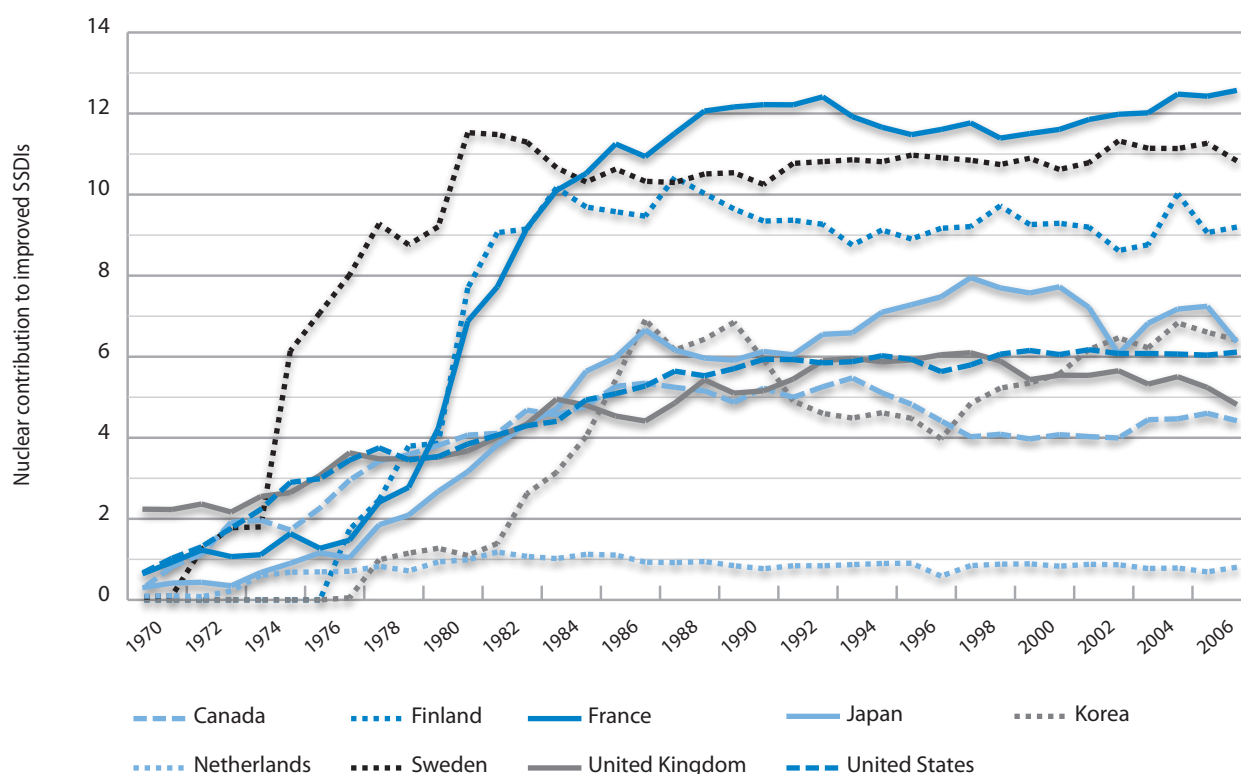


Figure 3: The contribution of nuclear power to improved SSDIs



The widespread adoption of nuclear energy from this perspective is understandable given its advantages in strengthening the external dimension of energy supply security:

- In terms of value, nuclear power plants source more than 90% of their inputs domestically.
- Uranium imports are widely diversified and are frequently supplied by other OECD countries.
- Nuclear energy would be unaffected by a sudden tightening of restrictions on greenhouse gas emissions.

Overall, in the face of geopolitical supply risks, whether due to import dependence, resource exhaustion or changes in the global carbon regime, nuclear energy holds advantages that other fuels such as oil, coal and gas do not enjoy: wide availability of resources for a long time to come, modest impacts of increases in resource prices and resilience against carbon policy shifts.

In terms of the internal dimension, the joint IEA/NEA study on the *Projected Costs of Generating Electricity: 2010 Edition* shows that nuclear energy is a very attractive option at real interest rates that are below or only slightly above 5%. The attractiveness of an investment in power generation, however, is not only defined by its lifetime costs of electricity that correspond to the sum of the lifetime costs taking

into account the average discounted revenue. One key element is the uncertainty to which investors are exposed. The advantage of nuclear energy in this context is that its average cost remains very stable in the event of changes in fuel costs or in the price of carbon. Doubling the carbon price, for instance, from USD 30 per tonne of CO<sub>2</sub> to USD 60 per tonne would increase the total average cost of coal-produced power by 30%, more than doubling its variable cost in the process. This is not an unrealistic number. Given current commitments to reduce global carbon emissions by 50% by 2050 in order to limit the rise of global mean temperatures to 2°C, modelling results imply marginal costs for carbon abatement of at least USD 100 per tonne of CO<sub>2</sub> and perhaps much higher.

Based on these strengths, many OECD countries invested massively in nuclear power development during the 1970s and 1980s. As shown in the figure, nuclear energy has contributed significantly to the increase in energy supply security of these countries (Figure 3 extracts the nuclear contribution to the SSDI in Figure 2). In the case of France, the contribution of nuclear power to the SSDI is more than 12 points in 2007 (about 30% of its SSDI score), followed by Sweden with 11 points (21%), Finland with 9 points (26%), and Japan and Korea with approximately 6 points (about 17% of the total SSDI score).

## The role of governments

To the extent that markets cannot ensure security of supply by themselves, governments need to play a role. Regarding the external dimension, in addition to ensuring adequate shares of domestically produced energy, governments need to ensure transparent global markets; the realisation of the comparative advantage of each trading partner is of particular importance. In terms of the internal dimension, the focus must be on creating appropriate market conditions and incentive systems that enable all technologies to deliver their potential contribution to the security of supply, in particular high fixed cost, low-carbon technologies.

Due to its complexity and the dynamic evolution of the many parameters involved, as well as public demand for “secure” supply, energy security remains an uninternalised externality, or a public good that markets are unable to provide at an appropriate, acceptable level. Even in the presence of a globalised marketplace for most energy commodities, given its importance for the functioning of the economy, energy supply security thus remains a policy issue for which governments need to assume responsibility.

Nuclear energy, as an essentially carbon-free, largely domestic source, possesses a number of attractive characteristics that enable it to contribute to both the external and internal dimensions of energy supply security. It is cost-competitive, with high energetic density and low sensitivity to variations in the resource price, unlike fossil fuels. Uranium resources are also well-distributed, with OECD countries such as Australia, Canada or the United States holding significant shares.

Due to its large fixed costs (not only at the level of the individual plant but also at the level of education, regulatory infrastructures, fuel cycle strategies, etc.), nuclear energy will never be wholly an ordinary industry. Nevertheless, as a concrete response to widely recognised problems, nuclear energy is increasingly being viewed more dispassionately and judged on its merits as part of the solution to questions of security of supply, cost stability and reductions in greenhouse gas emissions.

### References

IEA (2010), *Energy Statistics of OECD Countries*, OECD/IEA, Paris.

IEA/NEA (2010), *Projected Costs of Generating Electricity: 2010 Edition*, OECD, Paris.

NEA/IAEA (2010), *Uranium 2009: Resources, Production and Demand*, OECD, Paris.

### Further reading

NEA (2010), *The Security of Energy Supply and the Contribution of Nuclear Energy*, OECD, Paris.

# Regulatory issues for new nuclear build and new entrants

by J. Nakoski\*

Many countries are showing growing interest in using nuclear power to meet increased energy demands, even in the current economic environment. Some 70 countries are discussing nuclear power as a potential part of their national energy policies. The level of interest in these countries does, however, vary. Of these countries, only a handful will make the commitment to license, construct and operate their first nuclear power plant before 2020. These “new entrants” are in addition to those countries that already have established nuclear power programmes and are increasing their nuclear capacity.

## Nuclear power plants under construction (as of 17 November 2010)

Country	No. of units	Capacity (MWe)
Argentina	1	692
Brazil	1	1 245
Bulgaria	2	1 906
China	22	22 020
Chinese Taipei	2	2 600
Finland	1	1 600
France	1	1 600
India	4	2 506
Iran, Islamic Republic of	1	915
Japan	2	2 650
Korea, Republic of	5	5 560
Pakistan	1	300
Russian Federation	11	9 153
Slovak Republic	2	782
Ukraine	2	1 900
United States	1	1 165
<b>Total</b>	<b>61</b>	<b>59 194</b>

Source: IAEA Power Reactor Information System (PRIS).

Lessons learnt from the past have demonstrated the impact that an event at a nuclear power plant in one country can have on the nuclear power programmes in other countries. These lessons, as well as others, have been incorporated into the nuclear power programmes of countries with established programmes and contribute to the excellent safety performance of nuclear power plants in these countries. However, recent experience shows that even for countries with mature programmes, challenges remain for licensing and constructing new nuclear

power plants. For new entrants, the challenges will potentially be more significant.

There are many challenges that countries adding new nuclear power capacity will face. To support a country’s decision on the nuclear power option, the International Atomic Energy Agency (IAEA) issued NG-G-3.1, “Milestones in the Development of a National Infrastructure for Nuclear Power”. This report provides a roadmap that addresses essentially all the issues a country may face as it seeks to introduce nuclear power in its energy mix. Included here is a brief overview of the main challenges associated with developing regulatory infrastructure, the subject of two forthcoming NEA reports due to be issued shortly.

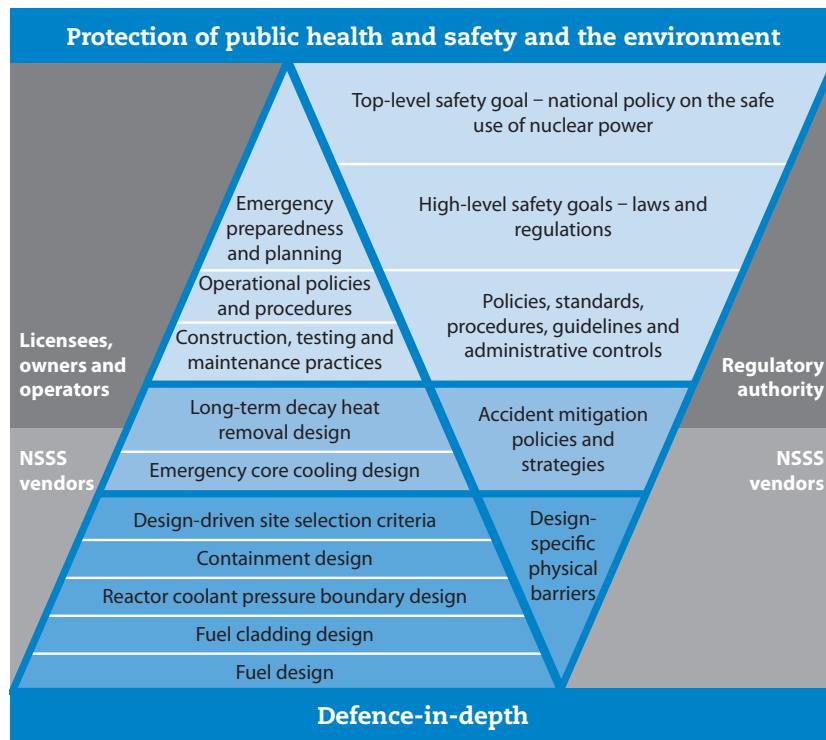
## Fundamental safety principles

Many of the countries starting a nuclear power programme have little experience in the safe application of this technology. An issue that new entrants need to address is understanding, then applying, fundamental safety principles to their decision-making processes. This concerns the licensees (owners and operators), the construction organisations, and the nuclear steam supply system (NSSS) vendors, as well as the government and the regulator.

While the licensee is primarily responsible for all aspects of plant safety, the latter starts with the design developed by an NSSS vendor. The regulator has a role in ensuring safety by verifying that the NSSS vendor’s design incorporates the concept of defence-in-depth to protect the public and the environment, and that the licensee applies this concept as it operates and maintains the plant in a manner consistent with the design.

In addition, during construction, the operator, the NSSS vendor, the construction organisations and the regulator need to ensure that the plant is constructed as designed and licensed. This includes conducting reviews, tests or analyses that demonstrate that the structures, systems and components are manufactured and constructed with the necessary quality to provide confidence that the plant can be operated as designed.

\* Mr. John Nakoski ([john.nakoski@oecd.org](mailto:john.nakoski@oecd.org)) works in the NEA Nuclear Safety Division.



Applying the fundamental safety principles to decision-making processes can be challenging as schedule and costs are also factors that influence the introduction of nuclear power to a country's energy supply. Licensees, vendors and construction organisations are responsible for implementing their decision-making processes such that there is a clear demonstration that the fundamental safety principles are being met while meeting schedules and keeping costs within budget. Regulators have the role of establishing the framework that requires safety to come before cost and schedule. Regulatory oversight needs to focus on ensuring that nuclear safety is the first component of the decisions made during all phases of a nuclear power programme, from design through decommissioning and long-term storage of spent fuel.

## Workforce development

Closely related to understanding and implementing strong safety principles is having a workforce with the technical, programmatic, trade and regulatory skills, as well as the knowledge and experience to support a nuclear power programme. Each organisation needs to understand its role in the overall programme; what skills, knowledge and experience are necessary to effectively implement this role; the gap between the skills, knowledge and experience of its staff; and what the organisation needs to be successful.

Before the recent renewed interest in nuclear power, very few countries had built any nuclear power plants over the past 30 years. These countries have educational and development programmes to

maintain and expand their workforce to support the increased scope of their nuclear programmes.

Other countries with mature nuclear power programmes have not been building new nuclear power plants and have been focusing on replacing the experienced workforce as its members retire. As these countries begin to add new nuclear plants, they are implementing programmes to increase the numbers of staff with the knowledge and skills to support their planned expansions. Building upon their existing staff, the programmes are transferring the knowledge and experience from their senior staff to recently hired personnel.

For new entrants, it is more challenging since they likely do not have a workforce that has the skills, knowledge and experience necessary to support a nuclear power programme. They need to build on the experience of countries with established programmes and by working with international organisations. Many new entrants have established bilateral and multilateral arrangements with experienced regulators to develop needed regulatory skills. IAEA Member States have established a Regulatory Co-ordination Forum to facilitate capacity building in countries adding nuclear power to their energy supply.

## Legislative and regulatory infrastructure

Undergirding a nuclear power programme are the laws and regulations that provide a legal framework for the peaceful use of nuclear energy. For countries with established nuclear power programmes, such frameworks are in place. However, for new entrants

it is an issue that should be addressed very shortly after the decision is made to pursue the addition of nuclear power to the energy supply.

While many new entrants have existing legislative and regulatory infrastructures supporting the peaceful use of nuclear energy for industrial and medical uses, a more robust system is required for using nuclear energy for power production in order to comply with international treaties and to meet international standards for safety, security and safeguards. With the objective of sharing information on regulatory infrastructure, the NEA Working Group on the Regulation of New Reactors (WGRNR) sponsored a workshop<sup>1</sup> on “New Reactor Siting, Licensing and Construction Experience” in September 2010. The State Office for Nuclear Safety of the Czech Republic hosted the workshop in Prague. Many of the 60-some participants were from countries developing their regulatory authorities to support new nuclear build. During the workshop insights were shared, with developing regulators encouraging experienced regulators to examine their practices for enhancements, and experienced regulators encouraging developing regulators to continue their focus on protection of the public and the environment.

IAEA Member States have worked together to develop safety standards that reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards and safety guides provide a framework for establishing legislative and regulatory policies and programmes. By following the framework established by these safety standards, new entrants can benefit from the experience of mature regulatory programmes as they build capacity to support a nuclear power programme.

A key part of the legal framework is the licensing process during which the regulator reviews and approves an application for a new nuclear power plant. During this process, the regulator assesses the technical aspects of the design; the organisational capability of the applicant to effectively manage the design, construction, testing, operation and maintenance of the reactor; the suitability of the site for the selected reactor design; and the plans for security and emergency response, among other issues.

As the regulatory body develops its licensing process, it will need to create the programmes and procedures to guide its staff in conducting these reviews and assessments consistent with the overarching legal framework and nuclear safety principles. The WGRNR is drafting a report that will describe the regulatory structure, licensing processes and resources used by a cross-section of experienced regulators and by the new entrants working with the group. This report will serve as a guide for regulators starting the review of their first new reactor application and provide a benchmark against which more developed regulators can assess their programmes.

After a nuclear power plant has been licensed for construction, the regulator’s role needs to shift from design reviews and analyses to verification that construction is being carried out in accordance with the design and to the appropriate level of quality. The licensee has the primary responsibility for ensuring that the plant is constructed as designed. However, within the regulatory framework the regulator is responsible for overseeing the activities of the licensee and construction work. This provides an additional assessment to ensure that the plant is being constructed as the regulator licensed it.

When the regulatory body is developing its construction oversight programme, it faces the challenge of balancing its need to independently observe construction activities with the construction schedule. In some regulatory programmes, hold points are established for the regulator to witness specific activities, approve the use of specific components, or approve the continuation of construction activities. Other programmes rely on close co-ordination between the regulator body’s staff overseeing the construction activities and the construction organisations to identify opportunities for the regulator to witness a sample of activities to gain confidence in the processes being used to ensure that the design is being respected and the necessary quality being achieved.

The WGRNR is also preparing a report that will provide insights into the policies and practices being used by mature regulators to oversee construction. These insights can serve as a guide for regulators developing or enhancing their construction oversight programmes.

## Conclusions

As countries develop their legislative and regulatory frameworks for new nuclear power programmes, it is necessary to ensure that the regulatory authority understands the fundamental nuclear safety principles and applies them to its decision-making processes. It needs to develop and maintain an experienced staff with the knowledge and skills to review the design and licensing of the plant, and to verify that the plant is constructed as designed and licensed. Finally, the legislative and regulatory framework must be in place to support the regulatory body, giving it the independence, responsibility and authority to implement the licensing reviews and oversight of construction. Without the legal framework supporting the regulatory programmes, the ability of the regulatory body to enforce its mandate to protect public health, safety and the environment cannot be met.

### Note

1. See [www.oecd-nea.org/nsd/workshops/new-reactor-siting/](http://www.oecd-nea.org/nsd/workshops/new-reactor-siting/) for more information.

# Transition from thermal to fast neutron nuclear systems

by K.A. McCarthy, Y.J. Choi and E. Bertel

Concerns about global climate change and security of energy supply are triggering renewed interest in nuclear energy. Although uranium resources for nuclear fuel are sufficiently abundant to support significant growth of nuclear electricity generation based on current reactor types for decades (NEA/IAEA, 2010), nuclear systems using fissile materials more efficiently are considered a desirable option from a long-term sustainable perspective.

Today, nearly 150 000 tonnes of spent nuclear fuel from light water and other nuclear reactor types are stored for cooling before disposal or treatment. These fuels contain 1 300-1 500 tonnes of transuranic elements (TRUs), mainly plutonium, and a smaller amount of minor actinides (MAs), such as neptunium, americium and curium. Continued generation of nuclear electricity in an increasing number of countries will inevitably lead to increased volumes of spent fuel requiring storage.

Advanced nuclear fuel cycles with critical or sub-critical fast neutron systems, such as Generation IV reactors and accelerator-driven systems (ADSs), can optimise the use of uranium resources, minimise radioactive waste and increase proliferation resistance. These nuclear fuel cycles can include the partitioning and transmutation (P&T) of TRUs and/or MAs, an option which can reduce radiotoxicity and heat load of radioactive waste.

In this context, researchers have studied the feasibility of implementing scenarios for a transition from the current fleet of thermal neutron reactors operated with a once-through or a partially closed fuel cycle to advanced fast neutron systems capable of using recycled fissile materials. Simultaneously, analysts responding to concerns of policy makers about cost-effectiveness, industrial aspects and international issues are investigating the opportunities and challenges associated with the different transition scenarios.

The NEA Nuclear Science Committee (NSC) (NEA, 2009a and NEA, 2009b) and the NEA Committee for Technical and Economic Studies on Nuclear Development and the Fuel Cycle (NDC) (NEA, 2009c) have undertaken several studies on technical, strategic and policy aspects of different fuel cycle transition scenarios. Their main findings are described below.

## Main findings from technical analyses of transition scenarios

Under the auspices of the NSC, the technical issues raised by transition scenarios, as well as the potential role of P&T, were investigated both at a national level and at a regional level for Europe. Global scenarios are also currently being studied.

P&T is an important component in some transition scenarios because it is considered as an efficient means to reduce the burden and stewardship requirement of radioactive waste. Indeed, most long-term radiotoxicity and residual heat from the radioactive waste are generated by plutonium and minor actinides, which may be significantly reduced through P&T. The concept is to separate such nuclides from the irradiated fuel and to transmute them into short-lived or stable materials. Partitioning and transmutation can be implemented by using thermal or fast neutron systems. In general, the use of a fast neutron critical or a sub-critical system has advantages in terms of an improved transmutation rate for TRUs and/or MAs. Analyses show that in countries without advanced fuel cycle technologies, it would take about 20 years to implement TRU fuel multi-recycling in sodium-cooled fast reactors, while it would take some 30 years to implement more advanced systems, such as TRU fuel recycling in other types of fast reactors or ADSs.

From a technical viewpoint, the major issues raised by transition scenarios include the design and development of:

- fuels for recycling in light water reactors (from standard plutonium recycling to TRU recycling);
- fuels for recycling in high-temperature reactors (from uranium fuels to deep plutonium burners);
- fuels for recycling in a fast reactor recycle (fuels for homogeneous or targets for heterogeneous TRU recycle, and dedicated fuels, e.g. for minor actinide consumption);

\* Dr. Kathryn A. McCarty ([kathryn.mccarthy@inl.gov](mailto:kathryn.mccarthy@inl.gov)) is Deputy Associate Laboratory Director, Nuclear Science and Technology, Idaho National Laboratory, Dr. Yong-Joon Choi ([yongjoon.choi@oecd.org](mailto:yongjoon.choi@oecd.org)) is the Scientific Secretary of the NEA Working Party on Scientific Issues of the Fuel Cycle and Dr. Evelyne Bertel is a consultant to the NEA.

- separation technologies (both with aqueous and pyro-processes);
- reactor (critical or sub-critical) design and related technologies (such as specific coolant technology and materials).

Beyond technology development requirements, issues such as adequate and timely management of fissile materials and industrial-scale deployment of advanced processes have to be addressed. Technology preparedness is essential to ensure that performance will remain excellent along the entire process chain from reprocessing to fuel fabrication when shifting from laboratory to commercial production in large industrial-scale facilities.

National scenarios were analysed in nine NEA member countries – Belgium, Canada, France, Germany, Japan, Korea, Spain, the United Kingdom and the United States – covering various nuclear energy development patterns. The analysis showed that:

- in countries which started using closed nuclear fuel cycles early and plan to continue using nuclear energy, stocks of TRUs and/or MAs can be stabilised by the end of the century;
- countries which want to diminish their dependence on nuclear energy can only partially reduce their inventories during this century, unless they act in a regional context;
- countries which will be implementing new nuclear fuel cycles, for example a fast reactor cycle, for plutonium and minor actinide recycle later in this century, e.g. around 2050, can still stabilise the minor actinide inventory over the entire nuclear fuel cycle during this century.

In addition, it is noted that the minor actinide inventory is related to the pace of fast reactor deployment and it will take a long time to replace all light water reactors by fast reactors as fast reactors will need plutonium from light water reactors as start-up fuel. To avoid growth in the minor actinide inventory, fast reactor fuel cycles should be deployed as early as possible. In this context, there can also be incentives, such as economic, resource availability, safety (use of best practices and internationally recognised technologies) and non-proliferation (strict international control over transport flows and a very limited number of jointly operated sites), to develop a “regional” approach.

Regional scenarios can in principle provide a framework for implementation of advanced nuclear fuel cycles, with efforts divided equitably among different countries and taking into account proliferation concerns and resource optimisation. Specific scenarios have been investigated as part of a wider effort underway in Europe to prepare a roadmap for the possible implementation of P&T technologies. Four potential groups of countries with different scenarios were suggested in the NEA study:

- Group A: stagnant or phase-out scenario for nuclear energy including management of the spent fuel;
- Group B: continued use of nuclear energy and optimisation of the plutonium resources for future deployment of fast reactors;
- Group C: subset of Group A, after stagnation, an envisaged “renaissance” of nuclear energy;
- Group D: initially with no nuclear energy but decides to add it to the energy mix.

Four different European scenarios using fast neutron systems, both ADS type (scenarios 1 and 2) or critical fast reactors (scenario 3), were investigated as follows:

- Scenarios 1 and 2 consider the deployment of a group of ADSs shared by Group A and B. The ADSs use the plutonium of Group A and transmute the minor actinides of the two groups. The plutonium of Group B is either mono-recycled in pressurised water reactors (PWR) and then stored for future deployment of fast reactors (scenario 1) or is continuously recycled in PWRs (scenario 2).
- Scenario 3 considers the deployment of fast reactors in Group B. These fast reactors use the plutonium of Groups A and B and recycle all the minor actinides.
- Scenario 4 corresponds to a “renaissance” of nuclear energy in selected countries. Starting from Scenario 3, Group B and some Group A countries will deploy fast reactors to manage their own transuranic elements.

The outcome of the studies indicates that P&T may benefit the whole region despite different nuclear energy policies in each country. A regional strategy may also favour a nuclear “renaissance” in some countries. If fast reactors with homogeneous recycling of non-separated TRUs are deployed, use of fast reactors and supporting infrastructure must take into consideration the relevant nuclear fuel cycle characteristics, e.g. conversion ratio, cooling time, etc., to meet the potentially different objectives of different countries within a regional area. If a “double strata” scenario, i.e. a scenario with both fast reactors and ADSs, is deployed, it should be noted that most of the ADSs will be used for minor actinide transmutation. The ADS is more apt to be used in a regional scenario where different countries with different objectives share resources, facilities and spent fuel inventories in order to minimise waste. The ADS would be less useful in the case of a single country with a stagnant or phase-out nuclear energy policy, which would deploy P&T in “isolation” for waste management.

Analyses of global transition scenarios currently underway at the NEA cover the infrastructure development needed to support global growth of nuclear energy, as well as how that infrastructure might be deployed in various regions. Nuclear fuel cycles such as once-through, limited recycling and continuous recycling are all options over the next several

Figure 1: Schematic diagram of scenarios 1 and 2

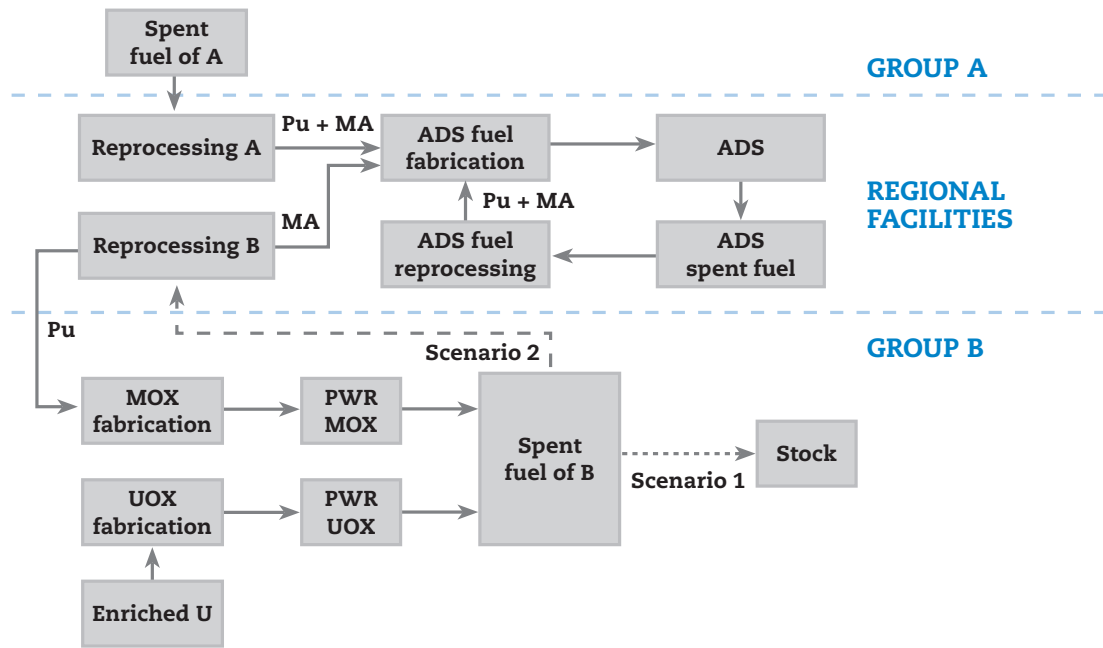


Figure 2: Schematic diagram of scenario 3

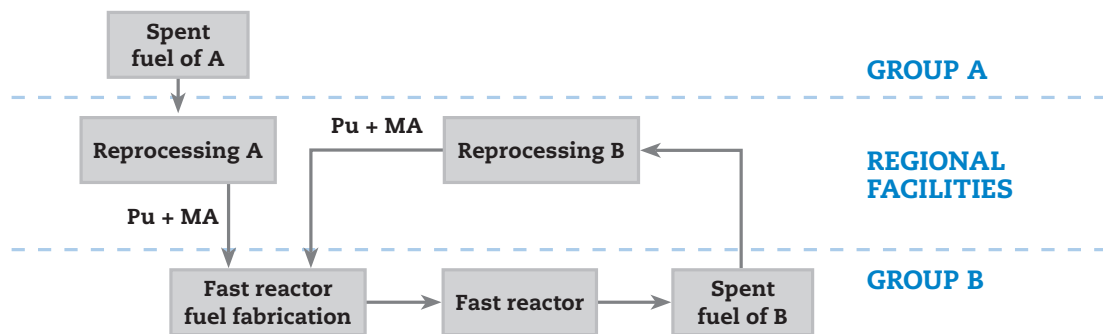
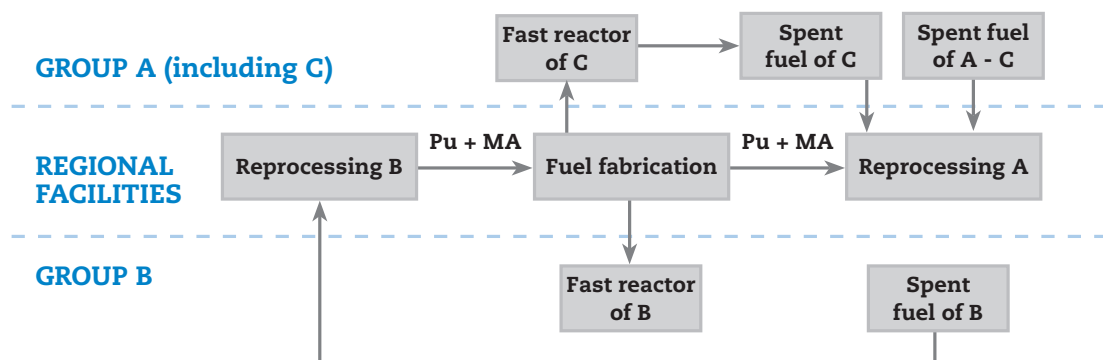


Figure 3: Schematic diagram of scenario 4



decades. The transition from current fuel cycles to advanced fuel cycles obviously will be dependent on the maturity and availability of specific technologies, as well as non-technical factors such as economics and various country-specific policies.

## Main findings on strategic and policy issues

In light of the age and performance of existing nuclear power plants, the role of nuclear energy is likely to grow in the coming decades through the lifetime extension of existing plants and the construction of new reactors, followed by the development and deployment of advanced nuclear systems beyond 2050. The lifetime of nuclear power plants in operation or currently being built is expected to exceed half a century. Advanced fast neutron systems of the fourth generation, which are under development, will not be available for commercial deployment before two decades or more. Therefore, transition to fast neutron systems will be pursued over long periods of time, likely up to the end of this century.

Fast neutron systems operated with closed fuel cycles offer possibilities for enhancing security of energy supply through better use of the energy content of natural uranium, and for facilitating waste management by reducing the volumes and radio-toxicity of radioactive waste ultimately requiring disposal. Recycling uranium, plutonium and minor actinides in fast neutron reactors can multiply by 50 or more the energy extracted from each unit of natural uranium mined. Furthermore, it shortens the time during which most radioactive waste requires stewardship.

However, the attractiveness of fast neutron systems and the relevance of transitioning from thermal to fast reactors vary from one country to another. Key parameters affecting the cost/benefit analysis of transitioning include the size and age of the nuclear reactor fleet, the expected future reliance on nuclear energy, access to uranium resources, domestic nuclear infrastructure and technology development, and radioactive waste management policies in place.

Transitioning from the current fleet of thermal reactors to systems based on fast neutron reactors and closed fuel cycles is a challenging endeavour. The management of fissile materials during the transition period requires careful long-term planning to evaluate the dynamic evolution of mass flows in evolving systems and to ensure continuing security of supply at all steps of the fuel cycle. In-depth analyses of requirements for materials and services are a prerequisite to embarking on transition scenarios and should be based upon reliable data and robust models.

Infrastructure adaptation is another key challenge to ensuring the successful transition from

thermal to fast neutron systems. Building industrial capabilities for the transition period might be difficult at the national level. Multinational facilities could provide opportunities for economies of scale and economic optimisation, which would be impossible at national level. International co-operation could also help ensure adequate supply of fuel cycle services at the global level while limiting the risk of proliferation.

The transition from thermal to fast neutron systems is a means to achieve national energy policy goals, and governments, which are responsible for designing energy policies, have a major role to play in facilitating the implementation of fast neutron reactors and closed fuel cycles when they are integrated within their strategic choices. Adaptation of legal and regulatory frameworks, R&D programmes, education and training, and stability of energy policy are key aspects of government involvement and responsibilities.

The nuclear energy renaissance expected in the first decades of the 21<sup>st</sup> century is likely to reinforce the attractiveness of fast neutron systems. Ambitious R&D programmes have been undertaken at the national level in many countries and in the framework of several international projects; they should lead to the design and development of advanced reactors and fuel cycle facilities responding to the sustainable development goals of governments and society.

The implementation of fast neutron systems will, however, require sustained efforts and enhanced international co-operation to address the challenges raised by the transition period. Scientists and analysts can provide policy makers with data and information in support of robust decision-making in this regard. Ultimately, decision makers should take adequate measures in order to ensure that the infrastructure is adapted to the requirements of evolving systems, and that the overall context of national energy policy is coherent and consistent with its goals.

## References

- NEA (2009a), *Nuclear Fuel Cycle Synergies and Regional Scenarios for Europe*, OECD, Paris.
- NEA (2009b), *Nuclear Fuel Cycle Transition Scenario Studies Status Report*, OECD, Paris.
- NEA (2009c), *Strategic and Policy Issues Raised by the Transition from Thermal to Fast Nuclear Systems*, OECD, Paris.
- NEA/IAEA (2010), *Uranium 2009: Resources, Production and Demand*, OECD, Paris.

# Explaining the shortage of medical radioisotopes

by C. Westmacott

As part of its work to examine the problems and to suggest possible solutions for ensuring the long-term, reliable supply of molybdenum-99 ( $^{99}\text{Mo}$ ) and technetium-99m ( $^{99\text{m}}\text{Tc}$ ), the NEA undertook an economic study on the  $^{99}\text{Mo}$  supply chain. This article presents an overview of the findings from *The Supply of Medical Radioisotopes: An Economic Study of the Molybdenum-99 Supply Chain*.

## The supply chain and historical implications

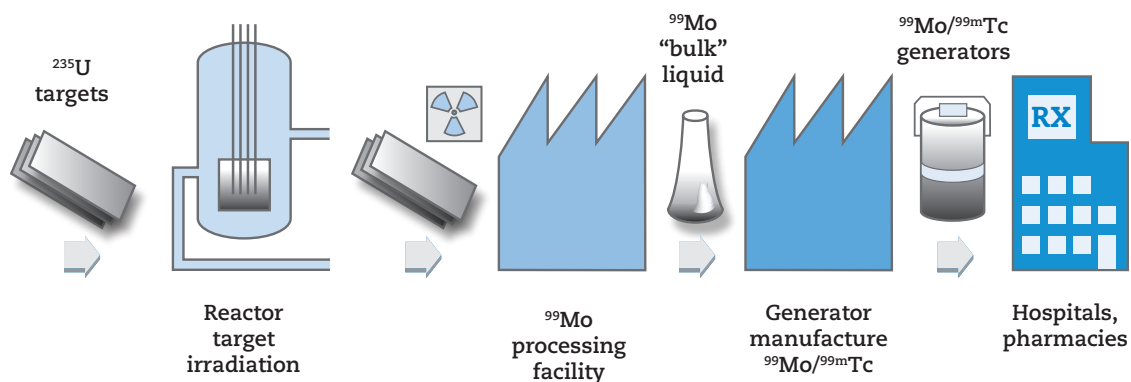
The supply chain consists of uranium target manufacturers, reactor operators who irradiate the targets to create  $^{99}\text{Mo}$  as part of the fission reaction, processors who extract the  $^{99}\text{Mo}$  from the irradiated targets and purify it to produce bulk  $^{99}\text{Mo}$ , generator manufacturers who produce generators with the bulk  $^{99}\text{Mo}$ , and radiopharmacies and hospital radiopharmacy departments who elute  $^{99\text{m}}\text{Tc}$  from the generator and couple it with “cold kits” to prepare radiopharmaceutical doses for nuclear medical imaging of patients (see Figure 1). Given the short half-lives of  $^{99}\text{Mo}$  (66 hours) and  $^{99\text{m}}\text{Tc}$  (6 hours), the logistical arrangements have to be quick and

predictable, since the economics and medical utility of  $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$  depend on minimising decay losses.

Historically, only five reactors have been producing 90-95% of global  $^{99}\text{Mo}$  supply, all of which are over 43 years old and subject to longer and more frequent planned and unplanned shutdowns. All the major producers irradiate targets using multipurpose research reactors, which were originally constructed and operated with 100% government funding, mainly for research and materials-testing purposes. When  $^{99}\text{Mo}$  production started, the reactors' original capital costs had been paid or fully justified for other purposes. As a result,  $^{99}\text{Mo}$  was seen as a by-product that provided another mission for the reactor that could generate extra revenue to support research. This resulted in:

- reactor operators originally only requiring reimbursement of *direct* short-run marginal costs;
- $^{99}\text{Mo}$  prices not covering any significant share of the costs of overall reactor operations and maintenance, or of capital costs or allowances for replacement or refurbishment costs;
- the by-product status remaining with no substantive pricing changes even as the importance of  $^{99}\text{Mo}$  production increased among reactor operating activities.

Figure 1:  $^{99}\text{Mo}$  supply chain



Source: Adapted from Ponsard, 2010.

\* Mr. Chad Westmacott ([chad.westmacott@oecd.org](mailto:chad.westmacott@oecd.org)) works in the NEA Nuclear Development Division.

As a result, prices paid to the reactor operator were too low to sustainably support the portion of reactor operations attributable to <sup>99</sup>Mo production, did not even cover short-run marginal costs in some cases, and did not provide enough financial incentive to support the replacement or refurbishment of ageing reactors.

The processing component, originally funded by governments, was commercialised in the 1980s and 1990s. Commercialisation was originally thought to be beneficial to all parties; however, contracts were based on historical perceptions of costs and pricing. This resulted in long-term contracts with favourable terms for commercial processing firms, with no substantial change to the prices for irradiation. Once these contracts were established, they set the standard for new processors and reactors that entered the market.

An unintended effect of commercialisation was establishing market power for processors. The contracts, in some cases, created a situation where the reactor operator had only one avenue for selling its <sup>99</sup>Mo irradiation services. Barriers to entry (both natural and created, such as aggressive pricing strategies) sustained this balance of power in the market and contributed to maintaining low prices for irradiation services.

A complicating factor was the historical existence of excess capacity of irradiation services. Some excess capacity is necessary to provide back-up at times when reactors are not operating, or when unexpected or extended shutdowns occur. However, operators were not compensated for maintaining reserve capacity, creating an incentive for them to use the capacity to gain revenue rather than leaving it idle, driving down the prices of irradiation services further, reducing reliability and perpetuating processor market power.

Further downstream, pricing strategies of generator manufacturers were focused on encouraging sales of their cold kits. These strategies had a feedback effect upstream, with profits not flowing back through the <sup>99</sup>Mo supply chain and limiting the flexibility to absorb proposed upstream price increases.

The question that arises is: *If the supply chain pricing structure was such that the irradiation services were economically unsustainable, why did reactors continue to irradiate targets?* The answer is related to the social contract between governments and the medical imaging community. Governments subsidised the development and operation of research reactors and related infrastructure, including radioactive waste management. Using part of this funding, reactor operators irradiated targets to produce <sup>99</sup>Mo. In return, citizens would receive an important medical isotope for nuclear medicine diagnostic procedures.

Although reactor operators were aware that government financial support was increasingly used for <sup>99</sup>Mo production, this may not have been transparent to governments. In some cases, the magnitude of

the change did not become clear until there were requests for specific funding to refurbish a reactor or to construct a new reactor. These subsidies were also supporting the production of <sup>99</sup>Mo that was being exported to other countries.

### *Governments are re-examining their subsidies*

Recently, governments from all major producing countries have indicated that they are reconsidering or no longer interested in subsidising new or ongoing production of <sup>99</sup>Mo at historical levels (or at all) – some more formally than others – questioning whether it remains in the public interest. With a change in social contract, the economics have to become sustainable on a full-cost basis or the availability of a long-term, reliable supply of <sup>99</sup>Mo will be threatened.

### *Prices must increase, but the impact on end users will be small*

Starting from a representative cost and pricing structure developed by the NEA, and based on information from supply chain participants, levelised unit cost of <sup>99</sup>Mo (LUCM) calculations were carried out to determine the magnitude of the price changes needed for economic sustainability. Their impact, based on various capital investment scenarios, was also examined. These scenarios range from using existing reactors to building a fully dedicated isotope reactor and processing facilities. Under all the scenarios, prices must increase. The analysis of the current economic situation found that, for existing reactors, the marginal revenue from production was lower than the marginal costs, with reactors facing a loss on every unit of <sup>99</sup>Mo produced.

The LUCM calculations indicated that significant price increases are necessary in the upstream supply chain in order for the latter to become economically sustainable. Reactor irradiation service prices would need to increase from EUR 45 per six-day curie (calculated from end of processing) to a range of approximately EUR 55 to 400. However, the analysis also finds that there is very little effect on the prices per patient dose. The reactor share in the final reimbursement rates would increase from approximately EUR 0.26 per procedure at pre-shortage prices to between EUR 0.33 and EUR 2.39 (see Table 1).

At pre-shortage prices, the irradiation price from the reactor (the EUR 0.26) is less than one-fifth of one percent of the final reimbursement rate (calculated as 0.11%). Even at the most extreme price increase from the reactor, the value of irradiation would increase to only 0.97% of the final reimbursement rate. The impact of the higher final radiopharmacy price on the reimbursement rate is minimal, increasing from 4.42% of the reimbursement rate to a maximum of 5.69%.

The analysis indicates that, while prices will increase for the downstream components, these should be able to be absorbed. However, this issue

**Table 1: Impact of price increases at hospital level**

	Irradiation value within final radiopharmaceutical price (EUR)	Irradiation value as % of reimbursement rate
Current situation pre-shortage	0.26	0.11
Required for economic sustainability	0.33-2.39	0.14-0.97

may require further study and possible assessment by hospitals and medical insurance plans, especially in the context of continued downward pressure on reimbursement rates or in cases where the health system provides fixed budgets to hospitals for radioisotope purchases.

#### Conversion to LEU would also have small effects on end users

The proposed conversion of targets normally containing between 45% and 93% <sup>235</sup>U (high enriched uranium – HEU) to targets containing less than 20% <sup>235</sup>U (low enriched uranium – LEU) for the production of <sup>99</sup>Mo has been agreed to by most governments for security and non-proliferation reasons. Even with uncertainty over costs of conversion for a major <sup>99</sup>Mo producer, it is clear that the current pricing structure provides insufficient financial incentive for the development and operation of LEU-based infrastructure.

However, in terms of the supply chain economics, the impact on the end user of converting to LEU targets is estimated to be quite small, even though the upstream price impact could be significant. Simulating conversion in a situation where the density of the uranium in the targets could not be increased significantly, the radiopharmacy price went from 5.06% to 5.58% of the final reimbursement rates and the share of the irradiation services increased from 0.35% to 0.86%.

### Recommendations and options

The study makes a number of recommendations and investigates options to assist decision-makers in restructuring the supply chain.

#### Government role in supporting the industry

Governments must first assess their role in the industry, especially as related to the level of subsidisation provided to the upstream <sup>99</sup>Mo supply chain (reactors and in some cases the processors). This is fundamentally a policy decision rather than an economic one.

The options for defining the social contract are based on the expected role of the government and the degree of financial support it is willing to provide. The government can choose to fund all capital and operating costs, with reactors charging only for direct marginal costs; to fund all infrastructure

costs but require operations (including maintenance, upgrades, share of total reactor operating costs/overheads and waste) to be funded commercially; or to require all <sup>99</sup>Mo-related capital and operating costs to be covered by market prices. A transition period could be considered to allow time for the market to adjust to any new pricing paradigm. However, the first two options may create distortions in the international market.

The commercial model does not result in the government abdicating any health care responsibilities. Governments may decide to continue to pay for the use of <sup>99m</sup>Tc through increasing health insurance reimbursement rates. This is considered a more appropriate subsidy as it ensures the continued supply of <sup>99m</sup>Tc without specifying how it is produced. This would enable alternative technologies, if they are economic and efficient, to enter the market freely.

#### Paying for the full costs of <sup>99</sup>Mo

Regardless of the definition of the social contract, the reactor operator must be remunerated for the full costs of <sup>99</sup>Mo production. In addition, reactor operators must be compensated for maintaining reserve capacity. Where this remuneration will come from depends on the national social contract.

If governments decide to continue to provide financial support for <sup>99</sup>Mo production and reserve capacity, they need to commit to *long-term, increased, ongoing* remuneration to reactor operators, including dedicated funding for reserve capacity. They then need to decide if their support is to be only for their domestic market or for exports as well. In the latter case, they need to be aware that they have effectively entered into a social contract with the global supply chain. Government funding, in this case, could take the form of unilateral or international funding arrangements, with funding coming from either general taxes or charges applied to the <sup>99</sup>Mo/<sup>99m</sup>Tc supply chain. An export tax could potentially be used to help reduce the amount of funds required from the general tax base.

Under a social contract of increased commercial funding, more appropriate market prices will be required to cover full costs. Reactor operators will need to require a substantial increase in prices, with commercial-based pricing becoming the norm in industry contracts over time.

For reserve capacity, end users should demand reliable supply and be willing to support it through a “reliability premium”. This demand and remuneration should flow back through the supply chain, resulting in the upstream providing reserve capacity and being paid for it. However, it is possible that there may be a role for government intervention, requiring minimum levels of reserve capacity.

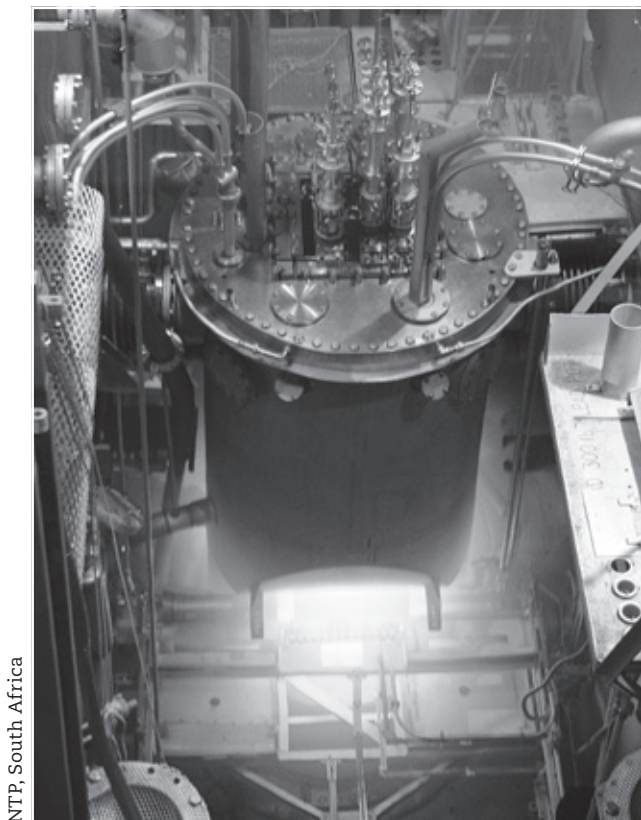
The challenge will be to develop a harmonised framework across producing countries that will allow a transition to full-cost remuneration in a period during which there are both old and new reactors, some with HEU and some with LEU targets. If new suppliers enter the market following the historically unsustainable remuneration model, this could result in commercial-based reactors not being able to sustain their current operations and new LEU-based  $^{99}\text{Mo}$  production infrastructure not being constructed or maintained without government assistance. Without harmonisation, long-term supply reliability would be threatened, with the new sources of supply only postponing pending supply shortages. One option for harmonisation would be for an expert panel to review the market and to provide a view on whether producers are applying the agreed-upon social contract.

### Changes must occur to secure long-term supply

The current economic structure of the  $^{99}\text{Mo}$  supply chain does not provide sufficient financial incentive to economically support  $^{99}\text{Mo}$  production at existing research reactors, let alone to develop new LEU-based production and processing capacity. It also does not recognise the economic value of reserve capacity. The lack of investment has resulted in a system reliant on older, less-reliable reactors. The shortage seen in 2009 and 2010 is a symptom of this economic problem.

It is clear that without ongoing financial support from governments, commercial pricing is required for the continued supply of reactor-based  $^{99}\text{Mo}$  in the medium to longer term and the conversion to LEU-based production. Changes are necessary to achieve a  $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$  supply chain that is economically sustainable and reliable. Even as short-term supply has stabilised, it is important to stress that the symptom has been addressed but the underlying problem – the unsustainable economic structure – has not.

For more information regarding NEA work on medical radioisotopes and to read the full economic study, please visit the NEA website: [www.oecd-nea.org/med-radio/](http://www.oecd-nea.org/med-radio/).



NTP, South Africa

View of the SAFARI-1 reactor located in South Africa. This is one of the reactors producing  $^{99}\text{Mo}$  for the global supply chain.

### Reference

Ponsard, B. (2010), “Mo-99 Supply Issues: Report and Lessons Learned”, paper presented at the 14<sup>th</sup> International Topical Meeting on Research Reactor Fuel Management (RRFM 2010), European Nuclear Society, ENS RRFM 2010 Transactions, 21-25 March 2010, Marrakech, Morocco.

# New nuclear build and evolving radiological protection challenges

by T. Lazo

**M**any trends and indicators suggest that the use of nuclear power for generating electricity will increase, perhaps significantly, in the coming 10 to 20 years and beyond. Any such expansion will not take place in a static scientific or social context, but rather in the midst of ongoing changes in many relevant fields, radiological protection, radioactive waste management and nuclear safety to name a few.

Regarding radiological protection, this evolution can be characterised in many different ways, but can conveniently be described as having scientific and socially driven aspects. These may well pose challenges to radiological protection (RP) policy, regulation and application in the future.

## Evolution in radiological protection and new nuclear build

Over the past 20 years, the system of radiological protection has evolved significantly, in terms of both scientific understanding and the social aspects of decision-making. The scientific underpinnings of radiological protection continue to progress and ongoing studies pose scientific questions that deserve attention (NEA, 2007a). In parallel, given the non-absolute certainty of science and the judgemental nature of defining what is “safe enough”, decision-making has become much more concerned with stakeholder engagement (NEA, 2007b).

Radiological protection challenges will certainly be encountered in the context of new nuclear build. However, approaches to meeting these challenges are not unique to new construction projects. Innovative yet sustainable approaches will be needed in addressing many radiological protection decision-making situations in the future, whether associated with existing or new facilities. Overall, to make progress on radiological protection issues it will be necessary to have transparency in decision-making structures and processes, to use state-of-the-art science and to engage with stakeholders.

In the context of new nuclear build, this translates into several levels of discussions and decisions. At the uppermost level, many governments have or will address the utility of nuclear energy in their overall energy mix. This is in essence a decision in the area of justification, and will be addressed at the national level according to national laws, legislation and traditions. It is difficult to see, however, how

such decisions could be taken without some level of “public debate”. At a lower level, decisions will be needed with regard to specific siting of new plants. Here again, national level laws and legislation will define the consultation and decision-making processes that will be used, and the more clearly these are defined and broadly understood, the more smoothly they will proceed.

Although most radiological protection decisions are not driven primarily by science, it evidently plays a key role in framing decisions that need to be made. In this context, it is essential that state-of-the-art science is used as the foundation for assessing radiological risks, keeping in mind, nevertheless, that science in general carries a fair amount of uncertainty. Hence, some judgement will be necessary when deciding whether, and if so how, uncertain scientific knowledge should be taken into account when applying a precautionary approach. The “tipping point” at which new science should induce change in RP approaches is a difficult, judgemental choice that will be very case-specific.

In the particular case of new nuclear build, while the evolution of new scientific knowledge does not seem to imminently call for change in RP approaches, there are clearly areas where scientific results *could* affect the way that radiological protection is structured and applied. For the moment, most of these questions are more in the “what if” stage, although this status does not dismiss the issues. Rather, it is suggested that scientists and regulatory authorities should increase their communication so that, as various aspects of this scientific research begin to reach closure, more detailed thinking as to the regulatory and practical implications of possible results could be undertaken in an open and transparent fashion.

*\* Dr. Ted Lazo ([edward.lazo@oecd.org](mailto:edward.lazo@oecd.org)) is Principal Administrator in the NEA Radiological Protection and Radioactive Waste Management Division.*

## Practical considerations for new nuclear power plants

It will also be important for new nuclear build to appropriately incorporate and implement lessons learnt from successful nuclear reactor operation. These include experience with exposure trends, but also with “good practice”. Both of these aspects can be included at the planning stage in order to ensure that worker and public exposures from new nuclear power plants are as low as reasonably achievable (ALARA) (NEA, 2010).

### *Incorporating operational RP lessons learnt into the design*

An important lesson learnt during the last decades is that a substantial amount of exposure in past decades has resulted from lack of attention during design. Factors such as nuclear safety and operational availability have traditionally dominated design and construction phases of nuclear power plants, with operational RP aspects often addressed to a lesser degree. There is, however, a significant potential to avoid radiation doses, as well as long-term maintenance costs, if operational radiation protection experience is embedded in the architectural design and construction of new plants (e.g. integrated ladders/stairs instead of mobile scaffolds, easily accessible cable tunnels, in-duct laid pipelines, etc.). The fact that new plant designs are targeting 60 years and more of operational lifetime adds further incentive to carefully assess and incorporate in design effective and efficient features for dose reduction and plant productivity (e.g. some maintenance operations could be performed even when the reactor is operating, or with a reduced shutdown time).

A recently published NEA study on operational RP lessons (NEA, 2010) has identified several “guiding principles” that are seen to be crucial for the successful integration of lessons in planning:

- *Proactive implementation of lessons learnt*: Crucial decisions affecting future radiation exposure of workers and also long-term expenses for maintenance, outages and modifications should be made during the design phase of a new nuclear power plant. Both radiation doses and costs can be reduced over the life cycle of the plant when practical experience from decades of operational RP in existing power plants is included in the architectural design at an early stage. It is also recommended to anticipate potential occupational exposure for the full life cycle of the plant (i.e. from operation to decommissioning) and to take optimisation measures in advance.
- *Balance of risks and allocation of resources*: Radiation exposure is not the only risk to be considered when designing a new plant. The allocation of resources for occupational health and safety at the design phase should be based on a rational balance aimed at optimising protection against all risks to workers.

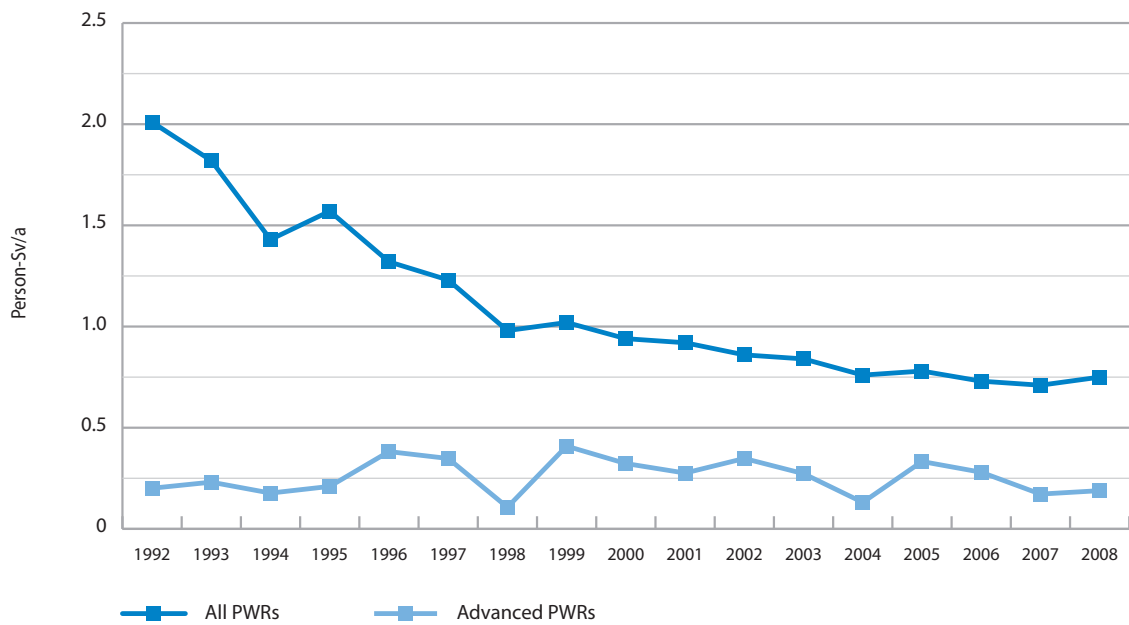
- *Effective communication in optimising design*: Licensing requirements for safety and protection of the public and the environment may require technical and organisational measures that increase radiation exposure of workers. The designer and operator must understand regulatory requirements and how those requirements are interpreted for surveillance, inspection and other activities during the plant’s operating phase. Having that clear understanding enables the designer to develop means and to use design elements that reduce radiation exposures. This requires close co-operation between regulators, designers and operators, as well as transparent and active consultation with other stakeholders.
- *Recognisable and effective operational RP*: The concept of operational RP should be forward-looking, addressing all phases of the life cycle of the power plant in order to demonstrate effective management and confidence. This should be supported by the full pool of operational experience. The management must always be aware that if the handling of operational RP appears negligent in the public’s or the regulator’s view, then trust in nuclear safety and in the reliability of management is put at risk. This jeopardises not only the operational availability of the plant but also nuclear technology as a whole.

### *Exposure benchmarks*

Since about 1990, the average annual collective dose at nuclear power plants has fallen by more than a factor of two. For pressurised water reactors (PWRs), this evolution is from just over 2 person-Sv/a per unit to under 0.75 person-Sv/a per unit. For boiling water reactors (BWRs), the decrease is slightly less, from about 2.6 person-Sv/a to 1.5 person-Sv/a per unit. For new-generation PWRs, the current annual collective dose is closer to 0.25 person-Sv/a per unit. These collective dose trends are shown in Figures 1 and 2. The advanced PWRs represent the latest French and German designs, whereas the PWR and BWR single-unit averages represent all plants of these types in the world.

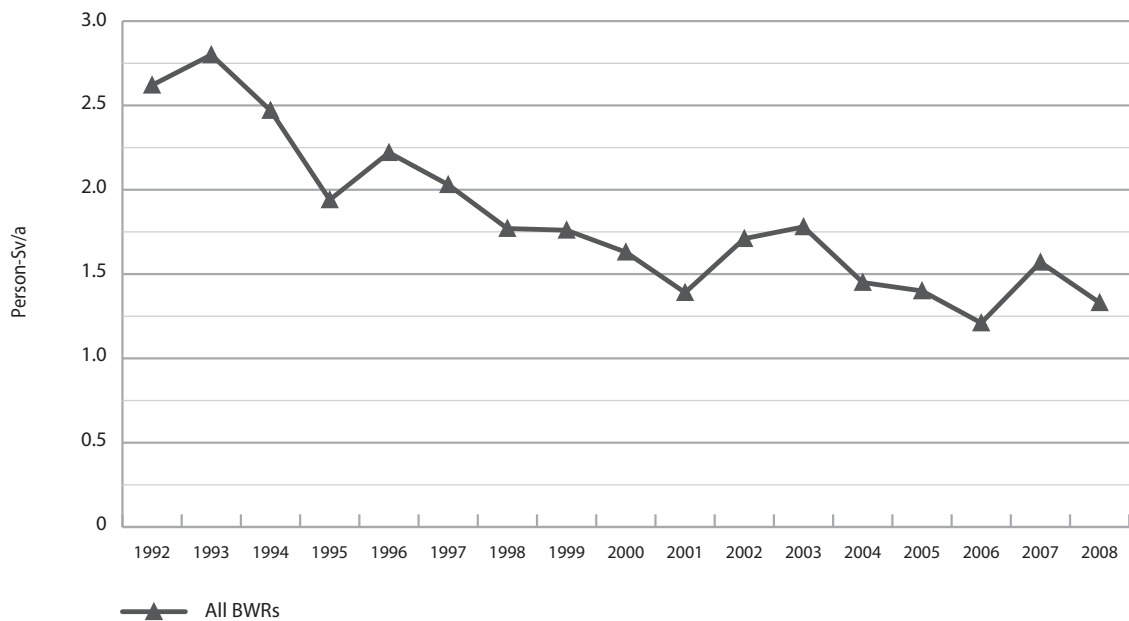
Given these trends, it seems reasonable that utilities wishing to build new nuclear power plants, and regulatory authorities involved in assessing license applications for new nuclear plants, would take this experience into account in establishing exposure benchmarks. For example, experience may be of use to establish, for planning purposes, annual collective dose benchmarks for new units, which could be on the order of 0.25 person-Sv/a for PWRs. Benchmarks for BWRs should be somewhere below about 1.5 person-Sv/a, but further data is needed in order to make a more accurate assessment. Based on current good practice and experience, such criteria could be useful in identifying the most appropriate protection options.

**Figure 1: Average annual collective dose trends for all PWRs and advanced PWRs**



Source: OECD/NEA Information System on Occupational Exposure (ISOE), 2008.

**Figure 2: Average annual collective dose trends for BWRs**



Source: OECD/NEA Information System on Occupational Exposure (ISOE), 2008.

## Designing for public and environmental protection

In terms of public exposures and environmental protection, the management of radioactive emissions from nuclear power plants continues to be a priority and is the subject of an ongoing study at the NEA. Assessed public exposures from gaseous and liquid emissions from nuclear power plants remain well below the 1 mSv/a dose limit. Traditionally, effluents have been managed through a focus on optimisation and applying best available techniques (BAT). However, the results of effluent management continue to show wide variation, even among very similar plants. Tritium has been seen to vary by more than a factor of two among sister-plant units (identical units, often at different sites), and iodine-131 by over four orders of magnitude. In this context, it is difficult to judge what would be used as a “benchmark” for optimum management of effluents for new nuclear power plants, and as such how the regulatory limitation of discharges should best be accomplished.

One approach taken to the regulatory limitation of discharges has been the establishment of “discharge limits” or “licensing technical specifications” that limit the total activity released per year, and perhaps also place limits on the discharge rate. Such limitation values have traditionally been set at higher levels than the actual discharges themselves. This “operating overhead” gives the operator flexibility to cope with non-routine events, unplanned maintenance and minor deviations from the design parameters. However, if the operating overhead is too large, there is reduced pressure for optimising, and the “apparently high” limitation values can lead to presentational difficulties, since in theory they give an operator the right to discharge much greater quantities of radioactivity than they actually do in practice. Too low an overhead may result in operators breaching a limit when carrying out reasonable and necessary activities, even if such emissions would have arguably negligible radiological impacts. This too may lead to presentational difficulties, since a breach of a licence technical specification implies inadequate performance and could call into question the quality of regulatory oversight. The challenge is to devise a transparent and consistent approach to setting levels that are stringent enough to guarantee a high level of performance in relation to discharges, whilst giving operators the flexibility they need to conduct normal, acceptable operations without infringing their discharge authorisations. In principle:

- Discharge limitation should be based on the minimum level of discharge that the operator has justified the need for in order to operate the plant.
- Limitation should provide necessary headroom based on operational fluctuations or trends in the level of discharge over the year that the operator has substantiated may occur in normal operation, even though optimisation and BAT have been applied.

- The headroom allowed between actual discharges and limiting values is kept to the absolute minimum strictly necessary for the normal operation of the plant.

In this context, it should be noted that limiting values are not set at levels corresponding to the boundary between acceptable and unacceptable radiological impact. In particular, they do not correspond to the dose limits or constraints contained in national or international legislation. Indeed, the application of optimisation and BAT at the planning stage should have eliminated any proposals which would give rise to doses approaching or exceeding such limits or constraints before the discharge limit-setting stage is reached.

## Conclusions

The construction of nuclear power plants has always raised issues of public concern. Even in the current climate in which nuclear energy is being seriously reconsidered in many countries at national government level and at multinational corporate level, the construction of new units has always raised questions that need to be resolved. Experience has shown that in such situations, decisions acknowledged as acceptable can take some time to be reached. To appropriately prepare to address questions of new nuclear build, governments should ensure that their established decision-making processes clearly and unambiguously lay out rules and responsibilities, and actively and effectively engage with stakeholders in gathering their views. The overall process will involve the use of state-of-the-art science and a statement of values applied when making judgements. Industry will need to ensure that its proposed facilities incorporate radiological and other lessons learnt, and to demonstrate that optimisation and work-management experience has been effectively applied to new plant designs, procedures and processes.

## References

- NEA (2007a), *Scientific Issues and Emerging Challenges for Radiological Protection: Report of the Expert Group on the Implications of Radiological Protection Science*, OECD, Paris.
- NEA (2007b), *Radiation Protection in Today's World: Towards Sustainability*, OECD, Paris.
- NEA (2010), *Occupational Radiological Protection Principles and Criteria for Designing New Nuclear Power Plants*, OECD, Paris.

# The Forum on Stakeholder Confidence celebrates a decade of work

by C. Pescatore, C. Mays and D. Diaconu

Since its foundation in 2000, the NEA Radioactive Waste Management Committee (RWMC) Forum on Stakeholder Confidence (FSC) has fostered constructive dialogues and interactions with hundreds of interested parties in radioactive waste management, ranging from specialists and academic researchers, national and local politicians to local stakeholders and associations. Many of those partners came to Paris in September 2010 to participate in the colloquium “Looking Back, Looking Forward in Stakeholder Engagement”. This Ten-year Anniversary Colloquium as well as the FSC’s eleventh regular meeting on the following two days were open to all interested parties.

This article describes the Forum and the online reports in which learning is shared. It highlights the two major topics discussed at the Colloquium and reviews the joint evaluation made there of FSC achievements. Finally, it points to the directions selected for a new decade of work.

## The FSC – a sustained experiment, an online resource

The FSC was created by the NEA in 2000 to promote the sharing of international experience in addressing the societal dimension of radioactive waste management. The FSC explores means to ensure effective dialogue amongst all stakeholders and to strengthen confidence in decision-making processes and socio-technical systems of radioactive waste management. The working definition given to the term “stakeholder” is “any actor – institution, group or individual – with an interest or with a role to play in the process.”

The Forum is composed of designated representatives from 16 NEA member countries. They are mainly government policy and regulatory officials, R&D specialists, implementers and industry representatives, although other profiles are present as well. The Forum is assisted in its work by academics (notably social scientists) inside and outside the fields directly concerned with radioactive waste management. Good relationships have been formed with representatives of regions and local communities who share an interest or stake in the topics discussed. Opportunities to participate include attendance at the national workshops, community visits and case study presentations at the regular

meetings, and contributions to desk studies and online consultations.

Through these varied, participative learning activities, the FSC has documented a wealth of experience told in many voices. This ongoing record benchmarks practice, and allows progress and change to be assessed. Study reports, proceedings of workshops and topical sessions, and two-page summary flyers are available online at [www.oecd-nea.org/fsc](http://www.oecd-nea.org/fsc).

A new document is the “Ten-year Record of Learning” which serves as an index to the themes approached and the people who contributed. FSC work has canvassed many questions and issues concerning the management of various categories of radioactive waste and the diverse solutions envisaged. Its scope and experience extend beyond geological repositories. Feedback from professionals and practitioners indicates that many of the FSC lessons are pertinent outside the area of waste management. The FSC online library is thus a precious resource, for its breadth, consistency, the broad participative basis on which the work rests, and its utility in addressing socio-technical decision-making in general.

## Ten-year Anniversary Colloquium

The Ten-year Anniversary Colloquium held on 15 September 2010 was the occasion to take stock of FSC achievements, to conduct a multi-stakeholder discussion of two important current themes and to gather guidance on new directions to be taken by the FSC in the coming years.

\* Dr. Claudio Pescatore ([claudio.pescatore@oecd.org](mailto:claudio.pescatore@oecd.org)) is Principal Administrator for Radioactive Waste Management and Decommissioning at the NEA, Ms. Claire Mays ([claire.mays@oecd.org](mailto:claire.mays@oecd.org)) is a consultant to the NEA and Dr. Daniela Diaconu ([daniela.r-diaconu@gmail.com](mailto:daniela.r-diaconu@gmail.com)), who provided input to this article, works at the Institute for Nuclear Research (INR) Pitesti in Romania.

## Building a durable relationship between the host community, the facility and the major institutional players with quality of life in mind

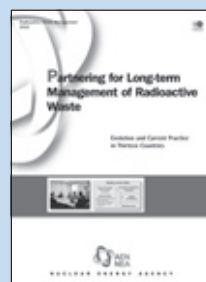
The FSC has broken away from traditional institutional discourse in suggesting that radioactive waste management facility siting is not about “acceptance” by a local community. Instead, FSC members are convinced that a facility should be embedded in a viable, long-term societal project, aimed at “ownership” and focused notably on the sustainable well-being of the host communities. Among the important features in creating such a project is the actual relationship formed among the stakeholders, and the symbolic relationship they will form with the site and facility. Prof. Erik van Hove of Antwerp challenged the Colloquium audience to consider today’s contradictory social situation: the higher economic development of society should offer opportunities for happier life, yet at the same time there is perhaps more loneliness and empty existences than ever before. He pointed out how the FSC’s proposal to give added community value to radioactive waste management is one way of addressing such imbalances.

Among the local representatives who took the floor were Catarina Blom of the Uppsala Regional Council (Sweden) and Mayor Kris van Dijck of Dessel (Belgium). Ms. Blom pointed out how politicians become mediators between the needs of technical researchers and the population; addressing waste management in a democratic manner reinforces democracy overall. Mayor van Dijck shared Belgium’s experience, showing that it is very important to involve people in the socio-technical decision-making, but that special instruments have to be created to support their engagement. Essential conditions in relationship-building are communication, correct information, a focus on safety planning and assurance of new jobs in a new industry. A repository should represent a profitable investment for the next generations, and local funds should be negotiated in this regard.

## Partnering for long-term management of radioactive waste

Early in 2010, the FSC issued a significant report (NEA, 2010) and summary flyer on the ways in which partnerships have been formed and conducted in 13 countries. The partnership approach is a collaborative working relationship between the community and the main developer of a radioactive waste management facility. Relevant levels of government, from local to national, may be involved either directly or indirectly, which adds confidence that future decisions or recommendations by the partnership will receive due consideration at higher levels. Other institutions may also play a role in the partnership. The formats chosen for partnership operation (permanent or temporary working groups, panels, etc.) and the outputs it targets (design plans, recommendations to elected or administrative authorities) are

## Recent publications of the Forum on Stakeholder Confidence



- *More than Just Concrete Realities: The Symbolic Dimension of Radioactive Waste Management.*
- *Partnering for Long-term Management of Radioactive Waste: Evolution and Current Practice in Thirteen Countries.*
- *Radioactive Waste Repositories and Host Regions: Envisaging the Future Together (Workshop Proceedings, France).*

## NEA News articles

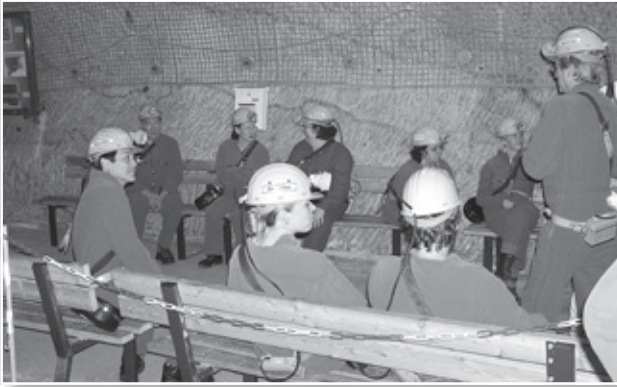
- “Partnering with stakeholders in radioactive waste management”.
- “Geological disposal of radioactive waste: records, markers and people”.

The FSC also offers several two-page summary flyers, most in English, French, Japanese and Spanish.

All are available online at [www.oecd-nea.org/fsc](http://www.oecd-nea.org/fsc).

set through legally binding agreements or through less formal arrangements. Overall, the partnership approach contributes to transparency and can support accountability in decision-making. Most importantly, it reflects a determination to empower communities in decisions that may affect their future.

At the colloquium, a critical look was taken at partnership, examining whether this governance tool is widespread and successful. In general, support was found and the conditions for achieving co-management were highlighted. The EC-funded COWAM (Community Waste Management) programmes have investigated and proved the capacity of social groups to create competence in assessing potential repository impacts and to analyse its strategic value. Serge Gadbois of Mutadis presented a stakeholder assessment of how the Aarhus Convention could support society to engage in such collaborative decision-making. Institutional and local members of different partnerships from Belgium, France, Hungary, Slovenia and the United Kingdom showed that there are common concerns: not negotiable are safety and security, benefits to the community, correct information and access to knowledge. Throughout these examples, there are similar expectations as well as frustrations regarding the institutional processes.



Technical visit during the October 2004 FSC workshop.



Participants at the Sixth Forum on Stakeholder Confidence in November 2006.

### *Joint assessment of the FSC as a framework for learning*

All FSC contacts were invited to evaluate the past decade of work and to provide guidance for the next. A survey was available online throughout the summer of 2010 and was completed by 64 stakeholders. While many stated that they belong to an institution with an official role in radioactive waste management (RWM), they did not emerge as a majority. Among the wide range of stakeholders who answered the survey, two groups were most strongly represented: implementers and operators, and interested citizens. The survey asked how people had learnt about the FSC, which themes are most pertinent, which publications are most appreciated, which are the most effective learning approaches applied by the Forum and which ideas have people taken away. Suggestions on improving the FSC and its service to stakeholders, as well as for new activities and themes, were also collected.

The survey results and the collection of reports and material available on the FSC web page, benefited from an outside and independent analysis. Teacher/researchers from the University of Versailles and Oxford pointed out that the FSC corpus explores a large range of methods, engaged a broad spectrum of problems and addressed the main characteristics of the waste management process: patience, the long-term dimension, costs, people and skills. FSC procedures and reports provide an excellent resource base for teaching and training in that everything is very well documented, representing multiple learning pathways and offering solutions to a class of sensitive problems and to contradictory aspects of the problems. Five dozen suggestions were made for new FSC explorations, including on the stepwise approach, knowledge maintenance and transfer, participation fatigue, expectations regarding participation processes and the stability of decision-making processes.

A first-time visitor to the FSC stated: “The presentations and discussions in panels gave me insight into the large and productive activity of the Forum as well as the different approaches to public involvement in decision-making processes in countries either already having a history (Finland, France, Spain, Sweden, the United Kingdom...) or just paving now (Italy, Poland) the way towards a democratic process in radioactive waste disposal implementation. All presentations reflected the need for dialogue and transparency, the need for a democratic framework, the need to understand the public’s concerns and requirements for authorities. The colloquium dialogue extended to the national scale in many NEA member countries.”

### **Reference**

NEA (2010), *Partnering for Long-term Management of Radioactive Waste: Evolution and Current Practice in Thirteen Countries*, OECD, Paris.

# Decontamination and dismantling of radioactive concrete structures

by P. O'Sullivan, J.G. Nokhamzon and E. Cantrel\*

The treatment and disposal of contaminated concrete is a major issue for almost all decommissioning projects due to the very large quantities of material which may be involved. The selection and use of different dismantling and decontamination techniques can significantly influence the total amount of contaminated material that needs to be managed. For example, if a contaminated building is fully demolished, all debris is considered contaminated and requires special handling. In the event that a surface removal technique is first used to separate the contaminated concrete, the volume of material requiring disposal as radioactive material will be significantly reduced, though care will be needed in case of possible non-superficial contamination along cracks and in pipe penetrations.

Significant increases in the volume of concrete to be handled in the near future may be expected given the growing trend towards prompt decommissioning rather than allowing a period of several years of safe storage/decay prior to final dismantling. This is because modern technology, improved work processes and emphasis on safety have negated the advantages of long-term decay. Advances in dismantling techniques (including remote dismantling), recycling/re-use, increasing waste storage costs, and improved planning processes have made this approach cost-effective, as well as generally being preferable to the local communities involved.

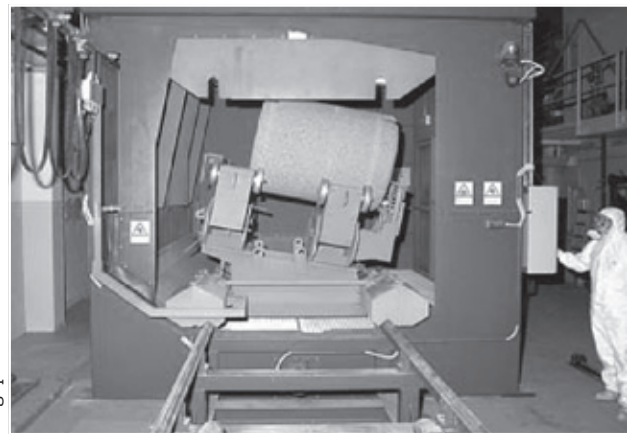
## Decontamination techniques

In recent years, a range of decontamination techniques have been used to reduce substantially the amount of contaminated material for disposal by removing surface contamination of varying depths. The following techniques are used when future land-use scenarios include reuse, when it is impractical to demolish the structure (e.g. a laboratory within a building) or to minimise waste volume:

- Scarifying techniques: the scarification process involves the physical abrading of coated or uncoated surfaces, i.e. the successive removal of multiple layers of contaminated surfaces until reaching a depth at which the surface is uncontaminated.
- Abrasive blasting techniques: these are typically used in conventional industry to clean equipment or surfaces of removable or fixed contaminants, such as grease, rust and paint, and/or to prepare

surfaces for coating applications. Depending on the overall objective and the nature of the surface material (e.g. steel, concrete...), the process uses different abrasive media such as plastic, glass or steel beads, or grit, such as garnet, soda or aluminium oxide. Compared to scarifying techniques, these processes may produce significant amounts of secondary waste. The possibility of recycling the abrasive material should always be addressed.

- High-pressure liquid jetting techniques: these comprise high-pressure water jetting (HPWJ) and liquid nitrogen jetting. HPWJ has proved to be a very effective method to clean concrete surfaces and to remove corroded concrete layers, which can strip concrete layers up to several centimetres in a single working step. The main problem arises from the resulting contamination of the water which can, in turn, lead to deep cross-contamination, especially in cracks and joints.



Belgoprocess

Abrasive blasting installation used for the decontamination of concrete containers.

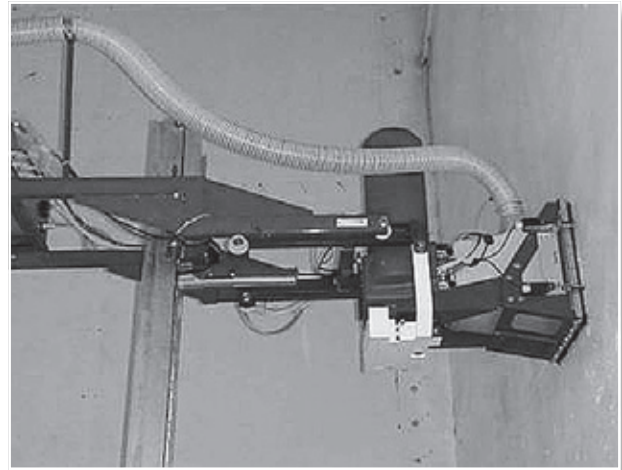
\* At the time of writing, Patrick O'Sullivan ([patrick.osullivan@oecd.org](mailto:patrick.osullivan@oecd.org)) worked in the NEA Radiological Protection and Radioactive Waste Management Division. Jean-Guy Nokhamzon ([jean-guy.nokhamzon@cea.fr](mailto:jean-guy.nokhamzon@cea.fr)) works for the French Atomic Energy Commission (CEA); he is Chair of the NEA Co-operative Programme on Decommissioning (CPD). Eric Cantrel ([ecantrel@sckcen.be](mailto:ecantrel@sckcen.be)) works for the Belgian Nuclear Energy Centre (SCK•CEN); he is Chair of the CPD Task Group on Decontamination and Dismantling of Radioactive Concrete Structures.

- Laser ablation: the principle of laser ablation (with low power) is based on the rapid heating of the surface causing the superficial layer to expand and spall. The resulting local shock-wave is sufficient to eject the paint/coating from the surface. This technology is currently in its demonstration phase; it differs from earlier high energy systems in that the contaminated layer is ejected from the surface rather than burnt.

## Dismantling and demolition techniques

Dismantling and demolition techniques are used whenever large quantities or deep layers of activated or contaminated concrete need to be removed. Depending on the plant layout, there are currently a large range of possible well-proven, highly reliable and generally economical techniques. Such techniques may be used, even at an early stage of a decommissioning project, for creating openings and accesses to rooms, e.g. hot cells, or to enlarge existing openings allowing shipment of equipment to the working place or removal of large components. They include:

- Diamond wire sawing: this enables the creation of wall openings and the detachment of large concrete structures. The saw-cut surfaces are very smooth. In contrast to most other cutting techniques, there are few limitations to the size and thickness of the components to be cut. Although diamond wire sawing techniques are normally used with water cooling, they may also be applied in dry conditions. Dust emissions can be reduced using a sealed collection system located at the outlet of the wire.
- Circular sawing: this may be considered as the primary option when very precise cuts are required. Appropriate guiding devices need to be attached to the structure to control the cutting forces and to avoid locking the blade, which reduces the attractiveness of this technique compared to wire sawing. The maximum cutting depth is about one metre.
- Hammering: when massive structures have to be removed, hydraulic hammering is a cost-effective technique (low investment, high yield, simple implementation) but it requires particular attention to safety aspects (structural stability, release of vibration energy, falling rubble, high noise levels). The removal of the activated material in the biological shield is a typical application.
- Drilling and spalling: this technique involves drilling 25-40 mm diameter holes, approximately 75 mm deep, into which a hydraulically operated spalling tool with an expandable tube is inserted. A tapered mandrel is then hydraulically forced into the hole to spread the “fingers” and spall off the concrete. Other options involve the use of spreadable side pistons instead of mandrels or



Laser ablation on carrier with vacuum.

the use of expanding grout. Drilling and spalling is recommended for hard-to-reach areas, for the separation of medium-scale blocks or as preparation for further treatment. Apart from the drilling process, spalling may be considered a quiet, safe and clean technique.

- High-pressure water jet cutting: abrasive water jet technology (AWJ) uses a multifunctional tool that can be used for almost all types of cutting, drilling and removal activities. The advantages are mainly related to the absence of mechanical tools that suffer from interference such as vibrations, thermal stress, seizures, tool abrasion and the condition and shape of the material being cut. Although AWJ cutting has been successfully applied to the underwater dismantling of reactor vessels and is considered an adequate tool for this application, there are certain drawbacks including possible cross-contamination by the contaminated water and the high amount of secondary waste. High-pressure water jet cutting might be considered in special cases or if efficient water and abrasive management is implemented.

## Conclusions

Dismantling and demolition works need to be planned and undertaken with due consideration being given to the need for accurate characterisation of the resulting debris, which may be destined for further treatment, free release or disposal. Typically, the choice of the dismantling or decontamination technique for a specific application is determined on a case-by-case basis by considering the advantages and disadvantages of each of the available techniques. A combination of different techniques is often necessary due to the diversity of situations found in the installation being decommissioned.



Concrete spalling.

Important considerations when selecting techniques for the decontamination and dismantling of concrete structures are the production of secondary waste, the containment of contamination, safety issues, and the yield and reliability of the techniques. Often, the application of a specific technique is closely connected to the possible use of adequate tool guidance systems to ensure expected standards of accuracy and yield. Special consideration must always be given to avoid causing unacceptable damage to the structure, especially for reasons of building stability.

Experience from decommissioning work undertaken during the past decade has highlighted the following issues related to the choice of concrete decontamination and dismantling techniques:

- When considering the use of scarifying techniques, a major issue is process automation. Scarifying tools are mostly extremely heavy, which tends to limit their size and subsequently their intrinsic performance. For the particular case of reactors, rooms to be decontaminated have highly variable dimensions and geometry. Therefore different (automated) handling devices might have to be considered in order to implement a given decontamination technique in different parts of the facility. For these reasons, manual treatment techniques are still often preferred since these have proven to be the most efficient in terms of global operation yield, though it should be noted that manual scarification is particularly strenuous for operators and therefore requires working with several shifts and regular breaks.

- In recent years, alternatives to strenuous/low-yield mechanical techniques (hammering, scarifying) have been thoroughly investigated (microwave, rebar heating, explosives), though few have proven to be compatible with the constraints of a dismantling project (including nuclear and industrial safety requirements, minimisation of waste volume and economics). However, recent active trials with (low energy) laser and nitrojet processes have demonstrated that both techniques are now mature enough to be implemented on decommissioning projects.
- Techniques currently being used for segmentation, such as diamond sawing and drilling techniques, are still being improved to match the specific needs of dismantling operations, e.g. recent common efforts of diamond tool manufacturers and the decommissioning industry have led to several successful applications of dry sawing of reinforced concrete.
- Abrasive blasting techniques (particularly grit blasting) have proven to be very versatile techniques for both *in situ* decontamination and for dismantled components, e.g. shielding blocks and containers. Concrete layers of several millimetres in thickness can be removed at high production rates provided that an adequate abrasive is chosen and is continuously recycled. Possible cross-contamination of surfaces is an issue to consider when planning the operation. Also, because of the porosity of the concrete, wet techniques which can induce cross-contamination should be avoided.
- Specific (operator) safety issues related to concrete decontamination and dismantling include: dust control/ventilation of the work area, airborne contamination, vibration, noise, projections (of debris and/or abrasives) and falling equipment.
- Different segmentation techniques are likely to be needed to deal with various radiological situations on a particular project, such as different types of contamination and depths of penetration, different quality of concrete, and shapes and size constraints of structures.

*Acknowledgement: this paper is based on and includes extracts from the NEA report entitled **Decontamination and Dismantling of Radioactive Concrete Structures**. It is available online at [www.oecd-nea.org](http://www.oecd-nea.org).*

# The Blue Ribbon Commission and siting radioactive waste disposal facilities

by C. Pescatore\*

On 21 September 2010, the NEA Secretariat was invited to address the Blue Ribbon Commission on America's Nuclear Future. What follows is a summary of the remarks made.

The successful siting of radioactive waste disposal facilities implies creating the conditions for *continued ownership* of the facility over time. Acceptance of the facility at a single point in time is not good enough. Continued ownership implies the creation of conscious, constructive and durable relationships between the (most affected) communities and the waste management facility. Continued ownership by host communities follows from being comfortable about safety, feeling that they are not condoning a dubious practice, but one that is in tune with the broader interests of society in general, and that the facility will contribute to the quality of life of the community and region across generations.

Being comfortable about the technical safety of the facility requires a degree of familiarity and control. Having peace of mind about the safety of the facility requires trust in the waste management system and its actors as well as some control over the decision making. Regulators are especially important players who need to be visible in the community. Their role in the service of people needs to be professed, verified and understood. Communities and regions that are familiar with nuclear power and have had a long, constructive relationship with its actors require less time for acquiring familiarity and control and for achieving trust, provided there is willingness to allow them some continued forms of influence.

The ideal site selection process should be step-wise, combining procedures for excluding sites that do not meet pre-identified criteria with those for identifying sites where nearby and more distant residents are willing to discuss acceptance of the facility. The regional authorities are just as important as the local authorities.

Before approaching a potential siting region or community, there should be clear results of national (and state) debates establishing the role of nuclear power in the energy mix, as well as information on the magnitude of the ensuing waste commitment and its management end-points, and the allocation of the financial and legal responsibilities until the closure of the project (and even beyond, as the closure of the repository does not necessarily equate to the closure of the issue).

Once the waste inventories and type of facilities have been decided upon, there should be agreement that all significant changes will require a new decision-making process. Successful siting is thus embedded in a larger system of decision making that includes nation- and/or state-wide debates on nuclear and waste management approaches, as well region-wide debates on the types of facility, the tolerable negative impacts and the desirable positive impacts.

Any proposed project has a much better chance to move forward positively if the affected populations can participate in its definition, including, at the appropriate time, its technical details. The technical approach, safety standards, monitoring and mitigation measures, among others, should be finalised only after deliberations with the host community/region during the siting phase. This way, refinement of the proposed technical approach is shared and iterative. A voluntary process, from which communities may withdraw for some time, improves the chances for community willingness to participate and for a sustainable outcome.

A partnering approach is generally best for developing the project with a host community. A variety of partnership organisations (which may incorporate NGOs, local government associations, units within or around local/regional governments) have been or are being set up in an increasing number of countries. Most often such organisations build their own expertise and influence the implementer's work. They collect, process and disseminate information on the facility and its impacts, monitor other players' performance and advise local governments. They also help identify socio-economic benefits aimed at compensating for potential losses and generally supporting the well-being of the host communities. The result of collaboration builds social capital, which is good for the quality and sustainability of decisions. The whole process takes time and may be seen as overly lengthy by some. Time is, however, necessary for the non-technical parties to understand their interests and build the relevant competences.

\* Dr. Claudio Pescatore ([claudio.pescatore@oecd.org](mailto:claudio.pescatore@oecd.org)) is Principal Administrator for Radioactive Waste Management and Decommissioning at the NEA.

Not rushing to a technical solution is also capital for ensuring a safe solution. Respect of the time dimension, both technical and societal, is fundamental for sustainable decision-making. Decision-making in discrete, well-identified steps is recommended to help deal with the time dimension. During the whole process *openness, transparency, technical competence and procedural equity* are key conditions for credible discourse and for public acceptance of waste management programmes.

## NEA literature

National radioactive waste management programmes are in various phases of siting final management facilities and rely on different technical approaches for different categories of waste. In all cases, it is necessary for institutional actors and the potential or actual host communities to build a meaningful, workable relationship. The NEA created its Forum on Stakeholder Confidence (FSC) in 2000 to explore means of ensuring an effective dialogue amongst all stakeholders and to strengthen confidence in decision-making and governance processes. The FSC promotes the sharing of international experience through topical sessions and studies and through national workshops and community visits. Lessons have been distilled with the concurrence of practitioners, the involved stakeholders and social/political science experts. The FSC's many publications are all germane to the subject of siting and sustainable decision-making, and are available on the FSC web page [www.oecd-nea.org/fsc](http://www.oecd-nea.org/fsc). Four FSC studies, in particular, warrant special attention.

The 2004 report *Stepwise Approach to Decision-Making for Long-term Radioactive Waste Management* reviews the large accumulated experience and the results of the academic studies in the field of siting, both within and outside the nuclear field, over the previous 20 years. It distils the basic recommendations for sustainable decision-making that the FSC still sponsors today.

The 2004 report *Learning and Adapting to Societal Requirements for Radioactive Waste Management* synthesises countries' experience of relationship-building. In this report the partnership approach is highlighted as a practical method for effective collaboration with local communities and informed consent.

The 2007 study *Fostering a Durable Relationship between a Waste Management Facility and its Host Community* summarises the expectations for sustained improvements to the quality of life of the affected communities and host regions, beyond the endowment of immediate economic benefits. The study highlights innovations in siting processes and in facility design that add value to the facility both in the short and in the long term.

Finally, the 2010 study *Partnering for Long-Term Management of Radioactive Waste* (based on a 2008-09 survey), documents the approach taken in 13 countries and the evolution of partnership arrangements. The study defines the basic components of the partnership approach: various administrative formats of *collaboration* with communities, community benefits, volunteerism and veto arrangements.

Two-page FSC flyers, available online, summarise the main findings of each of the above studies ([www.oecd-nea.org/fsc](http://www.oecd-nea.org/fsc), see rubric "FSC flyers").

# NEA joint projects: nuclear safety, radioactive waste management,

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. All NEA joint projects currently under way are listed below.

Project	Participants	Budget
<p><b>Behaviour of Iodine Project (BIP)</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: July 2007-March 2011</p>	Belgium, Canada, Finland, France, Germany, Japan, Netherlands, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	≈€ 350 K /year
<p><b>Cabri Water Loop Project</b>            Contact: <a href="mailto:radomir.rehacek@oecd.org">radomir.rehacek@oecd.org</a>            Current mandate: 2000-2015</p>	Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States.	≈€ 74 million
<p><b>Computer-based Systems Important to Safety (COMPSIS) Project</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: January 2008-June 2011</p>	Chinese Taipei, Finland, Germany, Hungary, Republic of Korea, Sweden, Switzerland, United States.	€ 80 K /year
<p><b>Co-operative Programme on Decommissioning (CPD)</b>            Contact: <a href="mailto:wei-whua.loba@oecd.org">wei-whua.loba@oecd.org</a>            Current mandate: January 2009-December 2013</p>	Belgium, Canada, Chinese Taipei, European Commission, France, Germany, Italy, Japan, Republic of Korea, Slovak Republic, Spain, Sweden, United Kingdom.	≈€ 70 K /year
<p><b>Fire Incidents Records Exchange (FIRE) Project</b>            Contact: <a href="mailto:alejandro.huerta@oecd.org">alejandro.huerta@oecd.org</a>            Current mandate: January 2010-December 2013</p>	Canada, Czech Republic, Finland, France, Germany, Japan, Netherlands, Republic of Korea, Spain, Sweden, Switzerland, United States.	≈€ 84 K /year
<p><b>Fire Propagation in Elementary, Multi-room Scenarios (PRISME) Project</b>            Contact: <a href="mailto:greg.lamarre@oecd.org">greg.lamarre@oecd.org</a>            Current mandate: January 2006-June 2011</p>	Belgium, Canada, Finland, France, Germany, Japan, Netherlands, Republic of Korea, Spain, Sweden, United Kingdom, United States.	€ 7 million
<p><b>Halden Reactor Project</b>            Contact: <a href="mailto:radomir.rehacek@oecd.org">radomir.rehacek@oecd.org</a>            Halden contact: <a href="mailto:Fridtjov.owre@hrp.no">Fridtjov.owre@hrp.no</a>            Current mandate: 2009-2011</p>	Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Japan, Kazakhstan, Norway, Republic of Korea, Russian Federation, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States.	≈€ 43 million

# radiological protection

At present, 15 joint projects are being conducted in relation to nuclear safety, 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 of the respective areas of research.

## Objectives

- Provide separate effects and modelling studies of iodine behaviour in a nuclear reactor containment building following a severe accident.
  - Provide data and interpretation from three radioiodine test facility (RTF) experiments to participants for use in collaborative model development and validation.
  - Achieve a common understanding of the behaviour of iodine and other fission products in post-accident reactor containment buildings.
- 
- 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 BWR and PWR fuel.
- 
- Define a format and collect software and hardware fault experience in computer-based, safety-critical NPP systems in a structured, quality-assured and consistent database.
  - Collect and analyse COMPSIS events over a long period so as to better understand such events, their causes and their prevention.
  - Generate insights into the root causes of and contributors to COMPSIS events, which can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences.
  - Establish a mechanism for efficient feedback of experience gained in connection with COMPSIS events, including the development of defences against their occurrence, such as diagnostics, tests and inspections.
  - Record event attributes and dominant contributors so that a basis for national risk analysis for computerised systems is established.
- 
- Exchange scientific and technical information amongst decommissioning projects for nuclear facilities.
- 
- 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 with the aim to better understand such events, their causes and their prevention.
  - Generate qualitative insights into the root causes of fire events which can then be used to derive approaches or mechanisms for their prevention or for mitigating 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-based inspections.
  - Record characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies.
- 
- Answer questions concerning smoke and heat propagation inside a plant, by means of experiments tailored for code validation purposes.
  - Provide information on heat transfer to cables and on cable damage.
- 
- 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.

# NEA joint projects

Project	Participants	Budget
<p><b>Information System on Occupational Exposure (ISOE)</b>            Contact: <a href="mailto:halilburcin.okyar@oecd.org">halilburcin.okyar@oecd.org</a>            Current mandate: 2008-2011</p>	Armenia, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Lithuania, Mexico, Netherlands, Pakistan, Republic of Korea, Romania, Russian Federation, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, United Kingdom, United States.	≈€ 450 K /year
<p><b>International Common-cause Failure Data Exchange (ICDE) Project</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: April 2008-March 2011</p>	Canada, Finland, France, Germany, Japan, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	≈€ 110 K /year
<p><b>Melt Coolability and Concrete Interaction (MCCI) Project</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: April 2006-December 2010</p>	Belgium, Czech Republic, Finland, France, Germany, Hungary, Japan, Norway, Republic of Korea, Spain, Sweden, Switzerland, United States.	€ 3.4 million
<p><b>Piping Failure Data Exchange (OPDE) Project</b>            Contact: <a href="mailto:alejandro.huerta@oecd.org">alejandro.huerta@oecd.org</a>            Current mandate: June 2008-May 2011</p>	Canada, Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Spain, Sweden, Switzerland, United States.	≈ € 50 K /year
<p><b>Primary Coolant Loop Test Facility (PLK-2) Project</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: April 2008-September 2011</p>	Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	€ 3.9 million
<p><b>Rig of Safety Assessment (ROSA-2) Project</b>            Contact: <a href="mailto:abdallah.amri@oecd.org">abdallah.amri@oecd.org</a>            Current mandate: April 2009-March 2012</p>	Belgium, Czech Republic, Finland, France, Germany, Hungary, Japan, Republic of Korea, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States.	€ 2.7 million
<p><b>Sandia Fuel Project (SFP)</b>            Contact: <a href="mailto:radomir.rehacek@oecd.org">radomir.rehacek@oecd.org</a>            Current mandate: July 2009-June 2012</p>	Czech Republic, France, Germany, Hungary, Italy, Japan, Norway, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	€ 4 million

## Objectives

- Collect, analyse and exchange occupational exposure data and experience from all participants.
  - Provide broad and regularly updated information on methods to improve the protection of workers and on occupational exposure in nuclear power plants.
  - 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 for mitigating 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.
- 
- Provide experimental data on melt coolability and concrete interaction (MCCI) severe accident phenomena.
  - Resolve two important accident management issues:
    - the verification that molten debris that has spread on the base of the containment can be stabilised and cooled by water flooding from the top;
    - the two-dimensional, long-term interaction of the molten mass with the concrete structure of the containment, as the kinetics of such interaction is essential for assessing the consequences of a severe accident.
- 
- Collect and analyse piping failure event data to promote a better understanding of underlying causes, impact on operations and safety, and prevention.
  - Generate qualitative insights into the root causes of piping failure events.
  - Establish a mechanism for efficient feedback of experience gained in connection with piping failure phenomena, including the development of defence against their occurrence.
  - Collect information on piping reliability attributes and influence factors to facilitate estimation of piping failure frequencies, when so decided by the Project Review Group.
- 
- Investigate safety issues relevant for current PWR plants as well as for new PWR design concepts.
  - Focus on complex heat transfer mechanisms in the steam generators and boron precipitation processes under postulated accident situations.
- 
- Provide an integral and separate-effect experimental database to validate code predictive capability and accuracy of models. In particular, phenomena coupled with multi-dimensional mixing, stratification, parallel flows, oscillatory flows and non-condensable gas flows are to be studied.
  - Clarify the predictability of codes currently used for thermal-hydraulic safety analyses as well as of advanced codes presently under development, thus creating a group among OECD/NEA member countries who share the need to maintain or improve technical competence in thermal-hydraulics for nuclear reactor safety evaluations.
- 
- Address potential accident conditions and perform a highly detailed thermal-hydraulic characterisation of full-length, commercial pressurised water reactor (PWR) fuel assembly mock-ups.
  - Provide data for the direct validation of appropriate codes.
  - Address applicability to other fuel designs, also considering that BWR data will be made available to project participants.

# NEA joint projects

Project	Participants	Budget
<p><b>SESAR Thermal-hydraulics (SETH-2) Project</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: March 2007-December 2010</p>	Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Slovenia, Sweden, Switzerland.	€ 2.5 million
<p><b>Steam Explosion Resolution for Nuclear Applications (SERENA) Project</b>            Contact: <a href="mailto:jean.gauvain@oecd.org">jean.gauvain@oecd.org</a>            Current mandate: October 2007-September 2011</p>	Canada, Finland, France, Germany, Japan, Republic of Korea, Slovenia, Sweden, Switzerland, United States.	€ 2.6 million
<p><b>Studsvik Cladding Integrity Project (SCIP-2)</b>            Contact: <a href="mailto:radomir.rehacek@oecd.org">radomir.rehacek@oecd.org</a>            Current mandate: July 2009-June 2014</p>	Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	€ 1.5 million /year
<p><b>Thermochemical Database (TDB) Project</b>            Contact: <a href="mailto:mireille.defranceschi@oecd.org">mireille.defranceschi@oecd.org</a>            Current mandate: 2008-2012</p>	Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	≈€ 441 K /year

## Objectives

- Generate high-quality experimental data that will be used for improving the modelling and validation of computational fluid dynamics (CFD) and lumped parameter (LP) computer codes designed to predict post-accident containment thermal-hydraulic conditions for current and advanced reactor designs.
  - Address a variety of measured parameters, configurations and scales in order to enhance the value of the data for code applications.
  - Study relevant containment phenomena and separate effects, including effects of jets, natural convection, containment coolers and sprays.
- 
- Provide experimental data to clarify the explosion behaviour of prototypic corium melts.
  - Provide experimental data for validation of explosion models for prototypic materials, including spatial distribution of fuel and void during the pre-mixing and at the time of explosion, and explosion dynamics.
  - Provide experimental data for steam explosions in more realistic, reactor-like situations to verify the geometrical extrapolation capabilities of the codes.
- 
- 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.

# New publications

## General interest

---

### **The Strategic Plan of the Nuclear Energy Agency – 2011-2016**

ISBN 978-92-64-99135-4. 40 pages. Free: paper or web.

### **Nuclear Energy Technology Roadmap**

48 pages. Free: paper or web.

This nuclear energy roadmap has been prepared jointly by the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA). Unlike most other low-carbon energy sources, nuclear energy is a mature technology that has been in use for more than 50 years. The latest designs for nuclear power plants build on this experience to offer enhanced safety and performance, and are ready for wider deployment over the next few years. Several countries are reactivating dormant nuclear programmes, while others are considering nuclear for the first time. In the longer term, there is great potential for new developments in nuclear energy technology to enhance the role of nuclear power in a sustainable energy future.

## Economic and technical aspects of the nuclear fuel cycle

---

### **Comparing Nuclear Accident Risks with Those from Other Energy Sources**

ISBN 978-92-64-99122-4. 52 pages. Free: paper or web.

Nuclear accident risks are raised frequently in discussions of the acceptability of nuclear power generation, often framed in the context of the Three Mile Island and Chernobyl accidents. In reality, the safety record of nuclear power plants, by comparison with other electricity generation sources, is very good. This report describes how safety has been enhanced in nuclear power plants over the years, as the designs have progressed from Generation I to Generation III, and why it is important that safety remain the highest priority. This is illustrated by considering core damage frequencies and large radioactive release frequencies for each generation of nuclear power plants. It also compares severe accident data (those resulting in five or more fatalities) between different energy sources, both for immediate fatalities and for delayed (latent) fatalities, recognising that the latter data are often more difficult to estimate. Finally, it uses results of opinion surveys to analyse public confidence in nuclear operations and how this is correlated with trust in legislation and regulatory systems. It has been written for a general audience.

### **The Supply of Medical Radioisotopes**

**An Economic Study of the Molybdenum-99 Supply Chain**

ISBN 978-92-64-99149-1. 128 pages. Free: paper or web.

### **An Economic Study of the Molybdenum-99 Supply Chain: Summary**

ISBN 978-92-64-99150-7. 36 pages. Free: paper or web.

The reliable supply of molybdenum-99 ( $^{99}\text{Mo}$ ) and its decay product, technetium-99m ( $^{99\text{m}}\text{Tc}$ ), is a vital component of modern medical diagnostic practices. Disruptions in the supply chain of these radioisotopes – which cannot be effectively stored – can suspend important medical testing services. Unfortunately, supply reliability has declined over the past decade, due to unexpected or extended shutdowns at the few ageing,  $^{99}\text{Mo}$  producing, research reactors and processing facilities. These shutdowns have created global supply shortages. This study offers a unique analysis of the economic structure and present state of the  $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$  supply chain. It finds that the shortages are a symptom of a longer-term problem linked to insufficient capital investment, which has been brought about by an economic structure that does not provide sufficient remuneration for producing  $^{99}\text{Mo}$  or support for developing additional production and processing infrastructure. To assist governments and other decision makers in their efforts to ensure long-term, reliable supply of these important medical isotopes, the study presents options for creating a sustainable economic structure. The study will also enhance understanding amongst stakeholders of the costs of supplying  $^{99}\text{Mo}$  and ultimately contribute to a better functioning market.

## Uranium 2009: Resources, Production and Demand

ISBN 978-92-64-04789-1. 456 pages. Price: € 130, US\$ 182, £ 117, ¥ 16 900.

With several countries currently building nuclear power plants and planning the construction of more to meet long-term increases in electricity demand, uranium resources, production and demand remain topics of notable interest. In response to the projected growth in demand for uranium and declining inventories, the uranium industry – the first critical link in the fuel supply chain for nuclear reactors – is boosting production and developing plans for further increases in the near future. Strong market conditions will, however, be necessary to trigger the investments required to meet projected demand. The “Red Book”, jointly prepared by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, is a recognised world reference on uranium. It is based on information compiled in 40 countries, including those that are major producers and consumers of uranium. This 23<sup>rd</sup> edition provides a comprehensive review of world uranium supply and demand as of 1 January 2009, as well as data on global uranium exploration, resources, production and reactor-related requirements. It provides substantive new information from major uranium production centres around the world, as well as from countries developing production centres for the first time. Projections of nuclear generating capacity and reactor-related uranium requirements through 2035 are also featured, along with an analysis of long-term uranium supply and demand issues.

## Radioactive waste management

---

### Geoscientific Information in the Radioactive Waste Management Safety Case

#### Main Messages from the AMIGO Project

ISBN 978-92-64-99138-5. 56 pages. Free: paper or web.

Radioactive waste is associated with all phases of the nuclear fuel cycle as well as the use of radioactive materials in medicine, research and industry. For the most hazardous and long-lived waste, the solution being investigated worldwide is disposal in engineered repositories deep underground. The importance of geoscientific information in selecting a site for geological disposal has long been recognised, but there has been growing acknowledgement of the broader role of this information in assessing and documenting the safety of disposal. The OECD/NEA Approaches and Methods for Integrating Geological Information in the Safety Case (AMIGO) project has demonstrated that geological data and understanding serve numerous roles in safety cases. The project, which ran from 2002 to 2008, underscored the importance of integrating geoscientific information in the development of a disposal safety case and increasingly in the overall process of repository development, including, for example, siting decisions and ensuring the practical feasibility of repository layout and engineering.

### Radioactive Waste in Perspective

ISBN 978-92-64-09261-7. 204 pages. Price: € 48, US\$ 67, £ 43, ¥ 6 200.

Large volumes of hazardous wastes are produced each year, however only a small proportion of them are radioactive. While disposal options for hazardous wastes are generally well-established, some types of hazardous waste face issues similar to those for radioactive waste and also require long-term disposal arrangements. The objective of this NEA study is to put the management of radioactive waste into perspective, firstly by contrasting features of radioactive and hazardous wastes, together with their management policies and strategies, and secondly by examining the specific case of the wastes resulting from carbon capture and storage of fossil fuels. The study seeks to give policy makers and interested stakeholders a broad overview of the similarities and differences between radioactive and hazardous wastes and their management strategies.

## Radiological protection

---

### Evolution of the System of Radiological Protection

#### Implementing the 2007 ICRP Recommendations – Fifth Asian Regional Conference, Chiba, Japan, 3-4 September 2009

ISBN 978-92-64-99147-7. 28 pages. Free: paper or web.

Since 2002, the NEA has been actively facilitating the detailed discussion of the evolving system of radiological protection in an Asian context. Its work in this area has included four previous conferences to discuss various International Commission on Radiological Protection (ICRP) draft general recommendations. The Fifth Asian Regional Conference on the Evolution of the System of Radiological Protection was the first in this series to be focused directly on the implementation of the new ICRP recommendations. This conference report provides very useful, practical insight into the Asian approach to implementing this new radiological protection philosophy.

## Occupational Radiological Protection Principles and Criteria for Designing New Nuclear Power Plants

ISBN 978-92-64-99142-2. 112 pages. Free: paper or web.

Global demand for electricity continues to grow and numerous new nuclear power plants (NPPs) are being planned or constructed in NEA member countries. Most of these new NPPs will be of the third generation, and will be designed for as long as 80 years of operation. The successful design, construction and operation of these plants will depend broadly on appropriately implementing the lessons from experience accumulated to date. This case study introduces a policy and technical framework that may be used when formulating technical assistance and guidance for senior managers of NPPs, designers, manufacturers, contractors and authorities responsible for regulating occupational radiation exposure. It is aimed in particular at assisting design and license assessments of new NPPs. Although not targeting the needs of countries introducing nuclear power for the first time, this case study can also provide valuable input on occupational radiological protection issues for the implementation of new nuclear energy programmes.

## Strategic Aspects of Nuclear and Radiological Emergency Management

Planning for Effective Decision Making; Consequence Management and Transition to Recovery

ISBN 978-92-64-99146-0. 72 pages. Free: paper or web.

The collective experience of the NEA Working Party on Nuclear Emergency Matters (WPNEM), and in particular, the experience from the International Nuclear Emergency Exercise (INEX) series, has shown that it is important to plan and to implement emergency response actions based on a guiding strategic vision. Within this context, Strategic Aspects of Nuclear and Radiological Emergency Management presents a framework of strategic planning elements to be considered by national emergency management authorities when establishing or enhancing processes for decision making, and when developing or implementing protection strategies. The focus is on nuclear or radiological emergency situations leading to complex preparedness and response conditions, involving multiple jurisdictions and significant international interfaces. The report is aimed at national emergency management authorities, international organisations and those who are seeking to improve the effectiveness of emergency management. Its goal is to provide insights into decision-making processes within existing emergency planning arrangements. It also highlights common areas of good practice in decision making. Specific areas for improvement, identified during the INEX-3 consequence management exercise, are included, particularly in support of decision making for countermeasures for consequence management and the transition to recovery.

## Nuclear law

---

### International Nuclear Law: History, Evolution and Outlook

10<sup>th</sup> Anniversary of the International School of Nuclear Law

ISBN 978-92-64-99143-9. 424 pages. Free: paper or web.

This publication commemorates the International School of Nuclear Law which is celebrating its 10<sup>th</sup> anniversary in 2010. The purpose of the publication is to provide an overview of the international nuclear law instruments, their background, content and development over the years and to present an outlook on future needs in the field of international nuclear law. Renowned experts in the nuclear law field have contributed scholarly papers on the various aspects of international nuclear law, including international institutions, protection against ionising radiation, nuclear safety, non-proliferation of nuclear weapons and safeguards, nuclear security, transport of nuclear material and fuel, management of spent fuel and radioactive waste, liability, compensation and insurance for nuclear damages, environmental protection and international trade in nuclear material and equipment. This publication is dedicated to the school's 500+ alumni from all around the world.

### Nuclear Law Bulletin, No. 85

Volume 2010/1

ISSN 0304-341X. 164 pages. 2010 subscription (2 issues): € 114, US\$ 150, £ 91, ¥ 16 500.

The *Nuclear Law Bulletin* is a unique international publication for both professionals and academics in the field of nuclear law. It provides subscribers with authoritative and comprehensive information on nuclear law developments. Published twice a year in both English and French, it features topical articles written by renowned legal experts, covers nuclear legislative developments worldwide and reports on relevant case law, bilateral and international agreements and regulatory activities of international organisations. Feature articles in this issue address the independence of the nuclear regulator, the European nuclear safety directive, the nuclear renaissance in Italy and the Temelín case in the European Court of Justice.

# Nuclear science and the Data Bank

---

## Boiling Water Reactor Turbine Trip (TT) Benchmark

### Volume IV: Summary Results of Exercise 3

ISBN 978-92-64-99137-8. 276 pages. Free: paper or web.

In the field of coupled neutronics/thermal-hydraulics computation there is a need to enhance scientific knowledge in order to develop advanced modelling techniques for new nuclear technologies and concepts, as well as for current applications. Recently developed “best-estimate” computer code systems for modelling 3-D coupled neutronics/thermal-hydraulics transients in nuclear cores and for coupling of the core phenomena and system dynamics (PWR, BWR, VVER) need to be compared against each other and validated against results from experiments. International benchmark studies have been set up for that purpose. The present volume is the last in a series of four and summarises the results of the third benchmark exercise, which analyses a turbine trip (TT) in a BWR in its entirety, involving pressurisation events in which the coupling between core phenomena and system dynamics plays an important role. Exercise 3 also analyses four extreme scenarios which allowed participants to test the capabilities of their code(s) in terms of coupling and feedback modelling. The data made available from experiments carried out at the plant make the present benchmark particularly valuable. The data used are from events at the Peach Bottom 2 reactor (a GE-designed BWR/4).

## JANIS 3

### A Java-based Nuclear Data Display Program – 2010

DVD. Free: paper or web.

## NUPEC BWR Full-size Fine-mesh Bundle Test (BFBT) Benchmark

### Volume II: Uncertainty and Sensitivity Analyses of Void Distribution and Critical Power – Specification

ISBN 978-92-64-99124-8. 44 pages. Free: paper or web.

The government of Japan and the Japanese Nuclear Power Engineering Corporation (NUPEC) have released high-quality data, based on a series of void measurements using full-size mock-up tests for boiling water reactors (BWRs), with the aim of assisting the scientific community to advance its understanding of the two-phase flow (a system containing both gas and liquid) in BWR fuel bundles. An international benchmark, based on the NUPEC data, has been defined to encourage advancement in the development of two-phase flow theory which is of importance, for example, for the evaluation of the safety margins in a reactor. The benchmark specifications are being designed so that it systematically assesses and compares the capability of the numerical models to predict detailed void distributions and critical powers. This report is the second in a series and describes the specification of the sensitivity and uncertainty analysis exercises undertaken to assess the accuracy of the results obtained when modelling basic thermal-hydraulics in a single channel relative to void fraction and critical power. Further volumes will be published, with a synthesis showing to what extent the most recent models are capable of predicting two-phase flow in BWR fuel bundles.

## VVER-1000 Coolant Transient Benchmark

### Phase 2 (V1000CT-2) Summary Results of Exercise 1 on Vessel Mixing Simulation

ISBN 978-92-64-99152-1. 144 pages. Free: paper or web.

Recently developed best-estimate computer code systems for modelling 3-D coupled neutronics/thermal-hydraulics transients in nuclear reactors need to be validated against results from experiments and compared with each other to help understand how the different modelling methods adopted affect the accuracy of the simulation. This benchmark was set up for that purpose. This report is one of a series covering benchmarks designed to test modelling methods for a range of transient scenarios in a VVER-1000 reactor. In this case, the transient is initiated by isolation of one steam generator causing asymmetric loop heat-up. The benchmark is based on experiments conducted at the Kozloduy nuclear power plant.

## OECD/NEA Nuclear Energy iLibrary

Online and archive package  
Price: € 1 060, \$ 1 400, £ 850, ¥ 154 000.

Online package only  
Price: € 710, \$ 930, £ 565, ¥ 103 000.



The **OECD/NEA Nuclear Energy iLibrary** subscription includes one copy of each new print publication and online access to all books and periodicals published by the OECD Nuclear Energy Agency. It includes access to the twice-yearly *Nuclear Law Bulletin*, the annual *Nuclear Energy Data*, the biannual *Uranium: Resources, Production and Demand*, as well as the NEA's numerous analytical studies, conference proceedings and other reports not published in print form. Usually there are about 45 items per year. The archive subscription includes online access to all titles published by the OECD since 1998 and all online-only publications from 2003 onwards. Customers will be given access details by e-mail within 48 working hours following purchase.

To subscribe, see :

[www.oecd.org/bookshop?16121s1](http://www.oecd.org/bookshop?16121s1)

### Where to buy NEA publications

#### In North America

OECD Publications  
c/o Turpin Distribution  
The Bleachery, 143 West Street  
New Milford, CT 06776  
United States  
Toll free: 1 (800) 456 6323  
Fax: 1 (860) 350 0039  
E-mail: [oecdna@turpin-distribution.com](mailto:oecdna@turpin-distribution.com)

#### In the rest of the world

OECD Publications  
c/o Turpin Distribution  
Pegasus Drive, Stratton Business Park  
Biggleswade, Bedfordshire  
SG18 8QB, United Kingdom  
Tel.: +44 (0) 1767 604960  
Fax: +44 (0) 1767 601640  
E-mail: [oecdrow@turpin-distribution.com](mailto:oecdrow@turpin-distribution.com)

Online ordering:

[www.oecd.org/bookshop](http://www.oecd.org/bookshop)

Secure payment with credit card.

### Where to order free NEA publications

OECD Nuclear Energy Agency  
Publications Service  
12, boulevard des îles  
92130 Issy-les-Moulineaux, France  
Tel.: +33 (0)1 45 24 10 15  
Fax: +33 (0)1 45 24 11 10  
E-mail: [neapub@oecd-nea.org](mailto:neapub@oecd-nea.org)



Please note  
our new website  
address:

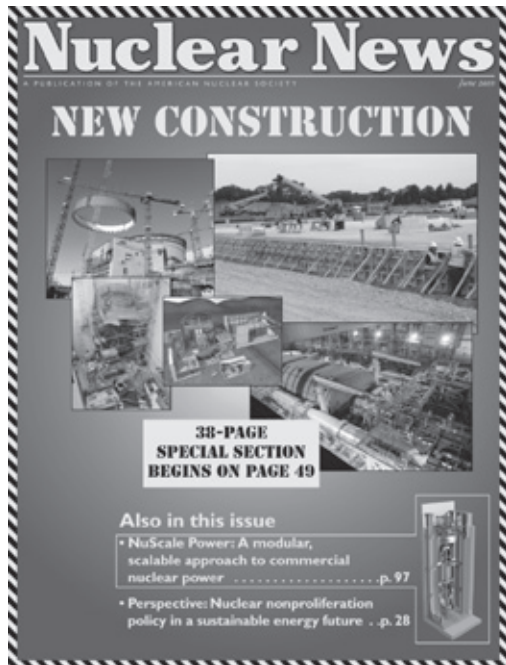
[www.oecd-nea.org](http://www.oecd-nea.org)



From the American Nuclear Society (ANS)

# Nuclear News

THE WORLD'S PREMIER NUCLEAR MAGAZINE



**Nuclear News** has been an integral part of the advertising plans of more than 1000 companies and organizations since the magazine accepted its first advertisement in 1960. The magazine covers the latest developments in the nuclear field, a large part of which concerns nuclear energy — in particular, the 104 operating U.S. nuclear power plants, and more than 330 operating in the rest of the world. News reports cover plant operations, maintenance, security, international developments, waste management, fuel, and industry. Also covered are nonpower uses of nuclear science and technology, including nuclear medicine, food irradiation, and space nuclear applications. Other sections of the magazine include calendar, calls for papers, short courses, publications, new products and services, and literature from suppliers.

Published as a special 13th issue of the year, the mid-April *Nuclear News* **Buyers Guide** lists nearly 1000 worldwide suppliers throughout 470 categories of products and services for nuclear science and technology. This annual directory is the primary commercial reference publication the nuclear industry relies on year-round.

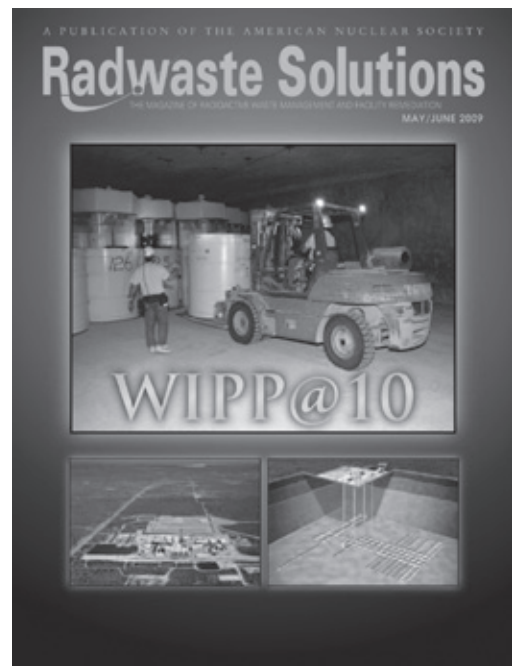
# Radwaste Solutions

THE MAGAZINE OF RADIOACTIVE WASTE MANAGEMENT AND FACILITY REMEDIATION

**Radwaste Solutions** is the magazine of radioactive waste management and facility remediation. In the United States, this business is centered on four industry subsets: (1) the Department of Energy's remediation of its weapons production and research facilities; (2) the DOE's civilian radioactive waste activities (primarily, the Yucca Mountain Project, which remains on hold while the Nuclear Regulatory Commission and the courts decide the project's future); (3) nuclear utilities, and (4) nonpower, non-DOE activities. Also, other countries are cleaning up and decommissioning their government nuclear facilities and older nuclear power plants, and U.S. businesses are increasingly obtaining contracts and subcontracts to perform this work.

In 2009, as part of the \$800-billion American Recovery and Reinvestment Act, the DOE's Environmental Management Office, which oversees site cleanup, received an additional \$6 billion for cleanup and decommissioning work. This large infusion of funding into the DOE cleanup budget has meant thousands of jobs and many cleanup contracts and subcontracts over the last two years.

A large portion of that \$6 billion is still funding major cleanup projects, which must be completed by the end of 2011.



**ADVERTISE: 1-708-579-8226**

**SUBSCRIBE: 1-708-579-8207**

**Publications of the American Nuclear Society**

**www.ans.org**

OECD/NEA Publications, 2 rue André-Pascal, 75775 PARIS CEDEX 16  
PRINTED IN FRANCE – ISSN 1605-9581