

NEA News

2005 – No. 23.1

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An analysis of uranium exploration and price

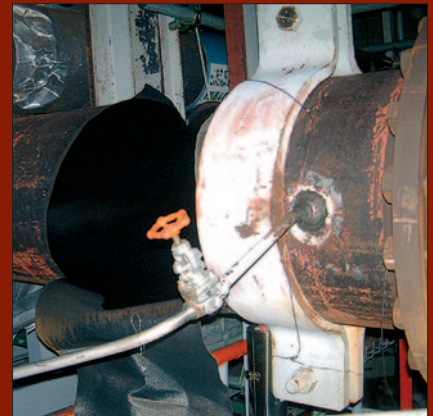
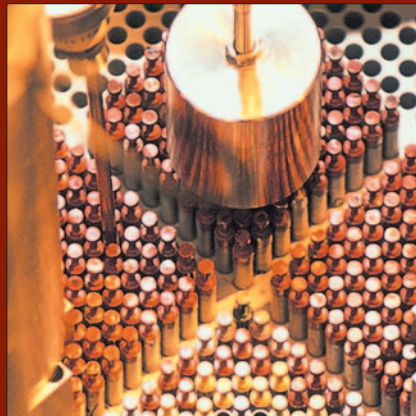


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The OECD Nuclear Energy Agency (NEA) is an intergovernmental organisation established in 1958. Its primary objective is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological 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 28 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, 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.

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Cover page: Yellow cake being filtered (P. Lesage, AREVA, France), refined yellow cake (NEI, United States), fuel rods at the Eole experimental reactor (P. Stroppa, CEA, France), pipe failure at Mihama Unit 3 (JNES, Japan), site characterisation for geological disposal (Posiva Oy, Finland).

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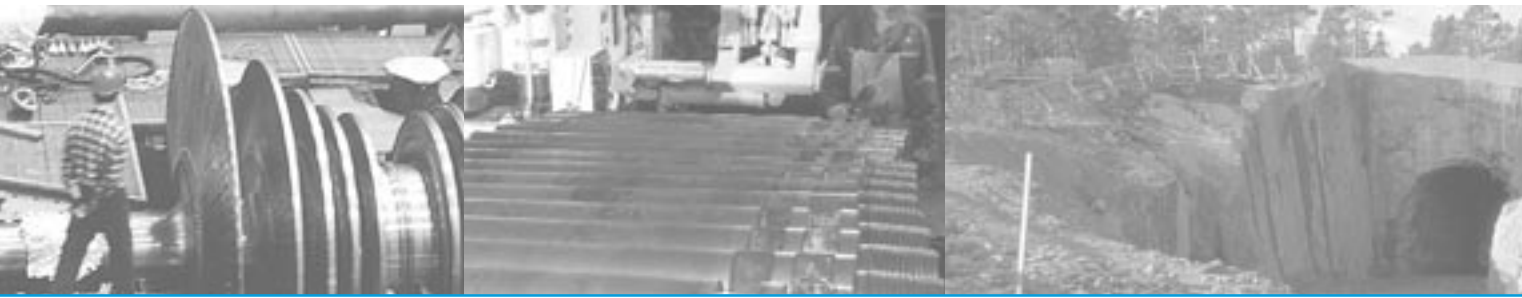
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Ministers take a close look at nuclear energy



Nuclear energy was the focus of considerable attention in this spring's international agenda. At the international conference on Nuclear Power for the 21st Century held in Paris in March, 74 countries and 10 international organisations were represented. In May, nuclear energy was also debated at the Meeting of the International Energy Agency (IEA) Governing Board at Ministerial Level, the OECD Forum on Fuelling the Future: Security, Stability, Development, and at the Meeting of the OECD Council at Ministerial Level, held back-to-back with the OECD Forum.

At the Nuclear Power for the 21st Century conference, opinions about nuclear energy were largely, though not exclusively, positive. Many Delegates tended to consider that nuclear energy can, under the right conditions, be part of a response to the challenge of meeting expanding energy demand, ensuring the security of energy supply, while addressing climate change. An overview of the main themes covered during the conference is provided in the news brief on page 21.

In the other meetings, the focus was less on nuclear energy and more on energy issues all-around. At the OECD Forum, the general sentiment was that urgent action was required in the energy sectors of both developed and developing countries. Ministers at the Meeting of the IEA Governing Board at Ministerial Level stressed that energy security remained their core mission, and described their vision of energy security as greater global availability of reliable, affordable, clean energy. At the Meeting of the OECD Council at Ministerial Level, on 3-4 May, Ministers underlined that sufficient supply of clean and affordable energy is crucial for economic and social development. They further considered that investment in energy technology and infrastructure must



be directed towards sustainable, efficient technology with less negative climate impact. During a joint meeting held between the Delegates attending the Meeting of the OECD Council at Ministerial Level (MCM) and the Meeting of the IEA Governing Board at Ministerial Level, participants discussed how governments can improve the framework conditions to ensure timely investment in energy infrastructure that meets the tests of security of supply, economic efficiency, environmental sensitivity and affordability.

The messages from these high-level gatherings seem clear, and I firmly believe that we cannot afford to underestimate the importance of meeting the energy challenges before us. Our economies depend upon it, as do our health and well-being. Meeting growing energy demands must be done with due consideration for preserving the environment. To succeed, a full range of approaches – starting with energy conservation measures, but also including cleaner energy sources, greater use of renewables and appropriate environmental-preservation agreements and incentives – will be necessary.

Luis E. Echávarri
NEA Director-General

Nuclear regulatory decision making

B. Kaufer, T. Murley *

Nuclear safety regulators are continuously faced with making a wide variety of decisions. Some of these may be made on the regulator's own initiative, for example a regulation on new reporting requirements, but the large majority of decisions are made in response to stimuli from outside the organisation. A new CNRA report¹ has found that in all decision-making scenarios, whether difficult or straightforward, the nuclear regulator will benefit from a structured decision-making framework.

Nuclear power programmes in OECD countries have matured over their four decades of commercial operation; this maturation has brought many improvements in safety through backfits in technology as well as programmes and improvements in operational performance of nuclear power plants generally. In parallel with these changes in nuclear plants' performance, safety regulation of nuclear power plants has matured, most notably in the use of new safety analysis methods such as probabilistic safety analysis (PSA); in the regulatory responses to new information

and insights from operating experience, especially from the accidents at Three Mile Island and Chernobyl; in the consideration of human factor and organisational impacts upon nuclear safety; and in an increased emphasis on quality management systems.

It has been recognised for some years that the nature of the relationship between the regulatory body and the operator can influence the operator's safety culture at a plant, either positively or negatively.^{2,3} An important factor affecting the relationship between the regulator and the operator is the nature of the

regulator's decision-making process. In light of these insights, the NEA Committee on Nuclear Regulatory Activities (CNRA) judged that it was an appropriate time to examine the broad issue of regulatory decision making. That judgement was the basis for deciding to prepare a report providing an international consensus on the integrated decision-making process. To pursue this objective, an expert group was formed with senior-level regulators.



Types of regulatory decisions

Perhaps the bulk of the decision cases that come before a regulator are straightforward issues, but that does not mean that they are unimportant or that the regulator does not

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need to consider them carefully. Rather, it simply means that there are substantial precedents of case histories and adequate time for the regulator to define the issues clearly, to analyse alternative actions and to involve the appropriate stakeholders. In other words, for such issues there is ample opportunity for the regulator to implement its deliberative, structured decision-making process.

Some of these decision issues will be more challenging for the regulator. They are frequently characterised by unexpected circumstances, lack of complete information, uncertain or contradictory information, disagreement among the safety experts, a real or perceived urgency to make a decision, an incomplete understanding of the consequences of a decision, or all of the above. Adding to these difficulties is often the concern in the mind of the regulator that its decision-making actions may have profound effects not only on public safety but on the public's perception and confidence in the regulatory body itself.

Whether a decision issue is straightforward or difficult, a nuclear regulator will benefit by having a structured decision-making framework and by having experience in following its procedures.

Basic principles for regulatory decision making

A fundamental tenet of nuclear safety is that the operator has the responsibility for safely operating its nuclear power plant(s). It is the nuclear regulator's responsibility to oversee the operator's activities in order to ensure that the plant is operated safely. Nothing the regulator does should ever diminish that

fundamental distinction in roles between the operator and regulator. A regulator's decisions must be grounded in the nation's laws and the regulations and standards that implement those laws. But even further, the regulatory body should promote safety by setting a good example in its own performance.

When approaching regulatory decisions several basic principles can be applied such as assessing safety significance, gathering sufficient information to make an informed decision, seeking input from outside stakeholders, maintaining consistency in decisions, and most importantly, acting as a competent, professional, independent body that makes regulatory decisions on the basis of protecting safety, security and the environment.

In making a decision on a difficult issue, the regulator will have to consider how the decision will appear in retrospect if it turns out to be wrong or not to have the desired outcome. In difficult cases there will frequently be pressure on the regulator from many sources, so the regulatory body should ask itself some questions before rendering a final decision:

- Is there a clear safety basis for the decision?
- Is there a clear legal basis for the decision?
- Were normal procedures followed?
- Were all stakeholder views considered?
- Was there due diligence used in gathering the necessary information?
- Is the decision consistent with earlier precedents?
- Has the regulator ensured that the decision was not made prematurely, bypassing some regulatory require-

ments to satisfy the operational needs of the plant operator?

This questioning is not meant to suggest that the regulator should allow itself to become paralysed by concerns that a decision may not turn out well. Rather, it is a reminder that the regulatory body should assure itself that it has approached the decision following its procedures in a structured manner, has considered all relevant input, has used sound safety principles and has not appeared to be unduly pressured in making the decision.

Criteria for regulatory decisions

Current, comprehensive and clear regulations are essential for a good decision-making process, but these cannot cover all the aspects of the issues that a regulator will face. There will always be questions of completeness, differing interpretations and unexpected situations. For these reasons a regulatory body will usually be guided by broad criteria that form the foundation of its safety philosophy.

One of these criteria is the level of safety and environmental protection to be required by the regulator. There are various statements on the basic level of protection criterion in OECD countries, but they all acknowledge that it is not possible to achieve zero risk in nuclear activities. Some of the criteria for the basic level of protection in OECD countries are:

- no unreasonable risk,
- adequate protection of public health and safety,
- risk as low as reasonably practicable,
- safety as high as reasonably achievable,



Miklos Bereginvei, PAKS NPP, Hungary



C. Cîeutat, La Médiathèque EDF, France



AECL, Canada

Some of the criteria for the basic level of protection in OECD countries include adequate protection of public health and safety, risk as low as reasonably practicable, and safety as high as reasonably achievable.

- risk limited by use of best technologies at acceptable economic costs.

A related question is what criterion should be used for the level of assurance that the required safety criteria are met? Here again, there are various formulations of the criterion for the level of assurance in OECD countries, but they all recognise that absolute assurance cannot be achieved. Most countries have some variation of a “reasonable assurance” criterion.

These criteria are seen to be qualitative aspirational criteria rather than quantitative safety requirements that must be met. In practice, they are what some may call “revealed standards”. That is, the sum of perhaps hundreds of case history decisions and case law over several years will yield a working definition of what these criteria mean.

Beyond these qualitative aspirational criteria a regulatory body may adopt quantitative safety goals – for example, numerical goals for protecting

the health and safety of people living near nuclear power plants. In order to be more useful in practical decision making, the health goals are often supplemented by numerical goals for core damage frequency (CDF) and large, early radioactive release frequency (LERF). Clearly the use of these latter safety goals requires the production and maintenance of high-quality, plant-specific PSAs as well as operator and regulatory staffs proficient in PSA methodology. Although the promulgation and use of quantitative safety goals is fairly common among OECD regulatory bodies, these criteria are generally regarded as not appropriate for use as the sole basis for making regulatory decisions. Instead, the quantitative safety goals are best used as guidelines by the regulator to supplement other regulatory criteria.

A fundamental principle for safety regulators is the practice of conservative decision making. This is exemplified by the traditional defence-in-depth safety philosophy. Since the

earliest days of commercial nuclear power, regulators have embraced defence in depth to require multiple layers of protection to prevent accidents and to mitigate their consequences. The use of defence-in-depth principles and safety margins have been, and continue to be, effective ways to account for uncertainties in equipment and human performance. As more operating experience and improved safety analysis methods give us a deeper understanding of nuclear plant safety, safety margins and their uncertainties, it may be possible to reduce overly conservative margins or to add margins where needed.

Elements of the regulatory decision-making process

The basic principles and criteria for regulatory decision making should be embodied in a practical, integrated framework that regulators can use in their daily activities. The framework need not be rigid but must be consistent with national

laws, customs, international treaties, regulations and the internal policies of the regulator. The basic elements of an integrated framework are to (a) clearly define the issue, (b) assess the safety significance, (c) determine the laws, regulations or criteria to be applied, (d) collect the relevant information and data, (e) judge the expertise and the resources needed, (f) agree on the analyses to be performed, (g) assign priority to the issue among the other tasks of the agency, (h) make a well-informed decision, and finally (i) write a clear decision and its basis, and publish the decision when needed.

The elements above are not meant to be followed in sequential order; in fact, several of them can be conducted in parallel and some could even be omitted in certain situations. The rigour and depth with which the elements are followed should generally be proportionate to the safety and regulatory significance of the issue being considered.

The regulator's responsibility does not end with the decision and its publication. Clearly, there are follow-up actions a regulator should take to ensure that its decision is implemented. Likewise, the decision and its basis must be stored in the regulatory body's established document control system. This will enable effective follow-up actions and will facilitate retrieval of the information to assist in future decision making.

Implementing the elements of the decision-making process

The regulatory body can use the elements above to develop a regulatory decision-making framework and to integrate it into its overall management

system, similar to its planning and budgeting processes, taking into account the national laws, customs and internal policies of the regulator. In this way the decision-making process will over time become part of the culture of the regulatory body's organisation.

The integrated decision-making framework will cover the great majority of decisions faced by a regulatory body. But every regulator will encounter special situations that are unique in some aspect or that do not fit neatly into the framework outlined above. The CNRA report on *Nuclear Regulatory Decision Making* provides advice on how best to approach a number of these types of situations, notably: decision making in the face of uncertainties, handling safety culture issues, facing differing opinions, considering information from safety advisory bodies and using risk information in regulatory decisions.

Communicating regulatory decisions

In any discussion of the basic principles and criteria that a safety regulatory body should consider when making a decision that can affect a wide range of stakeholders, it is necessary to keep in mind how those stakeholders might view the decision and its rationale. In this regard, it is important for the regulatory body to consider how its decisions are communicated to its stakeholders.

For many of the difficult issues facing the regulator, the outside party most directly affected will be the plant operator. In some complex or contentious cases, the regulator may want to explain the written decision in a meeting with the operator, perhaps in a meeting open to the public.

Conclusion

There is no guide or handbook that will tell a regulator how to make a proper decision, especially for difficult cases where the issues may be contentious and the circumstances unique. That is the value of having a decision-making framework to fall back on. Beyond that, the regulator will have to rely on its experience and good judgment, keeping in mind that safety, and, to some degree at least, the credibility of the regulatory body may be at stake in the regulatory decision and the way it is made. ■

Notes

1. The CNRA booklet on *Nuclear Regulatory Decision Making* was published this spring and is available on the NEA website at www.nea.fr and upon request from the NEA Secretariat. Its contents formed the basis for this article.
2. NEA (1999), *The Role of the Nuclear Regulator in Promoting and Evaluating Safety Culture*, OECD/NEA, Paris.
3. NEA (2000), *Regulatory Response Strategies for Safety Culture Problems*, OECD/NEA, Paris.

An analysis of uranium exploration and price

R. Price *

The primary production of uranium has been less than reactor requirements since the mid-1980s and secondary sources have had to make up the difference. By 2002, world uranium production provided only about 54% of world reactor requirements. This dependence on secondary supplies is projected to continue into the near future. Over the longer term, however, primary production will need to expand.

One result of the abundance of secondary sources has been a consistently depressed market price for uranium over the past several decades. These low market prices led to the curtailment of exploration and the closing and/or consolidation of many uranium production companies and production centres. Consequently, during this time the level of uranium exploration has been at low levels and mainly oriented towards development.

Yet, after 2020, when secondary sources of uranium are expected to decline in availability, reactor requirements will have to be increasingly met by primary production. To meet this increasing demand, primary production capability will need to increase significantly. As a first step, new exploration will be needed to provide the increased resource base necessary to support this expansion. A barrier to new exploration has been the low price for uranium.

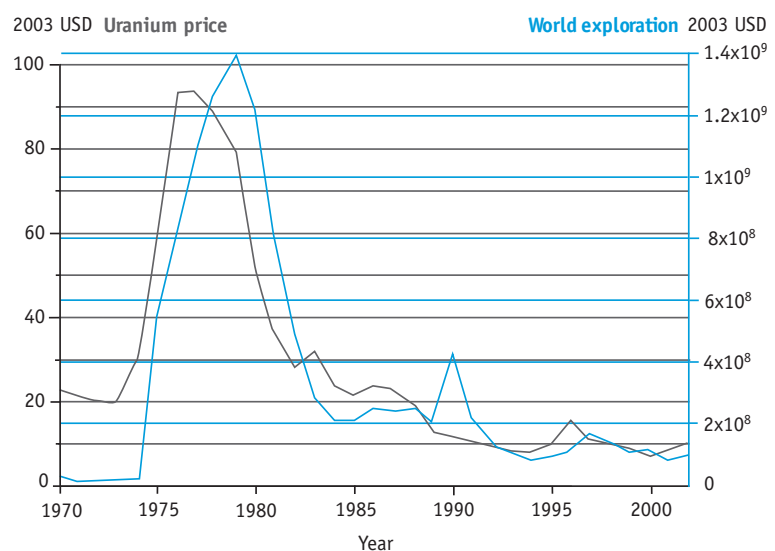
Over the past several years, though, there has been a significant increase in the market

price of uranium. Since the beginning of 2001, the price of uranium has rebounded from lows not seen since the early-1970s, and had almost doubled by July 2004.¹

Yet, despite the significance of this increase in relative terms, this price rise remains relatively modest at this point when compared with the historic peaks of the 1970s or even the short-lived peak in the mid-1990s, especially when viewed in constant terms (see Figure 1).

Will this increase in market price result in the increased exploration needed to support new production capability? To answer this question, a review of the data collected over the past 40 years was conducted to

Figure 1. World exploration and uranium price, in 2003 US dollars (1970-2002)



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attempt to determine whether exploration could be expected to respond to this price recovery, and in what time frame increased exploration could be expected to result.

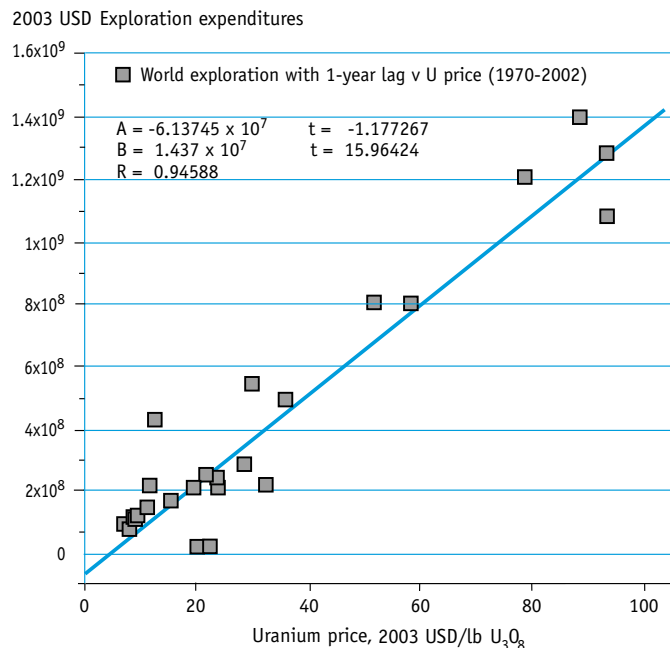
Data on uranium exploration was taken from the OECD/NEA series of publications entitled *Uranium Resources, Production and Demand* (known as the Red Book). The data there represent the total amount of money spent on exploration within a given country regardless of whether the source was domestic or foreign. Data on the price of uranium was taken from NUEXCO/TradeTech and was the annual average of the end-of-month unrestricted exchange values (without premiums).²

A look at Figure 1 indicates a possible correlation between price and exploration and further points to a time lag between a change in uranium price and changes in exploration expenditures. For world expenditures, the best correlation was observed with a one-year delay (see Figure 2).

The improvement in correlation when a time delay is introduced corresponds logically to the delays as the influence of the uranium price change works its way through the decision-making process in the exploration companies, as well as the time needed to initiate field studies once a decision has been reached. The results suggest that exploration is a competitive and open sector of the uranium industry, sensitive to uranium price, and aggressively responds to market signals.

The results indicate that even relatively modest price increases are followed by increases in exploration expenditures. Data for 2004 exploration expenditures is not yet available to verify whether market behaviour is

Figure 2. World exploration expenditures versus uranium price (2003 USD, 1970-2002)



indeed following as predicted, but press reports are providing circumstantial, anecdotal evidence that exploration activity is already picking up in Australia, Canada and the United States, thus leading to the conclusion that data will likely show an increasing trend.

Analysis using surface drilling data, a more direct measure of exploration activity, was also conducted to see if this would lead to a better predictor. Adequate data on surface drilling was available for Australia, Canada and the United States for the period 1975-2002. When plotted, however, the results were similar and showed no improvements over the results provided in Figure 2.

With reactor requirements to be increasingly met by primary production in the coming years, it is necessary to ensure that sufficient new discoveries of uranium are made to enable the expansion of production capability as secondary sources decline. Increased exploration activity will be needed to pro-

vide the resource base required to build new or expand existing production capability. An analysis of historical information indicates that past price increases have resulted in increased exploration. Recent price increases can therefore be expected to begin the increased exploration needed to support the expansion of uranium production capability. ■

Notes

1. TradeTec, LLC (from www.uranium.info/index.html).
2. Total exploration expenditure includes exploration and development expenditures. Exploration includes the costs of all types of surveys, including: surface and underground drilling, logging, test mining and other costs related to the search for new deposits or extensions to known deposits. Prior to 1989 world data does not include the countries associated with the former Soviet Union and certain other non-western countries, e.g. China and Mongolia, and so represents only a sample of world activity and not the entire population. The inflation index used to convert to constant 2003 dollars was the Producer Price Index. Historical values of this index were obtained from <http://www.jsc.nasa.gov/bu2/inflation/ppi/inflatePPI.html>.

Lessons drawn from recent NPP operating experience

P. Pyy *

Countries need timely feedback from international nuclear power plant (NPP) operating experience in order to manage the safety of their installations effectively. One way to obtain this type of information is through the annual technical notes about lessons drawn from recent nuclear power plant operating experience prepared by the NEA Working Group on Operating Experience (WGOE). This article is based on the technical note for events experienced in 2003-4¹ (the third in the series²).

The WGOE technical notes are based on the issues reported in the joint NEA/IAEA Incident Reporting System (IRS) and, in some cases, the NEA joint safety projects dealing with operating experience data collection and analysis. The safety issues identified in the technical notes are generic in nature and, consequently, useful to decision makers. However, it is also suggested that national regulatory bodies, technical support organisations and nuclear operators put them in national context to see if they are relevant to the safety of the nuclear power plants (NPPs) in their countries.

WGOE

The NEA Working Group on Operating Experience (WGOE) has an important task to refine and report messages from international nuclear power plant operating experience to NEA member countries. This is done via reporting to the NEA Committee on the Safety of Nuclear Installations (CSNI) and the NEA Committee on Nuclear Regulatory Activities (CNRA). Apart from technical notes, the WGOE issues technical reports about selected topics dealing with the analysis of nuclear operating experience, including risk insights where relevant. The group also seeks to advance practices to collect and analyse operating experience in member countries.

Recent safety issues emerging from the Incident Reporting System

Recent events of safety significance reported to the IRS include erosion-corrosion of piping, electrical disturbances, and foreign material intrusion into the primary coolant system.

All three of these areas illustrate the continuing need to institute an appropriate and timely corrective action programme both by the utilities and the regulators in order to avoid recurrence.

Electrical disturbances

Several electrical events, both plant-centered and in the off-site grid, have been reported in recent international operating experience. The previous technical note [NEA/CSNI/R(2004)4] reported the August 2003 massive grid disturbance in the United States, which propagated into parts of Canada, and more information has recently been presented. For example, the Pickering station, which consists of eight units, experienced a total loss of off-site power and natural circulation secured the plant cooling for a number of hours. The event revealed deficiencies in a number of safety systems, including emergency service water, firewater, standby diesel generators, and the licensing basis for these and other systems. Corrective actions, including changes in plant design and operation, are currently being taken.

Furthermore, in June 2004 there was a loss of off-site power at the Palo Verde NPP in the United States involving a complete loss of 5 500 MWe

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IRS

The Incident Reporting System (IRS) is the only international reporting system for regulators and governmental organisations which provides an assessment of safety-significant nuclear power plant events, as well as detailed information on analyses of the root causes and lessons learnt from the safety perspective. The IRS is operated by a joint IAEA and NEA secretariat. A guideline for IRS reporting has been in use since June 1998. The system, based on quarterly CD distribution, is now in use in 31 countries. In 2005, it is planned to make trial use of the web-based IRS. Periodic reports on *Nuclear Power Plant Operating Experience* (the "Blue Book") have been published for the periods 1996-1999 and 1999-2002. The next Blue Book for 2002-2005 is planned for spring 2006, in conjunction with the International Conference on Future Uses of Operating Experience scheduled to take place in Germany.

of generating capacity on the grid, including more than 3 700 MWe from the three units at Palo Verde. The cause was traced to a single failure of protective circuitry at an off-site substation. In general, the station responded according to design, although one emergency diesel generator failed to start. It was observed that the transmission company operators had not analysed a situation involving the simultaneous loss of all three units. The event was considered risk-significant and the corrective actions included improvements in the off-site grid components.

These loss of off-site power events had common messages: 1) the operating utilities may have inadequately analysed grid disturbances; 2) there is a need to review operating procedures, communication plans, equipment and the licensing basis for a widespread and long loss of off-site power event, and 3) there may be frailties in the interconnected grids when large concurrent trips of generating capabilities occur.

Foreign material intrusion into the primary system

There have recently been two significant events involving foreign material intrusion. At the Tihange plant in Belgium, a severely damaged spiral-wound metallic gasket was found in a safety injection system check valve, and a fuel failure was observed some months later. The fuel anti-debris devices were unable to catch some portions of the gasket, and the mechanical damage of the fuel

New and severely damaged gaskets at the Tihange plant.



AVN, Belgium

cladding was likely caused by pieces of the gasket that went through them.

Another foreign material intrusion event was experienced at the Fessenheim facility in France. A human action on a valve alignment in the chemical and volume control system (CVCS), combined with a design modification, resulted in intrusion of demineralised resins into the primary coolant system. This led to the contamination and exposure of workers, obstruction of the sampling system, and a six-month outage of the facility for cleanup and repair. The nuclear safety consequences included inoperability of a number of control rods, blockage of injection to reactor coolant pump seals, and increased potential for failure of high-pressure injection pumps due to bearing failure.

Although foreign material intrusion is a recurring concern, these two events were particularly significant. The first one led to a fuel failure and the second one to safety system impairments and a long outage.

Erosion-corrosion of piping

As regards piping, a significant event occurred at the Mihama plant in Japan that involved the failure of a condensate water pipe in the turbine hall. The event resulted in severe injuries to plant personnel, including five fatalities. Some of the main features of the event are:

- The ruptured portion of the piping should have been inspected according to plant guidelines. However, it had not been inspected since the plant start-up in 1976.
- An unauthorised residual life evaluation rule was applied by the plant operating organisation.

- The quality management system of the operating organisation was not sufficient to check the contracted work.
- The secondary piping inspection had been within the scope of the utility's self-imposed inspections.

A number of precursor events have taken place at similar plants, for example in Japan and in the United States (e.g. at Surry in 1986), and many of them may be found in the IRS database. As a corrective action, improvements in inspection practices of both the operator and the regulator are being considered and/or already applied. For instance, since 1 October 2003 this previously self-imposed inspection is now legally required, and the Japanese regulatory agency NISA (Nuclear and Industrial Safety Agency) reviews secondary wall thickness inspection by the utilities. In addition, the Japanese Society of Mechanical Engineers is preparing a piping thickness management standard, and NISA has recently issued guidelines for the inspection and management of pipe and wall thinning.

Recent safety issues emerging from other WGOE work

Other work carried out by the WGOE has highlighted additional safety issues including recurring events, events involving the use of and performance of contractors, and the origins of common-cause failures (CCFs).

Recurring events

The WGOE has continued to study recurring events (it previously issued two reports on the topic). The latest theme concerns corrective actions against PWR loss of decay heat

removal in reduced inventory conditions during outages. More than 50 such events have occurred over the past 25 years. Several types of regulatory corrective action approaches have been used, ranging from information notices, advisories and suggestions, to formal and binding decisions by the regulatory authorities. In 1988, the US NRC issued a generic letter with non-binding suggestions on means for reducing the number of occurrences. A notable effect was observed, but events continue to occur, even in 2004. By contrast, for instance, France and Korea issued binding requirements that seem to have stopped the recurrence there. In France, an automatic makeup function was provided; a detailed work schedule and necessary conditions were required prior to mid-loop entry; and a vortex detection device was installed. In Korea, there were requirements for better training of staff, better level instruments, revision of residual heat removal pump procedures, review of critical level calculations and revised technical specifications.

The WGOE is currently investigating whether a similar study on the risk-significant issue of loss of heat sink or loss of service water to safety-related equipment should be initiated.

Events involving contractors

The theme chosen for the WGOE in-depth discussion at its annual meeting in 2004 was the influence of contractor (and subcontractor) work on the evolution of events. There is an increasing use of contractors and subcontractors in the nuclear industry, although outsourcing is not new. Concerns about the use of contractors have increased lately due to

the fact that both the licensee and the contractor organisations may experience loss of competence via outsourcing. Small utilities and regulatory bodies dealing with large and sometimes multinational contractor organisations seem to be most vulnerable to this.

Member countries gave several presentations about events involving contracted work, including a brief interruption in decay heat removal due to maintenance during an outage, a plant start-up before some scheduled contracted work could be completed, and manufacturing deficiencies in the component cooling water system heat exchangers.

Ideas on how to avoid problems with contracted work and to improve the situation were presented. There was agreement that the licensees must be able to exercise contractor supervision in all circumstances. However, some events indicate a growing problem of detecting substandard performance. In addition, the licensees need to qualify the contractors, but the procedures for this may not be adequate or even exist in the light of recent experience. Furthermore, matters such as training on nuclear-specific requirements must be addressed by the licensee.

Contracting and subcontracting may, if not handled adequately, lead to losing a long-term safety focus. Core competencies must always be kept in-house in order to remain an intelligent customer. This includes, independently of the domain, the ability to qualify contractors, oversight of training of contracted personnel, supervision and approval of contracted work, and most importantly, continuing involvement in the maintenance of safety-focused thinking.

ICDE

The International Common-cause Data Exchange (ICDE) project was initiated in August 1994. The countries participating in the third agreement phase of ICDE are: Canada (CNSC), Finland (STUK), France (IRSN), Germany (GRS), Japan (NUPEC/JNES), Republic of Korea (KAERI), Spain (CSN), Sweden (SKI), Switzerland (HSK), United Kingdom (NII) and the United States (NRC). The objective of the ICDE project is to draw qualitative and quantitative insights from international operating experience data to help avoid common-cause failures or to mitigate their consequences. The ICDE data include both those events reported to regulatory bodies and those based on additional analysis of proprietary nuclear power plant databases. The main findings of the project are reported publicly.

Common-cause failures of batteries

The International Common-cause Data Exchange (ICDE) project has exchanged information on common-cause failures (CCFs) for more than ten years. The project's most recent report, issued in late 2003, was about batteries.³

Deficiencies in design were involved in about half of all the events. Of those, more than 90% occurred during battery manufacture, e.g. inadequate selection of component materials for the plates, in the electrolyte, in separators, in cells, or in terminal connections, and less than 10% occurred during the plant specification or modification process, e.g. calculation errors in the capacity definition. Deficiencies in maintenance and testing were involved in less than half of the events. Of these, approximately half were due to physical failures in the battery subcomponents, nearly 30% were due to electrical failures, some 20% due to direct human actions, and one event was due to premature ageing caused by lack of maintenance. The data suggests that the majority of maintenance and testing events could be

prevented with adequate practices and surveillance of the circuit continuity.

Generally, the main areas for improvement to prevent common-cause failures at NPPs are, according to the project findings: 1) scrutinizing existing operation, maintenance and testing procedures for deficiencies creating the potential for CCF of redundant systems, 2) ensuring comprehensive work control, 3) comprehensively prescribing the testing steps required in the requalification of components or systems after maintenance, repair or backfitting work, and 4) intensifying training, introducing ergonomically better designs and introducing more key locks. These findings apply to all component types which have been analysed in the ICDE project.

Concluding remarks

Almost all of the significant events reported recently in international meetings have occurred earlier in one form or another. Similarly, most of the topics highlighted in the 2001-2 and 2002-3 technical notes are still valid. Counteractions are in many cases

well-known, but information does not always seem to reach end-users and/or corrective action programmes are not always rigorously implemented. More needs to be done internationally to share experience on safety issues and their solutions, and to make sure that the information reaches the end-users at the NPPs.

The main findings that operation and maintenance dominate as causes for common-cause failures, and a number of recent events dealing with the increased role of contractors and subcontractors, show that the utilities and regulators may need to enhance oversight of the organisational arrangements, competence and safety culture of the licensees to ensure the safe operation and maintenance of NPPs.

Finally, an operating experience reporting and analysis programme is a prerequisite to successful safety management and is stipulated in the Convention on Nuclear Safety. In addition to this, many problem areas also require a review of operating experience on lower levels than plant events and combining this review with other analyses – such as PSA, organisational and task analyses, materials analyses and thermal hydraulic calculations – to find permanent solutions. Such a cross-disciplinary approach challenges the nuclear safety community to progress to the new era of safety management. ■

Notes

1. "Lessons Drawn From Recent Nuclear Power Plant Operating Experience", NEA/CSNI/R(2005)4.
2. The first two WGOE technical notes are referenced as NEA/CSNI/R(2002)24 and NEA/CSNI/R(2004)4.
3. "ICDE Project Report: Collection and Analysis of Common-cause Failures of Batteries", NEA/CSNI/R(2003)19.

Management of uncertainty in safety cases and the role of risk

B. Dverstorp, A. Van Luik, H. Umeki, S. Voinis, R. Wilmot *

Deep geological repositories aim to protect humans and the environment from the hazards associated with long-lived radioactive waste over time-scales often up to several thousand or even a million years. Radioactive waste management thus involves a unique consideration of the evolution of the waste and engineered barriers, and the interactions between these components and geological barriers over very long periods of time. Over long enough timescales, however, even the most stable engineered materials and geological environments are subject to perturbing events and changes that are subject to uncertainties. The uncertainties associated with the evolution of the disposal system have to be appropriately considered and managed throughout a repository development programme.

At each stage of a stepwise development programme, decisions should be based on appropriate levels of confidence about the achievability of long-term safety, with the

current level of technical understanding established through uncertainty analysis. A safety case¹ is a key input to support the decision to move to the next stage in repository development. A key output of the safety case is the identification of uncertainties that have the potential to undermine safety. The connection therefore needs to be made between key uncertainties that have been identified and the specific measures or actions that will be taken to address them, especially with regard to the R&D programme, in order to eventually arrive at a safety case that is adequate for licensing. Explicit treatment of uncertainties is thus an essential part of building confidence in the safety case. Confidence in the safety case is supported by a reliable safety assessment with a clear statement on data quality, clear justifications of assumptions and discussion of the sensitivities of the system performance to uncertainties. The uncertainties and the potential for reducing them in subsequent development phases should therefore

be described in the safety case at each stage.

There is a clear consensus among all national programmes on the importance of managing uncertainties in a safety case. Managing uncertainties and establishing levels of confidence can be approached in different ways. This requires a clear classification of the uncertainties since a large range of uncertainties are to be handled. Various classifications of uncertainty exist – such as epistemic uncertainties, uncertainties due to natural variability, and randomness – and the concept of uncertainty classification is both widely used and judged as necessary for performing uncertainty analyses. One part of the overall uncertainty management process is the evaluation of quantifiable uncertainties in a quantitative assessment of system performance. However, since not all uncertainties can be quantified, the use of other elements of information making up a safety case, such as complementary, qualitative lines of evidence, will also contribute to the uncertainty management

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process (NEA, 2004). Uncertainty management consists of understanding the potential implications of uncertainties, and in some cases planning to minimise these potential effects through the site selection process and design adaptations. Other issues, including policy, social context, availability of resources and decision-making timetables, also affect choices.

The presentation of a safety case will place most emphasis on the evaluation and argumentation of the expected performance of a waste management facility. However, making the case for the expected performance requires an illustration of performance in its uncertainty context while taking into account the current stage of system development.

Previous NEA activities on uncertainty issues

One of the earliest NEA activities on uncertainty issues was a meeting in Seattle in 1987 at which the importance of treating uncertainties in assessments of post-closure performance of disposal facilities was highlighted. This early recognition of the issue was developed through a series of NEA meetings and workshops in subsequent years. The Probabilistic Safety Analysis Group (PSAG) played an important role in encouraging debate of different approaches, and also organised a series of code inter-comparison exercises (NEA, 1997a). Other key activities include initiatives by the Integrated Performance Assessment Group (IPAG) (NEA, 1997b, 2002a); workshops on confidence building (NEA, 1999) and the handling of timescales (NEA, 2002b); and the ongoing development of the Safety Case Brochure (NEA, 2004).

These activities have led to some broad conclusions about

how uncertainties should be treated in a safety case:

- The safety case informs decisions at each stage of a step-by-step decision-making process. There is therefore a trend towards safety cases providing a statement on why there is confidence in the results presented, and on the sufficiency of the safety case for the decision at hand. With that perspective, such a statement should acknowledge the existing uncertainties, their significance at the present stage of assessment, and the future steps required to reduce uncertainty.
- Uncertainties should be recognised as an inevitable aspect of radioactive waste management systems, and these uncertainties will increase with the timescale considered.
- Uncertainties should be treated explicitly, and a systematic approach will aid understanding.
- A combination of deterministic and probabilistic approaches may be appropriate. Decision making is not based on a numerical value for uncertainty, and there is a need to clarify the role of each approach in the safety case.
- A range of scenarios needs to be considered in order to explore uncertainties. The issue of human intrusion has a special place within the scenarios considered.
- A range of arguments is important in treating uncertainties and developing a safety case. In particular a mixture of quantitative and qualitative arguments will engender confidence in both the provider and the reviewer. Overall, the safety case can best fulfil the requirements of decision making by including a statement on why there should

be confidence in the analysis of performance and associated uncertainties.

The 2004 workshop on the management of uncertainty

To build upon the lessons learnt from the earlier activities and workshops and to provide a forum for a focused discussion on the handling of uncertainty and risk, the Integration Group for the Safety Case (IGSC) decided to organise a workshop on the Management of Uncertainty in Safety Cases and the Role of Risk. The workshop was held in Stockholm on 2-4 February 2004 and hosted by the Swedish Institute for Radiation Protection (SSI). The overall aim of the workshop was to create a platform in order to better understand different approaches to managing uncertainty in post-closure safety cases and regulatory approaches in different national waste management programmes. The aims of the workshop were:

- to identify common elements in different approaches to managing uncertainty;
- to discuss different approaches to setting regulatory standards for regulatory review;
- to facilitate information exchange and to promote discussion on different technical approaches to the management and characterisation of uncertainty and on the role of risk;
- to explore the merits of alternative approaches to risk-informed decision making; and
- to identify the potential for further developments of methods or strategies to support the management of uncertainties.

The NEA prepared a synthesis of the workshop, which was published in proceedings (NEA, 2005). The main findings may be summarised as follows.

What is risk?

Diversity definitions are sometimes adopted for terms such as “risk”. The word “risk” could be interpreted as having different meanings for different



end-users (nuclear power plants, waste management organisations...), and a set of characteristics for which alternative approaches or viewpoints exist: objectivist/realist (regards risks as real) vs. constructionist (regards risk as a mental construct); quantitative vs. qualitative; and different mathematical formulations [e.g. probability times consequence; expected (negative) utility; and open formulations]. For technical experts, “risk” often means the product of probability and consequence. In public discussion risk may mean only the probability (of a negative consequence), although the consequences may be of most interest to the public. Both “constructed” (perceived) risk and “realist” risk do matter and the public may be concerned about both. As an example, in Andra’s usage, “risk” is defined as the characterisation of a potential danger in terms of both probability and importance. The product of both is rarely considered. Therefore, such expressions as “the probability of a risk” or “the importance of a risk” refer to two independent variables. “Risk”, in such expressions as “risk

analysis”, refers to the methods used in the field of both nuclear and non-nuclear industry, to identify potential sources of danger and rank them in terms of importance.

The following additional definitions were suggested:

- risk-based approach: “regulatory decision making solely based on the numerical results of a risk assessment”;
- risk-informed approach: “risk insights considered with other factors”;
- deterministic approach: “the use of fixed values in modelling for characterisation of uncertainty”;
- probabilistic approach: “characterisation of uncertainty with probabilistic distribution functions as input to modelling”;
- risk: “consequence times probability of occurrence”.

A general observation from the workshop discussions was that differences in the interpretation of key terms and concepts may hamper a good discussion and understanding of the national regulatory and assessment approaches. Hence, it was concluded that clear definitions, when making a safety case, are key to a successful dialogue with various stakeholders.

Regulatory approaches

There is no simple distinction to be made between regulations with risk or dose criteria. In particular, regulations requiring the calculation of dose for the normal or expected evolution may require an assessment of risk for less likely scenarios. Also, regulatory guidance requiring the calculation of risk for natural events and processes may not require an assessment of probabilities for human intrusion scenarios. Regulators have similar expectations regarding

the importance of treating uncertainty whatever the regulatory end-point. Although expectations regarding the evaluation and presentation of uncertainties do vary depending on the end-point used, there are similar expectations regarding the use of supporting arguments, transparency and traceability, justification of assumptions and other qualitative aspects of treating uncertainties, whether the end-point is dose or risk.

Regulators see interactions with implementers ahead of the licensing process as an opportunity to identify critical issues, to resolve differences in approach and to reduce the resources and time required for review of a license application. Overall, regulatory expectations are for safety cases that are risk-informed rather than risk-based.

Assessment of uncertainty and risk

All assessments must address the components of the risk triplet: What can happen? What are the consequences? and What is the likelihood? Approaches differ in the extent to which probabilities are assigned explicitly (e.g., as probability density functions) or implicitly (e.g., through the selection of likely and less likely scenarios). The explicit use of probabilities to characterise uncertainty is not restricted to calculations of risk. Overall, there is a role for deterministic and probabilistic calculations in both risk- and non-risk-oriented assessments.

A key difference between the alternative approaches to the treatment of uncertainty is the extent to which uncertainties are aggregated or disaggregated. Disaggregated analyses are of value for developing detailed system understanding and providing information for design choices and research

priorities. Aggregated analyses may be of value in assessing scenarios that have a similar effect on safety functions, and are required under some regulatory approaches.

All types of uncertainty assessment require the use of expert judgements. There is consensus as to the need for a formal process for documenting and using such judgements. The use of experts to quantify information is favoured in situations where there are conflicting sources, laboratory-scale data but field-scale uncertainties, limited evidence or information on uncertainties, and unverified models and procedures. Expert judgements attempt to record the information available at a particular time, and as with other approaches, may need to be updated as more information becomes available. The selection of experts is important, and the selection process may receive as much scrutiny as the judgements themselves. Perhaps the most unacknowledged difficulty in obtaining expert judgements is the specification of the explicit issues to be addressed.

Risk dilution, or risk dispersion, is recognised as a potential issue in some assessments depending on the methodology used and on the regulatory context. Risk dilution may under certain conditions lead to an apparent lowering of the calculated risk, for example, in connection with the evaluation of high consequence events with a large uncertainty as to their time of occurrence. There is no simple mathematical solution to this issue, which is related in part to regulatory philosophy as to who should be protected and the definition of the exposed group. The overall consensus at the workshop was that the proponent should explore potential risk dilution effects, and that regulators need to be aware of

such effects and consider developing guidance as to acceptable approaches.

Risk management and decision making

The decision-making process differs between countries, reflecting different legal frameworks and cultural traditions. The role of stakeholders in decision making also differ between countries. In all cases, early dialogue, together with transparency and openness, are recognised as important. Different end-users of information from a safety case may attach different meanings to the term risk. Results of risk assessments should therefore be set in a broad perspective so as to inform as wide a range of end-users as possible. Risk assessment is the initial stage of a sequence that also includes decision making and risk management. In the context of the safety of radioactive waste disposal facilities, the extent to which risks can be affected after repository closure is debatable. Potential risk management approaches include stepwise decision making, reversibility/retrievability and monitoring. No consensus was reached among workshop participants as to the role of these approaches, but it was concluded that an iterative coupling of risk assessment and risk management options would be of value.

A continued dialogue

A continuation of international dialogue between regulators and implementers in the area of uncertainty and risk management may be envisaged to further explore alternative regulatory approaches and to share experiences with different assessment tools and approaches. Risk assessment methodologies for disposal facilities are converging as programmes mature, but a contin-

ued dialogue would help in developing an understanding of the different approaches, with their associated strengths and drawbacks. Such an understanding would also help to provide assurance to stakeholders and decision makers that any particular approach is fit for its intended purpose. ■

Note

1. A safety case is a collection of arguments, at a given stage of repository development, in support of the long-term safety of the repository.

References

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Safety of the nuclear fuel cycle

B. Kaufer, D. Ross *

The nuclear fuel cycle starts with mining operations, and proceeds through the various steps in the cycle [milling, conversion, enrichment, fuel fabrication, fuel burn-up in the reactor, reprocessing (in some member countries), transport], to the final stages of spent fuel and radioactive waste storage and disposal. Transport is involved between steps in the cycle, and each step in the cycle has its unique safety aspects.

The NEA Committee on the Safety of Nuclear Installations (CSNI) Subgroup on Fuel Cycle Safety (FCS) was created in 1976 to advance the understanding of relevant aspects of nuclear fuel cycle safety in member countries. The subgroup constitutes a forum for the exchange of information and experience in areas related to nuclear fuel cycle safety. It has developed a system for the collection and dissemination of operating experience at the various steps in the fuel cycle, and meets regularly to discuss these events and to analyse in detail some of the more significant events.

The concept of a unified document on the safety aspects of all steps in the fuel cycle materialised about 25 years ago, with the first publication of *Safety of the Nuclear Fuel Cycle* by the NEA. In 1993, the FCS revisited the topic and

prepared a new edition. Over the past several years the FCS has been gathering material for another revision and update, which will be published later in 2005.

The nuclear fuel cycle

The nuclear fuel cycle consists of a number of activities which together make up the cycle. The FCS subgroup has chosen to omit two activities of the cycle from the reports on fuel cycle safety. Reactor operation, which is a fuel cycle safety topic, is covered elsewhere in the NEA programme of work, as are the safety aspects of high-level waste disposal. The fuel cycle may be characterised as either once-through (sometimes called “open”), where fuel, after discharge from the reactor, is ultimately taken to a disposal site. By contrast, a closed cycle is characterised by reprocessing and reutilisation of recovered fissile isotopes. Both aspects are covered in the fuel cycle safety reports.

The 2005 update of the *Safety of the Nuclear Fuel Cycle* discusses both the technical and safety aspects of the various steps in the fuel cycle. It also provides a summary of the more significant operational events over the past 50 years and the corresponding lessons learnt.

Nuclear fuel cycle safety over the past decade

For the most part, since the last update of the *Safety of the Nuclear Fuel Cycle* in 1993, the situation has been relatively stable. While the number of reactors in the OECD area increased by more than 10% (from 321 to 360), some member countries have decided not to build more plants. One development that might play a role in the future of nuclear power in OECD countries is the determination, essentially worldwide, to reduce the consumption of fossil fuel so as to reduce the amount of greenhouse gases and other undesirable byproducts of combustion. Certainly nuclear power could play an important role in the production of electricity without the emission of carbon dioxide and certain other undesirable elements and compounds. Developments over the past decade at various steps in the fuel cycle may be summarised in the following way:

- Nuclear power plants operated with no major safety problem.
- About 60 000 tonnes of uranium were mined each year, purified, converted, enriched (when necessary), fabricated into fuel assemblies and loaded into reactors.
- After use in reactor operation, the fuel was stored (either wet or dry) or shipped to reprocessing plants. At times, these shipments were quite

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lengthy, such as by ship from Japan to Europe.

- For the most part these fuel cycle operations were without incident; however, there were two events of note. Fuel cycle operational events of concern included major events at a pilot plant of the Power Reactor and Nuclear Fuel Development Corporation (PNC) in Japan. This involved a bitumen fire. The second event was an inadvertent criticality at a Japan Nuclear Fuel Conversion Company (JCO) facility, which involved loss of life of the operating crew.
- During the past decade, there has been additional interest in continuing the reduction of radiation exposure to workers, and in reducing discharges of radiation to the air and in water.
- Another factor of safety interest that grew and matured over the last decade was in the area commonly called “human factors” and its related topic, “safety culture”. These developed into matters of interest to regulators and owners alike, as the human element plays an important role in fuel cycle safety.

Evolution in the nuclear fuel cycle

Developments, both technical and geopolitical, since the 1993 version of the fuel cycle - safety report have contributed to the evolution in fuel cycle technology.

Mining and milling: There are several methods for mining uranium. One method, called *in situ* leaching (ISL), has received increased interest because it does not result in a large deposit of mill tailings after closure of the mine. ISL is not always possible, as it depends on an acceptable rock strata, and the traditional surface and underground mining methods remain predominant modes. In some countries,

notably in the United States, in European countries, and to a degree, in African ones, mining has essentially ceased. This is due to several factors, including the low grade of uranium in those countries, the relatively static nature of demand, the low price of uranium for nearly two decades up until 2001, and the availability of enriched uranium (after down-blending) from the weapons programme of the former Soviet Union.

Enrichment: Traditionally the enrichment method of choice was gaseous diffusion. Gaseous diffusion has the ability to produce a large quantity (throughput) of enriched uranium, but it consumes a large quantity of electricity in doing so. Most gaseous diffusion plants are quite old. Centrifuge plants are now considered the favoured technology. Over the past ten years, considerable efforts have been made to develop laser enrichment. However, after expenditures of more than one billion dollars, this concept is not yet viable.

Fuel fabrication: Evolution in fuel fabrication technology has not been significant over the past decade or so. Ceramic oxides are still used for fuel, and zirconium alloys are still the cladding of choice. Advancements in reprocessing have made the use of mixed-oxide fuel pellets (both uranium and plutonium) more widespread.

Reprocessing: Several additional reprocessing plants have opened in the United Kingdom and Japan. Plants at La Hague, France are operating at capacity.

Decommissioning: Decommissioning, one of the steps in the fuel cycle, is proceeding at a number of facilities around the world. No significant safety problems in this step have been reported.

Transport: Transport is a necessary step in the fuel cycle, and connects other steps. There have not been any significant

developments in transport during the past decade. However, there is continuing interest in the consequences of a severe crash, involving either a truck or a train, during the transport of spent fuel. Research is continuing in this area, as well as in the more recent area of interest concerning the potential for a terrorist attack on fuel shipments.

Event reporting

The FCS subgroup has maintained an event reporting system known as the Fuel Incident Notification and Analysis System (FINAS). This database now contains more than 100 events involving the various steps in the fuel cycle. This system provides a means for furthering the exchange of information, including on the all-important corrective actions and lessons learnt. In 2004, the NEA and the International Atomic Energy Agency (IAEA) agreed to convert FINAS into a jointly operated system. Among other things, this will result in a computer-based search and retrieval system for events, such as the one now used for events in commercial nuclear power plants.

Conclusions

Based on the record of the last decade, it can be said that the fuel cycle has truly matured. Significant improvements in technology and safety have been incorporated at various steps in the fuel cycle. The collection and dissemination of operating experience throughout the fuel cycle is improving significantly in style and format, and will now reach the member states of the IAEA. The FCS subgroup continues to provide a prominent forum for the exchange of safety information and, by publishing the 2005 update of the *Safety of the Nuclear Fuel Cycle*, will further advance the cause of nuclear safety. ■

News briefs

The Generation IV International Forum enters a new phase

The Generation IV International Forum (GIF) is a major international initiative aimed at developing the next generation of nuclear energy systems. It was launched by the US Department of Energy in January 2000 and formally chartered in 2001. The GIF reached an important milestone on 28 February 2005 when five of its members (Canada, France, Japan, the United Kingdom and the United States) signed the Framework Agreement for International Collaboration on Research and Development of Generation IV Nuclear Energy Systems, which sets out the steps to be taken to encourage the participation of R&D institutes and industry organisations in the GIF, while defining the necessary implementing provisions, such as the apportioning of intellectual property rights of the developed systems.

The framework agreement entered into force immediately following the signing ceremony held at the French Embassy in Washington, DC. On 13 April 2005, Switzerland announced its intention to accede to the agreement as well, and the other GIF members are expected to accede over the coming months. During this transition period, all members will continue to participate in GIF activities. The current GIF members are: Argentina, Brazil, Canada, Euratom, France, Japan, the

Republic of Korea, the Republic of South Africa, Switzerland, the United Kingdom and the United States.

Generation IV nuclear energy systems are expected to offer significant improvements over existing systems in the areas of economics; safety and reliability; proliferation resistance and physical protection; and sustainability. The GIF's 2002 Generation IV Technology Roadmap evaluated over 100 system concepts, identifying six with the greatest promise and setting out the research and development necessary to bring them to commercialisation within the 2030 time frame. The six concepts selected were:

- **Gas-cooled fast reactor system (GFR)**

The GFR features a fast-neutron-spectrum, helium-cooled reactor and a closed fuel cycle. The key challenges associated with this system concern the development of new fuels and materials operating at 850°C, the core design and the helium turbine.

- **Lead-cooled fast reactor system (LFR)**

The LFR features a fast-spectrum lead or lead/bismuth eutectic liquid metal-cooled reactor and a closed fuel cycle. Its key challenges concern the lead or lead-alloy handling and the development of the neces-

sary fuels and materials in the range of 550/800°C.

- **Molten salt reactor system (MSR)**

The MSR uses a circulating molten salt fuel mixture with an epithermal-spectrum reactor and a full actinide recycling fuel cycle. The molten salt chemistry and handling, and the development of materials and the fuel cycle are the main challenges for this system, which is intended to operate at 700/800°C.

- **Sodium-cooled fast reactor system (SFR)**

The SFR system features a fast-spectrum, sodium-cooled reactor and a closed fuel cycle. Reducing the capital cost and improving passive safety, especially under transient conditions, are the major challenges for this system, which already benefit from considerable technological experience.

- **Supercritical-water-cooled reactor system (SCWR)**

The SCWR system is a high-temperature, high-pressure, water-cooled reactor that operates above the thermodynamic critical point of water (374°C and 22.1 MPa, or 705°F and 3208 psia). Material corrosion and water chemistry in the range of 500/550°C, along with the development of materials, are the key challenges for this system.

- **Very high temperature reactor system (VHTR)**

The VHTR is a graphite-moderated, helium-cooled reactor with a once-through uranium fuel cycle. Also designed for hydrogen production and process heat application, this system's aim of operating above 1000°C presents significant challenges in terms of fuel and materials development, as well as safety under transient conditions.

As detailed in its charter and subsequent policy statements, the GIF is led by a policy group. The policy group is

responsible for the overall framework, policy formation and interactions with third parties. An expert group advises the policy group on R&D strategy, priorities and methodology and evaluates the research plans for each of the Generation IV systems. The GIF policy group meets two to three times a year to review past activities, provide guidance to the expert group and systems steering committees (one per system under development), and determine the programme's future direction. The GIF policy group is currently chaired by the United States, with vice-chairs from France and Japan.

At its January 2005 meeting, the GIF policy group confirmed arrangements under which the OECD Nuclear Energy Agency will provide Technical Secretariat support to the GIF, including the funding of this activity by GIF members through voluntary contributions. The NEA is able to offer long-standing experience with international working groups, neutrality, long-term continuity and a comprehensive approach to both the organisation and substance of the GIF R&D activities. ■

More information about the GIF is available at www.gen4.org.

Nuclear power for the 21st century

An international conference on Nuclear Power for the 21st Century was held in Paris on 21-22 March 2005. Organised by the International Atomic Energy Agency (IAEA) in cooperation with the OECD and the NEA, the conference was hosted by the French government. The aim of the conference was to analyse the potential contribution of nuclear energy to meeting the world's energy needs in an economic manner, while respecting social and environmental concerns. The conference was attended by ministers, high-ranking officials and experts from 74 countries and 10 international organisations.

The conference¹ on Nuclear Power for the 21st Century came at a very important time, with the twin demands of ensuring the security of energy supply and meeting the challenge of climate change pressing on all governments. It is in this context that a number of NEA member countries have been re-examining the potential role of nuclear energy in their national energy mix.

What emerged from the two days of ministerial interventions and roundtables with invited experts was a widely

held opinion that nuclear energy can, under the right conditions, be part of a response to the challenge of meeting expanding energy demand, and ensuring the security of energy supply while addressing climate change. But nuclear energy is not necessarily a solution for everyone, and some countries have made clear, including through nuclear phase-out policies, that nuclear is not their preferred option. In his keynote address to the opening session, Mohamed ElBaradei, IAEA Director-General acknowledged "...each

country and region faces a different set of variables when choosing its energy strategy, and energy decisions cannot be made on a 'one-size-fits-all' basis." Patrick Devedjian, French Minister Delegate for Industry highlighted, *inter alia*, the multifaceted nature of energy policy, which requires consideration of a number of factors including economic, social and environmental concerns.

Climate change

OECD Secretary-General Donald Johnston highlighted, as did many of the ministers

and participants in the roundtables, the likely consequences of climate change. "Climate change must be addressed quickly, seriously and objectively by the developed and the developing world," he told delegates. He also warned that the energy industry must be transformed worldwide. From transportation to electricity generation, major changes must take place, not only to attempt to stabilise the greenhouse effect, but also to adapt to the dwindling supplies of oil and gas in the longer term.

The climate change prognosis delivered by James Lovelock was even starker, "...I consider that the earth has now reached a state profoundly dangerous to all of us and to our civilisation." He went on to outline how climate scientists are sure that when carbon dioxide levels in the air rise to about 400 to 500 parts per million, the earth crosses a threshold beyond which global warming becomes irreversible. "We are now at 380 parts per million and at the present rate of increase, it could reach 400 parts per million in a shorter time than seven years," he warned.

What can be done? Nearly all conference speakers emphasized that all forms of energy generation need to be pursued, and that nuclear energy is not in competition with renewable sources of energy. As Mohamed ElBaradei remarked at the press conference on the first day "...we need all the energy sources that we can put our hands on – whether it's oil or gas or nuclear or renewables."

In a round table chaired by the NEA Director-General Luis Echávarri on world energy needs, International Energy Agency (IEA) Executive Director Claude Mandil told delegates that "there is no one single solution" to the world's energy problems. He outlined how more vigorous policies would significantly curb the

rate of increase in energy demand and emissions, but pointed out that a truly sustainable energy system would need faster technology development and deployment than is currently the case. He said that nuclear energy could play an important role in the global energy mix, while stressing that industry and governments will have to make this happen. This was a point that some later speakers also raised, particularly AREVA Executive Chair Anne Lauvergeon, who further noted that nuclear energy has been excluded from the present clean development mechanism (CDM) of the Kyoto Protocol. Under the CDM, countries can claim "emission credits" for financing emission-reduction projects in another country through the supply of clean energy technology. In his closing statement to the conference, Minister Devedjian explicitly called for nuclear and hydroelectric energy to be included in these mechanisms.

Security of supply

Another often cited reason for including nuclear power in the national energy mix was to maintain a stable energy supply, a point made during the Japanese, Czech and Hungarian ministerial statements. Nuclear energy may practically be considered as a domestic source of energy to the extent that uranium resources are widely distributed around the world and nuclear fuel can be easily and cheaply stored. Significant resources exist in Australia, North America, Africa and Central Asia. This distribution provides both security and diversity of supply. Dana Drabova, Chair of the Czech State Office for Nuclear Safety considered that it is "...the state's responsibility for creating conditions for reliable and permanently safe supplies of energy at acceptable prices and

for creating conditions for its safe and efficient use that will not threaten the environment and will comply with the principles of sustainable development."

Koichi Hirata, the Japanese Parliamentary Secretary for Economy, Trade and Industry emphasized that if the development of a fast breeder reactor cycle could be realised, "...Japan will be able to secure a semi-perpetual supply of energy." A comprehensive public evaluation of different energy scenarios from ten different perspectives, undertaken in 2004, led the Japanese government to conclude that the current policy of working towards a closed nuclear fuel cycle with reprocessing was the right choice. Other countries, notably France, have also chosen or are considering the reprocessing of their nuclear fuel in order to recover unused uranium and plutonium in the spent fuel elements and reduce the volume and radiotoxicity of material to be disposed of as high-level radioactive waste.

Radioactive waste management

A nuclear-specific challenge is radioactive waste management (RWM). Although acceptable solutions have largely been found and implemented for low-level and short-lived, intermediate-level waste, considerable progress still needs to be made regarding the disposal of long-lived, intermediate-level and high-level radioactive waste. In his statement read to the conference, John Efford, the Canadian Minister of Natural Resources noted that in accordance with Canada's Nuclear Fuel Waste Act, the Nuclear Waste Management Organisation is developing through public dialogue and consultations long-term options to be considered by

the government at the end of 2005. By making progress on this issue, it demonstrated that nuclear energy is compatible with sustainable development, said Efford. Christian Bataille, member of the Parliamentary Office for the Evaluation of Scientific and Technological Options, notably in charge of the radioactive waste management assessment mission, outlined the current plans in France, as proposed under the 1991 law that bears his name. On the scientific front these include: the introduction of advanced reprocessing and transmutation on an industrial scale by 2040; reversible geological storage of long-lived, high-level radioactive waste in underground repositories currently being researched; and the development of long-term storage solutions that could last between 100 and 300 years. On the policy front, Mr. Bataille emphasized three essential areas: continuing the dialogue with parliament and civil society on the RWM issue; the national responsibility for continuing to fund RWM research; and expanding the role of the national agency ANDRA to include long-term storage. A number of speakers underlined how closely the American and Finnish RWM projects at Yucca Mountain in Nevada and at Olkiluoto are being followed for the policy lessons that they might provide.

Economics

The economic position of nuclear energy seems to be growing stronger, and is being cited as such in an increasing number of sources. In his statement read to the conference, U.S. Secretary of Energy Samuel Bodman cited a new University of Chicago study that found that nuclear energy can become cost-competitive in liberalised markets with

electricity produced by coal and natural gas once the additional costs associated with building the first plants have been absorbed.

Being capital-intensive to develop and to build, nuclear power plant projects are increasingly the provenance of joint ventures. The advanced technologies being developed over the long term under the aegis of the Generation IV International Forum (GIF) were widely cited as examples of the sort of international co-operation necessary to bring these systems to market in a timely and cost-effective manner. Other means proposed to improve the economic prospects of nuclear energy included the further international harmonisation of safety criteria and the increasing use of regional initiatives, whereby nuclear power plants would provide electricity to several countries. Shunsuke Kondo, the Chairman of the Japan Atomic Energy Commission, suggested that the capital cost of new plants could be reduced by shortening their licensing and construction time through the use of standardised designs, sharing one-time engineering and licensing costs, developing modular cost-effective construction technologies, and developing associated planning and information management tools that reduce the labour intensity of these projects.

Governance

“Governance” was characterised by Antonio Carlos de Oliveira Barroso from the Brazilian National Nuclear Energy Commission as “...who has influence, who decides and how decision makers are held accountable.” There was widespread agreement amongst conference speakers that the governance of the nuclear industry is something of a special case. According to

Dominique Maillard, the French Director-General of Energy and Raw Materials, “...the particular features of nuclear energy mean that, more than any other form of energy, nuclear energy needs frameworks for use, which the government alone can establish and provide.” The particular features that he identified were the need to manage long-term economic interests, risk elements (including safety), non-proliferation issues and relations with civil society. His sentiments on governance were largely shared in the ministerial statements from Canada, Korea and Russia.

European Parliament Vice-President Alejo Vidal-Quadras Rocca saw the need for a European legislative framework for nuclear safety and radioactive waste management, using the EURATOM treaty as its legal basis. He emphasized that the aim was not to supplant either the competencies of member states or interfere with the existing international co-operation instruments established by the IAEA and others. In his ministerial intervention, Italian Minister Antonio Marzano stated that “...a single [European] nuclear market could also be advocated, which might be characterised by harmonised technical safety standards, shared criteria for physical safeguards and enhanced co-operation on nuclear waste and decommissioning.” This approach, should it be agreed by other European member countries, would benefit from economies of scale and existing institutions and eventually lead to a more coherent European nuclear policy and long-term strategy regarding our energy future.”

It is also worth noting the particular case of developing countries that are seeking to introduce nuclear in their energy mix. In order to be able to bring these plans to fruition,

international co-operation and transfer of nuclear knowledge will be necessary. These countries were widely represented at the conference and made requests to this effect.

Closing remark

Whilst the issues discussed over the two days will already

be familiar to regular readers of *NEA News*, the level of participation at the conference – in terms of both the number of countries that participated and the senior level of representation of nearly all the delegations present – is unique, and augers well for continued international dialogue on the risks and benefits of nuclear energy. ■

Note

1. Presentations given at the conference are available online at www.parisnuclear2005.org.

This news brief was prepared by Andrew Macintyre, NEA Central Secretariat.

Projected costs of generating electricity

The NEA and the International Energy Agency (IEA) have recently published their sixth report in a series of studies on projected costs of electricity generation. This latest study was conducted by a group of experts from nineteen member countries and two international organisations, the International Atomic Energy Agency (IAEA) and the European Commission (EC). The latter provided input data from three non-OECD countries. The overall objective of the study was to provide reliable information on key factors affecting the economics of electricity generation using a range of technologies. The report can serve as a resource for policy makers and industry professionals seeking to better understand generation costs of these technologies.

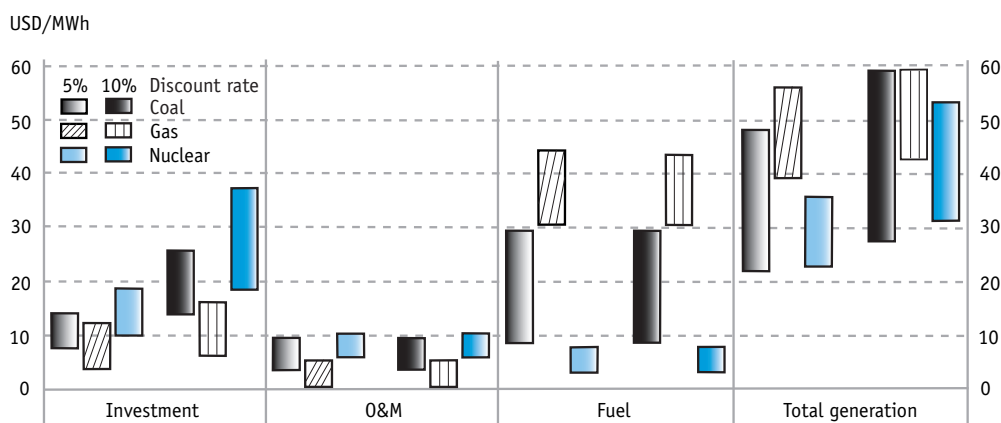
The report presents and analyses projected costs of generating electricity calculated with input data provided by participating experts and generic assumptions adopted by the group of experts. The

levelised lifetime cost methodology was applied by the joint IEA/NEA Secretariat to estimate generation costs for more than a hundred plants relying on various fuels and technologies, including coal-fired, gas-fired, nuclear, hydro, solar and wind power plants; cost estimates are also provided for combined heat and power plants using coal, gas and combustible renewables. The plants included in the study rely on technologies available today and considered by participating countries as candidates for commissioning by 2010-2015 or earlier. Generic assumptions for the main technical and economic parameters included an economic lifetime of 40 years for most plants, an average load factor for base-load plants of 85% and discount rates of 5% and 10%. The appendices to the report address a number of issues such as generation technology, methodology to incorporate risks in cost estimates, impacts of integrating wind power into electricity grids and effect of carbon emission trading on generation costs.

Electricity generation costs calculated are bus bar costs, at the station, and do not include transmission and distribution costs. The costs associated with residual emissions – including greenhouse gases – are not included in the costs provided because they are not yet borne by electricity producers, and therefore, are not reflected in the generation costs calculated in the study.

The cost estimates do not substitute for detailed economic evaluations required by investors and utilities at the stage of project decision and implementation, which should be based on project-specific assumptions using a framework adapted to local conditions and a methodology adapted to the particular context of the investors and other stakeholders. Moreover, the reform of electricity markets has changed decision making in the power sector and led investors to take into account the financial risks associated with alternative options as well as their economic performance. In view of the risks they are facing in

Range of levelised costs for coal, gas and nuclear power plants



competitive markets, in the absence of other considerations investors tend to favour less capital-intensive technologies. The methodology adopted for calculating generation costs in this study did not specifically seek to take business risks in competitive markets into account.

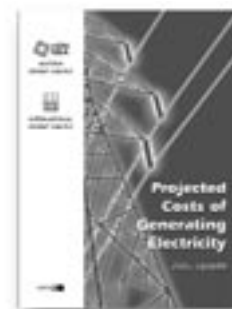
The nature of risks affecting investment decisions has changed significantly with the liberalisation of electricity markets, and this has implications for determining the required rate of return on generating investments. Financial risks are perceived and assessed differently. The markets for natural gas are undergoing substantial changes on many levels. Environmental policy is also playing an increasingly important role that is likely to influence fossil fuel prices significantly in the future. Security of energy sup-

ply remains a concern for most OECD countries and may be reflected in government policies affecting generating investment in the future.

Given the above considerations, the study finds that the lowest levelised costs of generating electricity from the traditional main generation technologies are within the range of 25-45 USD/MWh in most countries. The levelised costs and the ranking of technologies in each country are sensitive to the discount rate and the projected prices of natural gas and coal.

The study provides insights on the relative costs of generating technologies in the participating countries. Within the study's framework and limitations, it suggests that none of the traditional electricity generating technologies can be expected to be the cheapest

in all situations. The preferred generating technology will depend on the specific circumstances of each project. The study indeed supports that on a global scale there is room and opportunity for all efficient generating technologies. ■



Projected Costs of Generating Electricity: 2005 Update (ISBN 92-64-00826-8) can be purchased online at www.oecd.org/bookshop.

Erratum

In Issue 22.2 of *NEA News*, the table on NEA joint projects contained two errors in the budget figures. The budget of the Halden Reactor Project should have read US\$ 45 million, and that of the International Common-cause Data Exchange (ICDE) Project US\$ 150 000/year.

Third phase of the TDB Project

The NEA Thermochemical Database (TDB) is the product of an ongoing co-operative project to assemble a comprehensive, internally consistent and quality-assured database of chemical elements selected for their relevance to the assessment of waste disposal safety. The project, now in its 20th year under the aegis of the NEA, was established following the realisation that existing databases lacked internal consistency or were not sufficiently documented to allow the tracing of the original data sources. This resulted in inconsistent results, e.g., from the same speciation code, when using different databases for the same condition.

Major selection criteria for the inclusion of elements are mobility, radiotoxicity, inventory and half-life. Reviews of the chemical thermodynamics of uranium, americium, technetium, neptunium and plutonium were therefore the first to be published. During the second phase of the project, the database for those elements was updated and new reviews were completed for inorganic species and compounds of fission and activation products such as selenium, nickel and zirconium. In addition, reviews of organic compounds and complexes are being considered, and a new review of simple organic ligands (oxalate, citrate, EDTA and iso-saccharinic acid) and all of the previously cited elements (U, Np, Pu, Am, Tc, Se, Ni and Zr) will be completed during the second semester of 2005.

TDB III, the third phase of the NEA TDB Project, was started in 2003 with a planned duration of four years. The main objective of this new

phase is to extend the existing critically reviewed database to elements of relevance for the current needs of national radioactive waste management programmes. Following the decision by the Project Management Board (which consists of representatives from 16 organisations¹ with responsibilities in radioactive waste management in 12 OECD member countries) the elements being contemplated in this new phase are:

- Th (thorium), chosen for reasons of chemical consistency within the database for actinides;
- Sn (tin), present as a fission product in nuclear waste and whose thermochemical properties present substantial gaps and inconsistencies for solubility limiting species; and
- Fe (iron), a key element in determining the redox (oxidation-reduction) conditions in repositories for which a consistent thermochemical database is also lacking.

A high priority has been allocated to their inorganic species and compounds. The publication of the reviews for Th and Sn is planned for 2007. The Fe review is scheduled to be ready for peer-review early in 2007.

In addition to the review teams for these three elements, an expert team has been constituted to prepare guidelines for the evaluation of thermodynamic data for solid solutions. These non-stoichiometric solids have not been systematically contemplated for database work so far, but they may provide more accurate descriptions of waste as well as of engineered and natural barriers.

The TDB project combines a sound review methodology,

essentially an exercise in scientific excellence that remains unaltered throughout the project lifetime, and a stable organisational framework in line with its long-term objectives. The main products of these review exercises are the books published in the Chemical Thermodynamics Series, providing in the open literature:



- access to critical expert judgement of existing literature, reviewed by scientific peers;
- knowledge transfer between TDB review teams and model implementers;
- identification of areas needing further research.

For further information on the TDB project, its database and publications please see <http://www.nea.fr/html/dbtdb>. ■

Note

1. The following organisations participate in TDB III: NIRAS/ONDRAF (Belgium), OPG (Canada), RAWRA (Czech Republic), POSIVA (Finland), ANDRA (France), FZK INE (Germany), JNC (Japan), ENRESA (Spain), SKB (Sweden), SKI (Sweden), HSK (Switzerland), NAGRA (Switzerland), PSI (Switzerland), BNFL (UK), NIREX (UK), Department of Energy (USA).

New publications



General interest

Annual Report 2004

ISBN 92-64-01053-X

Free: paper or web.

Strategic Plan of the Nuclear Energy Agency – 2005-2009 (The)

Summary

ISBN 92-64-01057-2

Free: paper or web.

The NEA mission 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; as well as to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Economic and technical aspects of the nuclear fuel cycle

Beneficial Uses and Production of Isotopes – 2004 Update

ISBN 92-64-00880-2 – Price: € 24, US\$ 29, £ 16, ¥ 3 200.

Radioactive isotopes continue to play an increasingly important role in medical diagnosis and therapy, key industrial applications and scientific research. They can be vital to the health and well-being of citizens, and contribute to the world economy. It is therefore important to understand their production and use. This report provides a solid basis for understanding the production and use of radioisotopes in the world today. It will be of interest not only to government policy makers, but also to scientists, medical practitioners, students and industrial users.

Nuclear Energy Data – 2005

Bilingual

ISBN 92-64-01100-5 – Price: € 24, US\$ 29, £ 16, ¥ 3 200.

This new edition of *Nuclear Energy Data*, the OECD Nuclear Energy Agency's annual compilation of essential statistics on nuclear energy in OECD countries, offers a projection horizon lengthened to 2025 for the first time. It presents the reader with a comprehensive and easy-to-access overview on status and trends in nuclear energy in OECD countries and in the various sectors of the nuclear fuel cycle. This publication provides authoritative information to policy makers, experts and academics involved in the nuclear energy field.

Projected Costs of Generating Electricity – 2005 Update

ISBN 92-64-00826-8 – Price: € 70, US\$ 91, £ 47, ¥ 9 400.

This sixth study in a series on projected costs of generating electricity presents and analyses cost estimates for some 130 power and co-generation (heat and power) plants using coal, gas, nuclear and renewable energy sources. Experts from 19 member countries, 2 international organisations and 3 non-OECD countries contributed to the study. Levelised lifetime costs were calculated with input data from participating experts and commonly agreed generic assumptions, using a uniform methodology. The study shows that

the competitiveness of alternative generation sources and technologies depends on many factors and that there is no absolute winner. Key issues related to generation costs are addressed in the report including methodologies to incorporate risk in cost assessments, impact of carbon emission trading and integration of wind power into electricity grids. The projected costs presented are generic and do not reflect the full range of factors (e.g., security of supply, risks and carbon emissions) that investors and other decision makers need to take into account. This report will be, however, a reference for energy policy makers, electricity system analysts and energy economists.

Nuclear safety and regulation

CSNI Technical Opinion Papers – Nos. 7-8

Living PSA and its Use in the Nuclear Safety Decision-making Process

Development and Use of Risk Monitors at Nuclear Power Plants

ISBN 92-64-01047-5

Free: paper or web.

Probabilistic safety analyses (PSAs) for many of the nuclear power plants throughout the world are being maintained as "living PSAs" (LPSAs), being updated to take account of changes to the design and operation of the plant, improvements in the understanding of how the plant behaves in fault situations and improved PSA methods, models and data. One of the specific applications of a living PSA is the risk monitor, used by operators and regulators to provide risk information employed in the decision-making process to ensure the safe operation of nuclear power plants. Since the first risk monitors were put into operation in 1988, the number of risk monitors worldwide has increased rapidly. By the end of 2003 there were more than 110 in operation and this figure should increase to over 150 when those monitors being developed are placed in service. Combining these two technical opinion papers into a single publication provides the reader – notably senior researchers and industry leaders, nuclear safety regulators, nuclear power plant operators – with a concise assessment of the current state of the art, thus enabling better analysis when evaluating proposals or the development of these applications.

Joint CSNI/CNRA Strategic Plan and Mandate – 2005-2009

ISBN 92-64-01060-2

Free: paper or web.

The mission of the Committee on Nuclear Regulatory Activities (CNRA) and the Committee on the Safety of Nuclear Installations (CSNI) is to assist member countries in maintaining and further developing the knowledge, competence and infrastructure needed to support the safe operation of nuclear power plants and fuel cycle facilities throughout their life cycle, shared experience and up-to-date methods. Readers will find the committees' mission, joint strategic plan and mandates herein.

Nuclear Regulatory Decision Making

ISBN 92-64-01051-3

Free: paper or web.

The fundamental objective of all nuclear safety regulatory bodies is to ensure that nuclear utilities operate their plants at all times in an acceptably safe manner. In meeting this objective, the regulatory body should strive to ensure that its regulatory decisions are technically sound, consistent from case to case, and timely. In addition, the regulator must be aware that its decisions and the circumstances surrounding those decisions can affect how its stakeholders, such as government policy makers, the industry it regulates, and the public, view it as an effective and credible regulator. In order to maintain the confidence of those stakeholders, the regulator should make sure that its decisions are transparent, have a clear basis in law and regulations, and are seen by impartial

observers to be fair to all parties. Based on the work of a Nuclear Energy Agency (NEA) expert group, this report discusses some of the basic principles and criteria that a regulatory body should consider in making decisions and describes the elements of an integrated framework for regulatory decision making.

Review of the Role, Activities and Working Methods of the CNRA

Committee on Nuclear Regulatory Activities (CNRA)

ISBN 92-64-01062-9

Free: paper or web.

This report, prepared by an independent review group, characterises the current role, priorities and working methods of the NEA Committee on

Nuclear Regulatory Activities (CNRA), identifies and analyses issues of concern, and suggests ways to further increase the efficiency and effectiveness as well as the visibility of the committee. It also reviews the role and interactions between the CNRA and the other NEA standing technical committees and international organisations, and suggests ways to improve co-ordination and co-operation. In formulating its report, the review group examined various CNRA documents (e.g. summary records, reports), interviewed past and present CNRA members, standing technical committee chairs and others, and gathered additional input through a questionnaire. Conclusions and recommendations have been derived concerning the mid-term and long-term role and orientation of the committee and, in particular, the balance between technical- and policy-related activities.

Radiological protection

Optimisation in Operational Radiological Protection

A Report by the Working Group on Operational Radiological Protection of the Information System on Occupational Exposure

ISBN 92-64-01050-5

Free: paper or web.

Operational approaches to the optimisation of radiological protection continue to evolve at nuclear power plants. The continual improvement of protection has been greatly facilitated by the exchange of good practice and experience through

the Information System on Occupational Exposure (ISOE). With the forthcoming revision of the system of radiological protection, as recommended by the International Commission on Radiological Protection (ICRP), the ISOE programme considered that it would be important and useful to document good operational practice to ensure that it is reflected appropriately in the new ICRP recommendations. This report is a compilation of practical examples of good practice in optimisation. It is intended to assist nuclear power plants in providing the most appropriate protection for the public and workers, and to highlight for the ICRP concepts that should be reflected in its new recommendations.

Radioactive waste management

Geological Repositories: Political and Technical Progress

Workshop Proceedings, Stockholm, Sweden, 8-10 December 2003

ISBN 92-64-00830-6 – Price: € 55, US\$ 72, £ 37, ¥ 7 400.

Various long-term radioactive waste management options have been considered in order to protect humans and the environment both now and in the future. Most experts worldwide agree that disposal in engineered facilities, or repositories, located in appropriate formations deep underground, provides a suitable option. Engineered geological disposal

is seen as a radioactive waste management end-point providing security and safety in a sustainable manner that does not necessarily require monitoring, maintenance and institutional control. Internationally, this option is regarded to be technically feasible, acceptable from an ethical and environmental viewpoint, as well as acceptable from an international legal perspective. The Stockholm International Conference on Geological Repositories: Political and Technical Progress brought together over 200 high-level decision makers and other interested stakeholders from the national, regional and local levels. Regulatory bodies and radioactive waste management implementing organisations also took part. In addition to providing a forum for the exchange of the most up-to-date information in the field, it also served to strengthen international co-operation on radioactive waste management and disposal issues.

Management of Uncertainty in Safety Cases and the Role of Risk

Workshop Proceedings, Stockholm, Sweden, 2-4 February 2004

ISBN 92-64-00878-0 – Price: € 50, US\$ 65, £ 34, ¥ 6 700.

The OECD Nuclear Energy Agency (NEA) organised a workshop on the "Management of Uncertainty in Safety Cases and the Role of Risk" in Stockholm, Sweden, on 2-4 February 2004. The workshop's main objective was to discuss different approaches to treating uncertainties in safety cases for radioactive waste management facilities, and more specifically how concepts of risk can be used in

both post-closure safety cases and regulatory evaluations. This report includes a synthesis of the plenary presentations and the discussions that took place during the workshop. These proceedings will be of interest to waste repository safety assessors and managers.

Stability and Buffering Capacity of the Geosphere for Long-term Isolation of Radioactive Waste

Application to Argillaceous Media – "Clay Club" Workshop Proceedings, Braunschweig, Germany, 9-11 December 2003

ISBN 92-64-00908-6 – Price: € 55, US\$ 72, £ 37, ¥ 7 400.

Most experts worldwide agree that radioactive waste disposal in engineered facilities, or repositories, located in appropriate formations deep underground, provide a suitable waste management option for protecting humans and the environment now and in the future. An NEA workshop was organised on 9-11 December 2003 in Braunschweig, Germany, devoted specifically to argillaceous settings for deep geological repositories. The workshop brought together scientists from academic institutions, engineers from various research institutions or companies, consultants, regulatory authorities and national waste management organisations to establish the scientific basis for stability and buffering capacity of deep geological waste management systems. The present report synthesises the main outcomes of that workshop and presents a compilation of the related abstracts.

Nuclear Science and the Data Bank

Accelerator and Spallation Target Technologies for ADS Applications – A Status Report

ISBN 92-64-01056-4

Free: paper or web.

The efficient and safe management of spent fuel produced during the operation of commercial nuclear power plants is an important issue. Worldwide, more than 250 000 tons of spent fuel from reactors currently operating will require disposal. These numbers account for only high-

level radioactive waste generated by present-day power reactors. Nearly all issues related to risks to future generations arising from the long-term disposal of such spent nuclear fuel is attributable to only about 1% of its content. This 1% is made up primarily of plutonium, neptunium, americium and curium (called transuranic elements) and the long-lived isotopes of iodine and technetium. When transuranics are removed from discharged fuel destined for disposal, the toxic nature of the spent fuel drops below that of natural uranium ore (that which was originally mined for the nuclear

fuel) within a period of several hundred years. This significantly reduces the burden on geological repositories and the problem of addressing the remaining long-term residues can thus be done in controlled environments having timescales of centuries rather than millennia. To address the disposal of transuranics, accelerator-driven systems (ADS), i.e. a sub-critical system driven by an accelerator to sustain the chain reaction, seem to have great potential for transuranic transmutation, though much R&D work is still required in order to demonstrate their desired capability as a whole system. This report describes the current status of accelerator and spallation target technologies and suggests technical issues that need to be resolved for ADS applications. It will be of particular interest to nuclear scientists involved in ADS development and in advanced fuel cycles in general.

JEFF-3.0 Nuclear Data Library (The) JEFF Report 19 – Synopsis of the General Purpose File

ISBN 92-64-01046-7

Free: paper or web.

To master the technology and the economics of nuclear energy, deep insight is needed into the physical and chemical phenomena at work in nuclear reactors and all parts of the associated fuel cycle. Scientific knowledge should be constantly updated in order to:

- improve the safety and the economics of existing installations and anticipate possible problems;
- optimise the design of future installations;
- develop satisfactory techniques for radioactive waste storage and disposal.

One of the most important basic tools needed for accomplishing the above is accurate nuclear data.

NEA Data Bank member countries have long supported the development of the Joint Evaluated Fission and Fusion (JEFF) library, which is used as reference data for nuclear applications in many European countries. The third, improved version of the data library (JEFF-3.0) was recently issued. The present report describes the contents of this library.

Shielding Aspects of Accelerators, Targets and Irradiation Facilities – SATIF 7

Workshop Proceedings, Lisbon, Portugal, 17-18 May 2004

ISBN 92-64-01042-4 – Price: € 70, US\$ 91, £ 47, ¥ 9 400.

Particle accelerators are used today for an increasing range of scientific and technological applications. They are very powerful tools to investigate the origin and structure of matter, and to improve understanding of the interaction of radiation with materials, including transmutation of nuclides and beneficial effects of risks from radiation. They are used to identify properties of molecules that can be used in pharmacy, for medical diagnosis and therapy, or for biophysics studies. Particle accelerators must be operated in safe ways that protect operators, the population and the environment. New technological and research applications give rise to new aspects in radiation shielding. These workshop proceedings review the state of the art in radiation shielding of accelerator facilities and of irradiated targets. They also evaluate progress made and discuss the additional developments required to meet radiation protection needs.



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Employment opportunities

Vacancies occur in the OECD Nuclear Energy Agency Secretariat in the following areas:



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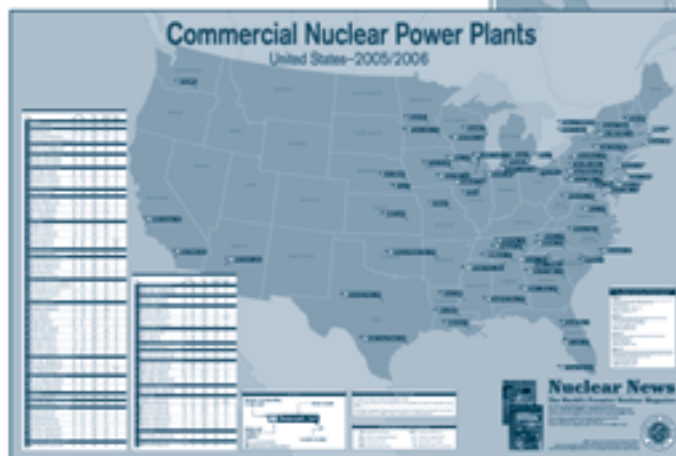


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OECD PUBLICATIONS, 2 rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(68 2005 01 1 P) – ISSN 1605-9581