Nuclear Power in 2004

Nuclear energy development

As of 31 December 2004, 352 reactors were in operation in OECD countries constituting about 84% of the world's total nuclear electricity generating capacity, and some 24% of the total electricity supply in the OECD area. During 2004, one reactor (960 MWe net) was started up in Korea, and another in Japan (1 325 MWe net). Four units were under construction in OECD countries, with a net capacity of about 4.2 GWe. After being in layup since 1997, the Bruce-3 reactor was reconnected to the grid in Canada. In the United Kingdom, the four 50 MWe net reactors at Chapelcross were permanently shut down.

In Japan, 17 units were shut down for inspections after quality-assurance issues were discovered in 2003. Sixteen were progressively returned to service by the end of 2004. In the United States, all pressurised water reactors were ordered in 2003 to undergo extensive inspections of their reactor pressure vessel heads as a result of corrosion discovered in the pressure vessel head of the Davis-Besse plant. The consequences of this order extended into 2004 as these plants underwent the inspections, and many needed to replace their pressure vessel heads as a result. Due to these extended shutdowns, there was a decrease in the amount of electricity generated in the United States and Japan during 2004, which in turn lowered the total generated in OECD member countries.

During 2004, Europe continued to be a region marked by two divergent opinions on the role to be played by nuclear energy. On the one hand, some countries continued to plan on including nuclear energy in their future energy mix, e.g. Finland and France. In Finland, TVO applied for a construction license at Olkiluoto, with the expectation that the government would grant the construction permit early in 2005. In France, EDF announced its decision to build a European pressurised reactor near Flamanville in the *Basse Normandie* region.

On the other hand, several other countries (such as Belgium, Germany, the Netherlands and Sweden) currently have phase-out plans, some of which remain under discussion. During 2004, the Swedish government announced that the Barseback-2 reactor would close in 2005. This would be the second reactor to close in Sweden as a result of its policy to phase out nuclear energy. Power uprates to several other reactors operating in Sweden are expected to make up for the reduction in installed capacity and thus minimise the impacts of this shutdown in the near term.

The Far East continued to be the major nuclear energy growth region, with new reactors having come on line in both Korea (Ulchin-5) and Japan (Hamaoka-5). Additional reactors – one in Korea and two in Japan – were under construction. The most significant operating incident (in terms of human life) that occurred in 2004 was in the Far East as well. In August, five workers were killed and six injured when a steam leak occurred at the Mihama-3 plant in Japan during preparations for maintenance inspections. Although this incident did not involve the nuclear part of the plant (similar incidents have occurred at industrial facilities in the past), it raised concerns about the adequacy of maintenance records. All of the 22 other PWRs in Japan were instructed to have their maintenance records reviewed to prevent any similar occurrences.

Korea Hydro & Nuclear Power Co. Ltd., Rep. of Korea

From left to right: Ulchin 1 to 6, Republic of Korea. Unit 5 came on line in 2004; Unit 6 will be completed in June 2005.

In parallel, renewed interest in the construction of new nuclear reactors continued to grow in the United States. In November 2004, the US Department of Energy (DOE) announced that it had awarded US$13 million in initial funding to support two consortia of nuclear industry vendors and utilities seeking to demonstrate the US Nuclear Regulatory Commission's (NRC's) combined construction and operating licensing process. The NRC granted final design approval to Westinghouse Electric's AP1000 advanced reactor, a design under consideration by one of the consortia. In a further bid to encourage construction of a new reactor, the DOE

2004 Nuclear Data Summary (as of 31 December 2004)

Country	Operational reactors	Installed capacity (GWe net)	2004 uranium requirements (tonnes U)	Nuclear share of 2004 electricity production
Belgium	7	5.8	845	55.2
Canada	22	12.0	1 700	15.1
Czech Republic	6	3.5	598	31.8
Finland	4	2.7	536	26.5
France	59	63.4	7 184	78.1
Germany	18	20.6	3 000	30.1
Hungary	4	1.9	512	38.5
Japan	52	43.9	7 140	30.0
Mexico	2	1.4	181	4.2
Netherlands	1	0.5	65	3.8
Republic of Korea	19	15.9	3 200	38.0
Slovak Republic	6	2.5	501	55.5
Spain	9	7.5	2 040	22.7
Sweden*	11	9.5	1 600	50.6
Switzerland	5	3.2	317	39.4
United Kingdom*	23	11.9	1 600	20.0
United States	104	99.7	24 143	20.0
Total	**352**	**305.9**	**56 108**	**23.5**

* Estimates

also announced that it will co-operate with the Tennessee Valley Authority (TVA) in a feasibility study on the construction of advanced boiling water reactors at the TVA's Bellefonte site. Additionally, work to restart the TVA's Browns Ferry-1 reactor remains on schedule, with operation to recommence in 2007 (after having been shut down in 1985).

Furthermore, license renewal and power uprating of existing reactors continue to add capacity and extend the operating life of the reactor fleet in the United States, even without new construction. In 2004, US utilities submitted applications for power uprates that, if granted, would add about 1 GWe net in capacity. The NRC also authorised in 2004 the extensions of operating licenses to 60 years for 7 reactors, in addition to the 23 authorised in previous years. Applications for extension are under review for yet another 16 reactors.

Uranium production, conversion and enrichment

Over the past several years there has been a significant and sustained increase in the market price of uranium. Since the beginning of 2001, the price of uranium has steadily risen from lows not seen since the early-1970s, and had almost doubled by the end of 2004. A variety of reasons have been put forward to account for this rise, including: an October 2001 fire that destroyed the solvent extraction facility at the Olympic Dam mine in Australia; flooding in the McArthur River mine in Canada, which stopped production for three months in the summer of 2003; leaks that led to a four-month shutdown of the Converdyn uranium conversion facility in early 2004; and uncertainties on the future availability of the Rössing mine in Namibia.

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 permit expansion of production capability as secondary sources decline. Thus, increased exploration activity will be needed to build new or expand existing production capability. Low uranium prices over the past decades have led to limited exploration expenditure during that time. However, an analysis of historical information indicates that past price increases have resulted in increased exploration. Recent price increases, and therefore greater potential for profitability, can thus be expected to trigger the increased exploration needed.

In December 2003, the uranium conversion facility at Metropolis, Illinois (USA) was shut down due to a leak of fluorine that travelled off site, which followed a series of smaller leaks in August and September. As a result, Honeywell performed several corrective actions and had to obtain NRC approval prior to being allowed to restart operations. The plant began a phased restart in March 2004. During the shutdown, Converdyn met the Metropolis commitments by using stored inventory and/or rescheduling deliveries. This incident increased perceptions of fragility in the uranium supply chain that likely contributed to increases in the price of uranium.

In 2004, the worldwide trend continued towards using centrifuge technology as the dominant enrichment method. Two separate efforts remain under way to create a commercial centrifuge enrichment capability in the United States: one by the US Enrichment Corporation (USEC), and the other by Louisiana Energy Services (LES). The NRC has accepted for detailed review their applications for construction and operation of enrichment plants. Both groups are planning on a 24-month review, with construction projected to begin in 2006. The USEC plant would be constructed in Ohio, while the LES plant would be located in New Mexico. In October, the European Commission conditionally approved AREVA's plans to acquire 50 per cent of Urenco's enrichment technology company as a means to gain access to Urenco's centrifuge technology, and to use it to replace the ageing Georges Besse gaseous diffusion plant.

JNFL, Japan

Centrifuge technology will be the dominant enrichment method in the years to come.

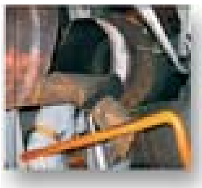
Nuclear safety and regulation

Overall, the safety performance of nuclear power plants in OECD countries continues to be very good, as reflected in a number of published performance indicators. The current safety record is built upon a mature regulatory system and a foundation of research. There is a general consensus that safety research can improve the efficiency and effectiveness of a regulatory system by helping to identify the items most important to safety and by anticipating future regulatory challenges, thus allowing resources to be focused on the most significant concerns.

In 2004, some significant events took place, drawing attention to such areas of concern as erosion-corrosion of secondary system piping and its inspection; vulnerabilities of nuclear power plants to loss of off-site power events; and disturbances caused by foreign material entering the primary cooling system. These three areas all represent well-known recurring phenomena, and illustrate the continuing need to respond to operating experience and to implement an appropriate and timely corrective action programme. Learning processes from prior events, and maintaining both competence and a high priority on safety, remain among the main challenges for the different parties involved in nuclear safety.

JNES, Japan

The pipe failure at Mihama Unit 3 in August 2004 led to instructions to review the maintenance records of all of the 22 other PWRs in Japan.



OECD nuclear safety and nuclear regulatory authorities were active in revealing and resolving issues in this field with the aim of continuously improving nuclear safety in OECD countries and beyond. They have established several additional joint activities and research projects to this effect.

Radiological protection

In the area of radiological protection, the development of new recommendations by the International Commission on Radiological Protection (ICRP) continued to be a central issue in 2004, with a clear and significant contribution from various stakeholder constituencies. Originally planned for completion in 2005, the first publicly available draft recommendations were presented by the ICRP Chair in May 2004, during the 11th International Radiological Protection Association Congress (IRPA-11) in Madrid. This was followed by the release of the draft recommendations in July 2004 on the ICRP website for open review and comment. Despite open discussions on this subject since 1999, the draft recommendations have triggered significant reactions within government and industry. As a result, the final approval of the new recommendations has been postponed until no earlier than 2006, when it is hoped that further clarity on several key issues will have been developed. These key issues include dose constraints (their nature, relationship with dose limits, and numerical values), the matrix expression of the collective dimension of group dose (previously collective dose), the characterisation of the individual (previously the critical group), and the nature and order of the Commission's three main principles (justification, dose restriction and optimisation). This dialogue and the current schedule demonstrate the extent to which the ICRP now values the input of radiological protection stakeholders. This new consultative process, while more lengthy than the previous ICRP "closed expert group" approach, should result in new ICRP recommendations that more appropriately address the needs of radiological protection policy makers, regulators and practitioners.

Work also continued this year to address the radiological aspects of national and international planning and preparedness to respond to chemical, biological, radiological and nuclear (CBRN) incidents, should they occur. In the radiological protection area much of the knowledge and experience needed to address radiological incidents already exist in national nuclear incident response organisations. Nonetheless, all walks of the radiological protection community (government, research and industry experts) spent significant efforts during 2004 to assure national readiness for terrorist attacks as well. This included organising and analysing large-scale response exercises; developing research programmes to address large-scale, rapid radiological contamination and dose assessment tools; and analysing the best approaches to address contamination and irradiated victims in urban environments. While there is broad agreement that national preparations as well as national and international guidance for radiological terrorist attacks are adequate, there is also a general understanding that, as with any safety preparations, continuing refinement has its use.

Finally, scientific studies of the effects of radiation on organisms are beginning to suggest some new and interesting challenges. For example, the model (linear no-threshold, LNT) currently used to relate radiation exposure to health risk (mainly cancer induction) seems to overestimate the risk of bone cancer, liver cancer and leukaemia for low alpha doses. In fact, some studies of human and animal populations that have been exposed to inhaled and/or ingested alpha emitters seem to indicate that there is a threshold dose below which there is no risk. As such, the question is raised of whether current risk estimate techniques appropriately estimate risks from chronic exposures. The answer may indicate that our current understanding is correct, but it could also pose significant challenges to the management of radiological protection in the future. New and ongoing research will need to be appropriately oriented to address both policy and regulatory questions and concerns.


NEI, United States

Emergency training with local and plant personnel at Southern California Edison Co., United States.

Radioactive waste management

One of the world's most important radioactive waste repository projects, Yucca Mountain in the United States, came under discussion in 2004 when a US court rejected, for formal reasons, a safety standard of the Environmental Protection Agency (EPA) guiding the long-term safety evaluation of the repository. The Yucca Mountain case revived the worldwide discussion on how to handle the very long timescales involved in radioactive waste disposal safety assessments, a discussion to which the NEA has actively contributed.

Another disposal programme of note is the deep geological repository project in Olkiluoto, Finland. Posiva Oy, the implementing organisation, started construction work on the ONKALO underground characterisation facility at the site of the foreseen repository just one year after the repository project received authorisation to proceed from Parliament. The over 500-meter deep tunnel leading down to the characterisation facility is expected to be completed by 2010. Research conducted at ONKALO will provide information to define the characteristics of sections of rock identified as being suitable for final disposal.

Posiva Oy, Finland

The ONKALO underground characterisation facility at the site of the foreseen repository in Finland.

The "nuclear package" proposed in 2003 by the European Commission (EC), which *inter alia* would have required EU countries to consider geological disposal and to establish a timetable for the long-term management of radioactive waste, was not adopted by the European Council in 2004. However, the Commission made a revised proposal for the package in September 2004 and the Council has set up an Ad hoc Working Party on Nuclear Safety to discuss a number of issues raised in the package.

Regarding stakeholder involvement, a specific concept of local partnerships set up in Belgium among three potential host municipalities and the waste management organisation ONDRAF/NIRAS, showed encouraging results in 2004. Reports issued by two of the municipalities led the partnership organisation to propose to host an integrated repository for low-level and intermediate-level waste, either as a surface or a deep geological facility. Once the municipalities have agreed on the conditions for a possible repository on their territory, the concrete implementation of the local conditions will be discussed. A comparable decision-making process was followed in Canada, when in October the municipality of Kincardine in Ontario and Ontario Power Generation (OPG) obtained the endorsement by the municipal Council of a hosting agreement for a deep geological repository for low- and intermediate-level waste.

Nuclear science

Over the past few years there has been marked interest in studying advanced reactor concepts and related fuel cycle strategies with the aim of improving their economics, safety and non-proliferation aspects as compared with current reactors, while at the same time minimising the generation of nuclear waste. Specific emphasis has been given to systems with one or more of the following criteria: fast neutron spectra, high temperatures and closed fuel cycles. Many of the proposed new reactor and fuel cycle concepts represent very advanced or completely new concepts, requiring a wide range of scientific feasibility studies, especially for the validation of core designs and for the development of new fuels and high-temperature materials.

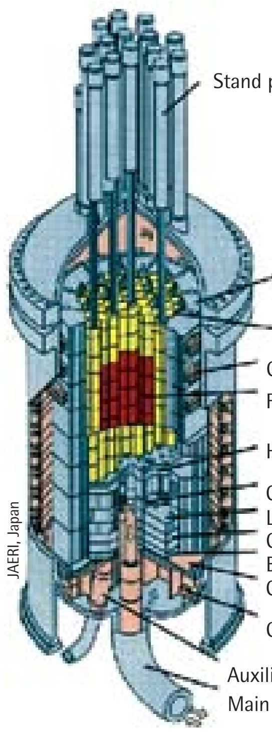
This interest in advanced reactor concepts in combination with, for example, an ageing workforce and falling student interest in nuclear disciplines has triggered an awareness of the need for better preserving the knowledge accumulated in the field of nuclear science and technology. A number of national and international initiatives, including the preservation of technical information in databases and strategies to transfer tacit knowledge, have been taken with the goal of safeguarding and sharing existing knowledge, and facilitating the transfer of that knowledge to future generations.

Nuclear data and software

The assessment of calculation tools and the validation of nuclear data performance are crucial issues in reactor and fuel cycle design studies, but are also of considerable importance for improving the performance of existing nuclear power plants. The notable increase in computing power, allowing Monte Carlo techniques and calculations of full three-dimensional models using best-estimate methods, are now being performed regularly, thus enhancing the accuracy of the results by eliminating earlier approximations in the codes.

In addition to more advanced computing techniques and models, more information about the accuracy of the associated nuclear data is also

Structure of the high-temperature engineering test reactor (HTTR) at the JAERI Oarai Research Establishment, Japan.



required to better assess the precision of the calculations. Most of the data libraries that are now being developed are, as far as possible, trying to incorporate uncertainty information in the form of covariance matrices. This nuclear data uncertainty information, together with proper sensitivity analysis and advanced nuclear model codes, will help nuclear physicists to better evaluate the confidence bounds of the calculated parameters (including reactor safety margins), providing prospects of improving the economics of current nuclear power plants.

Nuclear law

OECD countries have shown increasing concern in ensuring that adequate and equitable compensation is available to victims who suffer damage as a result of a nuclear incident taking place at a nuclear installation or during the transportation of nuclear substances. The adoption, in 2004, of Protocols to amend both the Paris Convention and the Brussels Supplementary Convention reflects the trends in member countries to significantly increase the amount of compensation to be made available to victims, to broaden considerably the scope of damage that will be subject to compensation, and to ensure that a much larger number of victims will be entitled to compensation than ever before. As for OECD countries not parties to the Paris or Brussels Supplementary Conventions, it is anticipated that several of them may soon amend their national nuclear liability legislation to reflect these same trends.

Member countries also wish to continue working to eliminate or minimise legal impediments to the safe use of nuclear energy and, to the greatest extent possible, harmonise legislation governing the peaceful uses of nuclear energy. To that end they continue to focus their attention on the impact of major events with international implications, such as terrorist acts, and on the need to develop new mechanisms for resolving issues which, until now, have not been studied from this perspective, such as harmonising legislation governing liability and compensation for damage arising from radioactive sources. Those goals will become increasingly challenging in light of the recent expansion of European Union membership.

The establishment of a University Diploma in International Nuclear Law at the University of Montpellier 1 in tandem with the International School of Nuclear Law further confirms the interest in maintaining and strengthening this specialised educational programme, which meets the concerns of OECD member countries to ensure that nuclear education and training are maintained at a high level, including in the field of nuclear law.

Signing the Protocols to amend the Paris and Brussels Conventions, Paris, France. From left to right: Mr. P. Reyners, Head of NEA Legal Affairs; Mr. D. Johnston, OECD Secretary-General; Mr. H. Rustand, Chair, Paris/Brussels Revision Group; and Mr. L. Echávarri, NEA Director-General.

David Sterboul, OECD