Nuclear Power in 2005

Nuclear energy development

As of 31 December 2005, 351 reactors were in operation in OECD countries constituting some 83% of the world's total nuclear electricity generating capacity and about 23.4% of the total electricity supply in the OECD area. During 2005, three reactors were started up in OECD countries: two in Japan and one in Korea. After being in lay-up since 1997, the Pickering-1 reactor was reconnected to the grid in Canada. Two reactors were shut down – one in Germany and one in Sweden – as part of those countries' phase-out plans.

OECD countries continue to have different approaches to the production and use of nuclear energy. At present, several countries officially have policies in place which exclude or plan to phase out the production of nuclear energy (this currently includes Austria, Belgium, Germany, Italy, Spain and Sweden, but the policies could evolve in certain countries given recent debates). Others are actively pursuing plans to increase their nuclear capacity in the future (Canada, Finland, France, Japan, Korea, the Slovak Republic and the United States) or are considering the possible introduction of nuclear power into their energy mix. A number of other OECD countries continue to use nuclear energy, but have not announced any plans for expansion or new construction. Overall, however, momentum to build new nuclear capacity grew. Key events that support this perception were that:

- In Finland, TVO began construction of the Olkiluoto-3 reactor, using the advanced European pressurised reactor (EPR) design.
- The French government and EDF, the country's primarily state-owned electricity utility, continued preparations for the construction of an EPR to be located near Flamanville in the Basse-Normandie region. Plans have also been announced to construct additional units in the future to replace those due to be retired.
- In Japan, Higashidori-1 and Shika-2, both boiling water reactors (one of which is an ABWR), were connected to the grid in March and July 2005 respectively. In October, the Japanese government adopted a new Policy Framework for Nuclear Energy, which stipulated *inter alia* that Japan should maintain its nuclear share of total domestic electricity generation at around 30-40% after 2030, and should aim to introduce fast breeder reactors (FBRs) commercially by 2050 and pursue a domestic nuclear fuel cycle policy based on spent fuel reprocessing. Following that decision, the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry (METI) began work on the Framework's implementation plan.
- In Korea, the Ulchin-6 reactor was started up and connected to the grid in January 2005. In June, construction of the Shin Kori-1 and -2 nuclear power reactors was approved by the Ministry of Science and Technology. The two new KSNP+ 1 000 MWe pressurised water reactors are expected to be completed respectively by 2010 and 2011.
- In the United States, Congress adopted the Energy Policy Act, which was signed by the President in August 2005. The law contains several incentives intended to encourage construction of new nuclear power plants, including electricity production tax credits, loan guarantees and risk protection for the first few companies pursuing construction of new reactors. Also, in December 2005, the Nuclear Regulatory Commission (NRC) certified the design of the AP-1000 advanced pressurised water reactor, which can now be referenced in a combined construction and operating license application. AREVA announced its intent to pursue design certification of the US evolutionary power reactor (US EPR) as a step towards marketing that design in the United States.

Tohoku Electric Power, Japan

View of the Higashidori-1 nuclear power plant, Japan.

Similar developments in non-OECD countries tend to confirm the growth in momentum. Three additional units came on line in 2005, and construction of another two units officially started. Plans for further expansion have been adopted in a number

2005 Nuclear Data Summary (as of 31 December 2005)				
Country	Operational reactors	Installed capacity (GWe net)	2005 uranium requirements (tonnes U)	Nuclear share of 2005 electricity production (%)
Belgium	7	5.8	1 367	55.0
Canada	20	12.5	1 800	14.4
Czech Republic	6	3.5	756	30.6
Finland	4	2.7	524	32.9
France*	59	63.4	7 185	78.1**
Germany*	17	20.3	2 900	30.1**
Hungary	4	1.8	370	39.4
Japan	54	46.3*	7 819	31.8
Mexico	2	1.4	360	5.2
Netherlands	1	0.5	65	3.7
Republic of Korea*	20	16.8	3 400	38.0**
Slovak Republic*	6	2.5	450	55.5**
Spain	9	7.5	1 177	19.8
Sweden*	11	9.4	1 400	50.6**
Switzerland*	5	3.2	270	39.4**
United Kingdom	23	11.8	2 300	20.6
United States	104	99.8	22 875	19.3
Total (OECD)	**352**	**309.2**	**55 018**	**23.4**

* Estimates. ** 2004 data.

of countries, and in a selection of others consideration is being given to the introduction of nuclear energy.

At the same time, plant life extensions, extending operating licences in many instances by an additional 20 years, contributes to available capacity. Extensions have been approved or are being pursued in several OECD countries, including Hungary, the Netherlands and the United States.

Uranium production, conversion and enrichment

In 2004 (the last year for which data is available), uranium was produced in just seven OECD countries, three of which produced only small amounts as part of mine remediation efforts. However, Canada (29%) and Australia (22%) accounted for half of world production. Production in OECD countries amounted to approximately 22 000 tonnes of uranium (tU) in 2004 and was expected to increase just slightly in 2005. Production in 2004 accounted for only about 40% of the uranium requirements in the OECD area, with the remainder being met by secondary sources (for example, excess commercial inventories).

Over the past several years there has been a significant and sustained increase in uranium market price. Since late 2001 the price of uranium has steadily increased, over five-fold by the end of 2005. This increase in price, coming after nearly two decades of price stagnation, has stimulated considerable exploration activities and has led to plans being announced for significant new production. This should help to meet expected demand in the years to come as secondary sources diminish and reactor requirements need to be met by primary production.

During 2005, conversion facilities continued to operate in Canada, France, the United Kingdom and the United States. In March 2005, Cameco announced a 10-year contract for conversion services to be performed at the BNFL Springfield site in the United Kingdom, thereby extending the life of the plant which had been slated to close in 2006.

In terms of uranium enrichment, the worldwide trend towards the use of centrifuge technology continued. In the United States, two efforts remain under way to create a commercial centrifuge enrichment capability. One, sponsored by the US Enrichment Corporation (USEC), will use advanced centrifuge technology adapted from prior US Government research. A second initiative, under Louisiana Energy Services (LES), is based on Urenco centrifuge technology. The USEC plant is expected to be constructed in Piketon, Ohio while the LES plant would be located in Lea County, New Mexico. On 15 June 2005, the NRC issued a Final Environmental Impact Statement and a Safety Evaluation Report for the proposed LES facility. Construction of the LES facility is expected to begin in 2006, and in 2007 for the USEC facility.

In Germany, in February 2005 the Northrhine-Westphalia State Ministry of Energy issued a licence for the planned capacity increase to 4 500 t SWU/y at Urenco's Gronau enrichment plant, which represents a potential increase of 150% over current capacity. The licence comprises the construction of a second enrichment plant next to the existing plant. First production at the new plant is expected to begin in the second half of 2007. In October, the European Commission conditionally approved AREVA's plans to acquire 50% of Urenco's Enrichment Technology Company as a means to gain access to centrifuge technology and to use it to replace the ageing Georges Besse gaseous diffusion plant in France.

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 industry, a robust regulatory system and a strong 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 2005, some significant events took place, drawing attention to latent failures on piping, switchboards and cable insulation. Latent failures have been an issue of concern in recent years and illustrate the continuing need to respond to operating experience and to implement an appropriate and timely corrective action programme. OECD nuclear safety and nuclear regulatory authorities have been active in revealing and resolving issues in this field and aim to improve nuclear safety continuously in OECD countries and beyond. They have established several joint activities and multilateral research projects to this effect.

A. Gonin, CEA, France

Radiological conditions are systematically monitored in and around nuclear power plants. Any releases are strictly regulated.

Radiological protection

Several of the evolving aspects of radiological protection are beginning to converge, building an increasingly clear picture of the issues that will shape radiological protection policy, regulation and application for the coming 10 to 15 years. The most important of these are the development of new International Commission on Radiological Protection (ICRP) recommendations, which traditionally have been the basis for most national RP regulations, and the increasing influence of stakeholder involvement in radiological protection decision-making processes.

Progress has been made towards the finalisation of the ICRP's general recommendations, which are now expected to be approved in late 2006 after further public comment on a yet-to-be-released new draft. It should also be noted that the ICRP is continuing its work on the radiological protection of the environment. Both of these activities will have a significant influence on the update of another important document, the International Basic Safety Standards (BSS). The work to develop a new BSS, as well as the parallel development of a new European Commission BSS Directive, began in 2005 and is expected to take several years.

The main current issues in radiological protection – accident management and rehabilitation, new site selection, decommissioning and site release, and operational releases – are significantly influenced by stakeholder involvement issues. As a result, regulatory policies and frameworks, organisational structures and decision-making processes are being revisited, and in some cases modified to ensure that they can appropriately and transparently address stakeholder involvement and the views and concerns it might generate. Radiological protection is, in general, moving towards more inclusive risk governance approaches, and this trend will most likely continue to evolve. The implications of this for the radiological protection profession will also continue to be explored, but will certainly include effects on education and training, as well as on processes and approaches for the formulation of issues and the development and implementation of solutions.

Radioactive waste management

In 2005, Canada and France, two major producers of nuclear-generated electricity, prepared important decisions for their future management of spent nuclear fuel and radioactive waste. In Canada, the Nuclear Waste Management Organisation (NWMO), which was created by the Nuclear Fuel Waste Act of November 2002 to develop a long-term approach for managing used nuclear fuel, presented its final report. Based on a comprehensive three-year effort that engaged specialists, stakeholders and citizens, the NWMO recommended adaptive, phased management for the long-term care of used nuclear fuel. The concept presented aims to isolate and contain Canada's used nuclear fuel deep underground in a suitable rock formation and includes an interim step for temporary, shallow underground storage as well as potential for retrievability. Final construction of a deep repository may be postponed for about 50 years to allow for implementation in phased and adaptive stages. A decision is now awaited from the Canadian government on the way forward.

In France, the government started a broad public discussion to feed into the 2006 parliamentarian debate and decision-making processes, in advance of the expiration of the 1991 "Bataille" law which had hitherto supported three axes for the management of spent fuel and waste: partitioning and transmutation, geological disposal and long-term storage. A report published by the Parliamentary Office for Evaluation of Scientific and Technological Options (OPECST) emphasizes that these approaches complement each other and proposes the further development of geological disposal for long-lived waste, and the development of long-term intermediate storage for spent fuel that might become subject to transmutation. The concept assumes the operation of a geological repository in the time frame 2020-2025, and the availability of industrial transmutation by 2040.

While the decisions to be taken in 2006 by the Canadian government and the French parliament will be closely monitored worldwide, the two most advanced geological repository projects – Yucca Mountain in the United States and Olkiluoto in Finland – are progressing. An important Yucca Mountain safety standard issued by the US Environmental Protection Agency (EPA) is under revision to include timescales beyond 10 000 years and up to 1 million years for which a dose limit based on natural background radiation is proposed. At the Olkiluoto site in Finland, construction work is progressing to build the ONKALO underground characterisation facility that will precede the geological repository planned at the same site.

Encouraging news regarding progress in the siting of low- and intermediate-level waste repositories came from Hungary and Korea. In Bátaapáti, about 60 km south of the Hungarian Paks nuclear power plant, the municipality held a referendum on whether it should allow a final waste repository on its territory. A clear majority of citizens voted in favour of hosting the geological waste disposal facility, thus paving the way for a parliamentarian decision to start the process. On a much larger scale, a similar vote was taken in the Korean town of Gyeongju, in North Gyeongsang province, to host the country's first low- and intermediate-level radioactive waste repository. Four communities had been selected as main candidates, and each of them held a referendum to decide whether its residents approved hosting the facility. While in all candidate cities more than two-thirds of the citizens voted

The site of the Bátaapáti waste repository, Hungary.

Attila Nagy, Index.hu, Hungary

View of the Gyeongju countryside, North Gyeongsang province, Korea.

positively for the project, Gyeongju had the highest approval rate and was selected by the government, which hopes to complete the facility by 2008/09.

Nuclear science

Concerns over energy resource availability, climate change, air quality and energy security have generated a renewed interest in nuclear power and especially in more advanced systems having improved economic, safety and non-proliferation aspects, and producing less nuclear waste than current reactors. The Generation IV International Forum (GIF) is carrying out research on six advanced systems having these characteristics. The development of these systems also requires further research in a wide range of scientific areas, such as the validation of core designs and the development of new fuels and materials for high-temperature applications. OECD countries are active in this area.

The renewed interest in some member countries to continue developing nuclear power as part of their energy mix, in combination with an ageing workforce and weak student interest in nuclear subjects in recent years, has spurred an awareness of the need to preserve 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 knowledge, have been undertaken with the goal of safeguarding and sharing existing knowledge, and facilitating the transfer of that knowledge to future generations.

Nuclear data and software

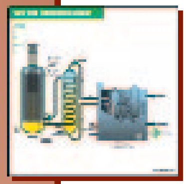
It is commonly recognised that well-validated computer codes and nuclear data are needed for assessing the quality of results from modelling exercises of current and advanced nuclear systems. The notable development in computing power is having a strong impact on the predictive calculations of different reactor and fuel cycle parameters. An increased use of Monte Carlo methods and calculations of full 3-dimensional models are improving the accuracy of the results by eliminating the approximations associated with earlier computation methods.

In addition to more advanced computing techniques and models, more information about the accuracy of the associated nuclear data is also required, and the major nuclear data libraries are now devoting more efforts towards the inclusion of uncertainty information in the form of covariance matrices. This uncertainty information, together with proper sensitivity analysis and advanced nuclear model codes, will assist nuclear physicists in better evaluating the confidence bounds of the calculated parameters, providing prospects to improve reactor safety margins as well as the economics of current nuclear power plants.

Nuclear law

OECD countries continue to show significant interest in ensuring that adequate and equitable compensation is made available to victims who suffer injury or damage as a result of a nuclear incident occurring at a nuclear installation or during the transport of nuclear substances. Those member countries which adopted the Protocols to amend the Paris and Brussels Supplementary Conventions in 2004 are now actively working to implement the provisions of those protocols into their national legislation, provisions which significantly increase the amount of compensation to be made available, which broaden the scope of compensable damage and which ensure more victims will be entitled to compensation than ever before. They are also

Generation IV International Forum (GIF)



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'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.
- **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.
- **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.
- **Sodium-cooled fast reactor system (SFR).** The SFR features a fast-spectrum, sodium-cooled reactor and a closed fuel cycle.
- **Supercritical-water-cooled reactor system (SCWR).** The SCWR is a high temperature, high-pressure, water-cooled reactor that operates above the thermodynamic critical point of water.
- **Very high temperature reactor system (VHTR).** The VHTR is a graphite-moderated, helium-cooled reactor with a once-through uranium fuel cycle.

These systems offer significant advances in sustainability, safety and reliability, economics, proliferation resistance and physical protection.

The GIF reached a major milestone on 28 February 2005 when five of the forum's member countries (Canada, France, Japan, the United Kingdom and the United States) signed the GIF Framework Agreement for the R&D phase. By the end of 2005, Korea and Sweden had also acceded to the agreement.

For each of the six concepts selected, a system steering committee has been set up to manage the R&D collaboration. The NEA serves as Technical Secretariat to the GIF.

aiming to finalise the two *Exposés des Motifs* for those conventions. Other OECD members are examining the benefits of adhering to the 1997 Protocol to Amend the Vienna Convention and still others are considering amending their national legislation to reflect the trends incorporated in these various amending protocols. All OECD members continue to evaluate the advantages of adhering to the 1997 Convention on Supplementary Compensation for Nuclear Damage.

Member countries are striving 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 search for solutions to problems arising from nuclear operators' inability to adequately insure against third party liability and material damage risks where nuclear incidents are caused by terrorist acts; to determine whether nuclear fusion installations should be covered by special nuclear liability regimes; to find means of avoiding potential conflicts between the international nuclear liability conventions and European Community legislation; to assess the impact of various international conventions on nuclear activities; and to help the development and implementation of nuclear safety assistance programmes with non-members. They are also active in supporting nuclear law education and information dissemination programmes.