Nuclear Power in 2009

Nuclear energy development

At the end of 2009, a total of 343 reactors were connected to the grid in OECD countries, constituting about 83% of the world's total nuclear electricity generating capacity and about 22% of the total electricity supply in the OECD area. During 2009, one new reactor was connected to OECD country grids (Tomari-3, Japan) and three were shut down (Hamaoka-1 and 2, Japan and Phenix, France); construction was initiated (first concrete poured) on one reactor (Shin-Kori-4, Republic of Korea).

Although nuclear energy policies can vary widely in OECD countries, ranging from phase-out policies to clear commitments to maintain nuclear power as a significant component of the energy mix, the gap is narrowing, as governments in Germany and Sweden, among others mentioned below, are actively reconsidering such restrictions. This is largely due to an increased recognition of nuclear power's ability to enhance security of energy supply and to provide competitively priced, baseload electricity that is essentially free of greenhouse gas emissions and supported by the safe operation of the existing fleet of power reactors. Some of the significant developments that occurred in OECD countries in 2009 are:

- In Belgium, the government agreed to extend the lifetime of its three oldest reactors by ten years until 2025, in exchange for annual payments from the operators amounting to between 215 and 245 million euros.
- In the Czech Republic, a draft State Energy Concept was released calling for a significant increase in the share of nuclear power in electricity production. In August 2009, a public tender was launched to select a contractor for the construction of two additional reactors at the Temelin site.
- In Hungary, parliament overwhelmingly granted preliminary approval to begin detailed preparation for the construction of new nuclear generating capacity at the existing Paks plant.
- In Italy, the adoption of new energy legislation in July 2009 officially ended the moratorium on nuclear energy and cleared the way for plans to build new nuclear power plants, with the long-term goal of providing 25% of the country's total electricity production.
- In Poland, the government adopted a resolution according to which a nuclear power programme shall be developed. Plans include the construction of two reactors for electricity generation, the first of which would be online by 2020.
- In the Slovak Republic, work continues to complete the construction of two reactors at the Mochovce site, where work had been halted in 1992. The government has proposed the construction of an additional two reactors, one of which at the Bohunice site where the Czech power company ČEZ has been selected to form a partnership for the construction project.
- In Spain, the nuclear regulator approved a government request to extend the lifetime of the Garona nuclear reactor (the country's oldest) by four years.
- In the United Kingdom, a draft Nuclear National Policy Statement, including a list of ten sites deemed potentially suitable for the construction of new nuclear power plants by the end of 2025, was issued by the government as part of an effort to remove unnecessary planning delays for large energy projects.

2009 Nuclear Data Summary (as of 31 December 2009)

	Operational reactors	Installed capacity (GWe net)	Uranium requirements (tonnes U)	Nuclear share of electricity production (%)
Belgium	7	5.9	1 135	51.7
Canada	20	12.7	1 600	14.8
Czech Republic	6	3.7	1 040	35.8
Finland	4	2.7	660	33.1
France	58	63.1	8 000	75.1
Germany*	17	20.4	2 600	23.4
Hungary	4	1.9	425	43.5
Japan	54	47.0*	8 870	26.0*
Mexico	2	1.4	154	4.4
Netherlands	1	0.5	60	3.2
Republic of Korea*	20	17.7	3 000	36.7
Slovak Republic	4	1.7	363	54.4
Spain	8	7.5	679	17.5
Sweden*	10	9.0	1 574	42.0
Switzerland*	5	3.2	278	39.0
United Kingdom*	19	10.1	951	13.2
United States*	104	100.7	16 424	19.6
Total (OECD)	**343**	**309.2**	**47 813**	**21.5***

* 2008 data. Operational = connected to grid.

- In the United States, resumed construction continues of the Watts Bar-2 reactor (initially suspended in 1988), and the Department of Energy (DOE) issued a final rule in the loan guarantee programme that paves the way for federal support for clean energy projects that use innovative technology, including nuclear power. However, the new administration announced the termination of the proposed Yucca Mountain spent nuclear fuel repository, indicating that a better solution for radioactive waste disposal would have to be developed.

As governments continue to develop nuclear energy initiatives, the ongoing global financial crisis, combined with the highly capital-intensive nature of investments in nuclear power have caused delays in their development. For example, new nuclear build projects in Canada and Turkey were postponed in 2009, at least in part due to financial reasons. Concerns about the cost of building new reactors in the United Kingdom and the United States have also been expressed.

In non-OECD countries, the Ignalia-2 reactor in Lithuania was shut down as a condition for entry into the European Union. In Bulgaria, the government put the Belene new build project under review due to rising costs, and the German utility RWE opted out of the partnership founded to construct the two reactors. One reactor was commissioned in India, and construction was initiated for nine reactors in China and one in the Russian Federation, in support of plans for a robust expansion of nuclear electricity generating capacity in these three countries. This brings the total number of reactors currently under construction in the world to 55. A consortium from the Republic of Korea was selected as the winning bidder to design, build and help operate four 1 400 MWe reactors in the United Arab Emirates.

Uranium production, conversion and enrichment

Preliminary, unofficial data indicate that global uranium production rose by about 15% in 2009, principally owing to significant increases in Kazakhstan. Uranium was produced in seven OECD countries in 2009. France, Germany and Hungary contributed only small amounts as part of mine remediation activities. Australia (16%), Canada (20%), the Czech Republic (<1%) and the United States (3%) together accounted for a significant share of world production. Production in OECD countries amounted to approximately 19 885 tonnes of uranium (tU) in 2009 (an increase of almost 3% from 2008), accounting for roughly 40% of uranium requirements in the OECD area. Remaining requirements were met by non-OECD production and secondary sources (material derived from dismantling warheads, excess commercial inventories and reprocessed uranium).

The spot price of uranium reached a peak of USD 354/kgU in June 2007, then declined to about USD 138/kgU in December 2008, partially due to the economic downturn. During 2009, the spot price varied between roughly USD 105/kgU and USD 135/kgU, as upward pressure for new reactor fuel (notably in China) was offset by the impending release of DOE inventory material. Long-term price indicators declined from about USD 185/kgU to USD 155/kgU. Uranium exploration and mine development activity continued in many countries. However, the challenging financial setting, as well as technical and permit issues, caused delays in OECD countries.

During 2009, uranium conversion facilities continued to operate in France, the United Kingdom and the United States. Operations in Canada were restarted after a six-month shutdown owing to a contract dispute with a major supplier. Construction of additional conversion capacity continued in France.

Construction of two new uranium centrifuge enrichment plants continued, one at AREVA's Georges Besse II facility in France, where rotation of the first cascade occurred in November 2009, and another at Louisiana Energy Services' National Enrichment Facility (NEF) in the United States, where construction remains on schedule and on budget for expected operation in 2010. Elsewhere in the United States, the US Enrichment Corporation stopped development of its new plant using the American centrifuge design after receiving notice that it would not be eligible for a DOE loan guarantee. The GE-Hitachi Global Laser Enrichment project continued, with an application having been made to license a full-scale commercial facility.

Nuclear safety and regulation

In 2009, the safety performance of nuclear power plants in OECD countries remained at a very high level, as in previous years. The main elements supporting this achievement are a mature industry, a robust regulatory system and a strong foundation of research. The number of nuclear power plants reaching the end of their initial design life is increasing and lifetime extensions continue to be an approach adopted by many OECD countries. The NEA continues to support regulatory authorities in their review of the adequacy of long-term operation and ageing management methods.

NEA countries agree that safety assessment and 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. Nuclear regulatory authorities and nuclear safety research institutions also continue to review operating experience feedback and to implement appropriate and timely corrective action programmes.

At the same time, several countries are licensing new reactors and NEA countries are promoting several initiatives, including the establishment of multinational programmes, to improve the efficiency of the design review of new nuclear power plants, and to share experience related to the regulation of new reactors. The initiatives seek to enhance nuclear safety worldwide, by promoting convergence on safety practices and by combining the expertise of participating regulatory authorities, while improving and expediting the safety review of new designs.

Radioactive waste management

In 2009, the new US administration announced its intention to terminate the Yucca Mountain programme and to convene a "blue ribbon" panel of experts to evaluate alternative approaches for meeting the federal responsibility to manage and ultimately dispose of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) from both com-

mercial and defence activities. The Yucca Mountain site was approved by the US President in 2002 after more than 20 years of site characterisation activities and after a joint resolution was passed by Congress for developing a repository. The US Department of Energy (DOE) submitted the license application to the US Nuclear Regulatory Commission (NRC) in June 2008, starting a three- to four-year review period for the NRC before deciding on the construction license – a decision that, if taken, will likely not be acted upon.

The Blue Ribbon Commission is to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle. It is expected to provide advice and to make recommendations on issues including alternatives for the storage, processing and disposal of civilian and defence-related spent nuclear fuel and radioactive waste. The Commission which is made up of 15 members who have a range of expertise and experience in nuclear issues, including scientists, industry representatives and former elected officials, has been tasked with producing an interim report within 18 months and a final report within 24 months.

Other national geological waste repository programmes are moving forward successfully. The Swedish Nuclear Fuel and Waste Management Company (SKB) has selected Forsmark as the site for the final repository of Sweden's spent nuclear fuel. Before construction work can begin, SKB must apply for a licence from the government, which it plans to do in 2010. The application will include an environmental impact assessment and a safety analysis of the repository. All spent nuclear fuel from Swedish nuclear power plants is planned to be disposed of in the final repository at a depth of nearly 500 metres in crystalline bedrock. In addition to the future repository, the system for managing spent nuclear fuel will also include the existing interim storage facility and an encapsulation plant in Oskarshamn, which was the second candidate site for the repository.

In Finland, the access tunnel of the ONKALO rock characterisation facility has nearly reached its final depth. In implementing ONKALO, requirements for a final disposal facility are already being taken into consideration. Submission of the construction licence application for the repository is planned for 2012. Finally, the new German government formed in October committed itself to pursuing action to end the moratorium on site exploration of the Gorleben salt dome. Further investigation of the salt dome in an open-ended manner should allow an assessment of the suitability of the site for a geological repository for spent nuclear fuel and high-level radioactive waste. Regarding repositories for long-lived, low- and intermediate-level waste, important milestones were reached in the siting of such facilities in France and Slovenia. Approximately 40 communities in the Aube District of France applied to host a low-level waste repository. In Slovenia, a decree confirming the location of a low- and intermediate-level waste repository in the municipality of Krško, in the vicinity of the Slovenian nuclear power plant, was passed by the government.

Radiological protection

During 2009, radiological protection practitioners became more familiar with the new International Commission on Radiological Protection (ICRP) recommendations published in 2008 and began assessing their practical ramifications. The latter are being raised in the ongoing discussions of the new International Basic Safety Standards (BSS), but also in discussions of how best to manage exposures to radon, and how to manage medical exposures better. The application of the new system of radiological protection in the context of an expanding nuclear fleet was also a key topic of discussion.

While the new ICRP recommendations maintain the pillars of justification of actions, optimisation of protection and limitation of exposures, the focus of the system is now squarely on optimisation. With this heightened understanding, the drafting of the new BSS during 2009 began to draw to a close. The BSS are seen by many as the instrument for practical implementation of the ICRP recommendations and a model or framework for the development or modification of binding national regulations. It is now expected that the draft BSS will be ready for final review and approval during 2010. The draft text reflects the importance of optimising protection in all exposure situations (planned, emergency and existing).

The management of public and worker exposures from nuclear power plants continues to help reduce exposures, suggesting that the processes and structures for optimising protection have been very effective. As many NEA member countries consider the introduction or expansion of a nuclear power programme, new challenges for the regulation of public and occupational exposure will arise. For example, many plants have been granted licences for lifetime extensions such that an increasing trend in maintenance requirements will need to be addressed in order to maintain exposures at levels that are as low as reasonably achievable (ALARA). In the context of new nuclear build, a concerted effort to incorporate current experience into new plant design will be necessary. This will include both plant-design features as well as procedural aspects. The management of radioactive effluents, to control public exposures, has been effectively carried out using a best available techniques (BAT) approach.

Recent epidemiological studies have shown that between 3% and 15% of all lung cancer deaths may be the result of domestic exposure to radon, with approximately two-thirds of these occurring in homes where the average radon concentration is less than 200 Bq/m^3. While the relative risk cited in these recent studies is consistent with previous understanding, the identification of statistically significant cancer deaths at such low exposures is new. The challenge to governments and regulatory authorities is that many countries have selected their radon action levels at or near 200 Bq/m^3, and have traditionally focused their remediation activities in homes at much higher levels. Radon exposure management programmes for both new and existing dwellings may thus come under new assessment, particularly in the context of the new ICRP recommendations on radon.

Regarding increased medical exposures, a recently published US report has shown that 48% of per capita annual exposure in the United States now comes from medical exposures, while 50% results from natural background radiation (including radon). While this is the first time that medical radiation has constituted such a large source, these numbers are of particular significance in that the number

of individuals exposed to medical radiation is far smaller than the US population exposed to natural background radiation. Exposure from industrial sources is less than 0.1% of the total annual exposure to the US population. As might be expected, medical (48%) and radon (37%) exposure management are being revisited by government and regulatory authorities to assess whether protection is optimised in all cases.

Nuclear science

In the field of nuclear science, much attention is being given to issues related to improving the performance and safety margins of current nuclear power plants, as well as to developing the next generation of reactor systems. The main scientific challenges concerning current nuclear power plants relate to reactor lifetime extension, the employment of higher burn-up fuel cycles and the increased utilisation of mixed-oxide (MOX) fuels. Among future reactor concepts, the fast spectrum and/or high-temperature systems have attracted the most attention: the fast reactors because of their efficient utilisation of fuel and their possibility to burn minor actinides, and the high-temperature reactors due to their improved thermal efficiency and potential spin-off applications, such as process heat or hydrogen production.

The verification and validation of computer codes used in the modelling and simulation of different reactor parameters continue to be important. Improved calculation techniques, in combination with uncertainty qualifications of the basic input data and the calculation methods themselves, provide a better understanding of and confidence in the performance and safety margins, with subsequent possibilities for significant economic benefits. These validation efforts are dependent on the availability of good, well-documented experimental information for comparison with calculations. Large efforts to preserve relevant experimental information are being undertaken as part of more general knowledge management activities.

The behaviour of existing structural and cladding materials, as well as the development of new ones, are of interest for both existing and future reactor systems. The behaviour of these materials over years of irradiation is of importance when considering the lifetime extension of existing reactors, as well as the employment of higher burn-up fuel cycles. In addition, and especially for new reactor concepts, there is a very strong incentive to model and develop new materials that can resist very high temperatures and more intense irradiations, as well as very corrosive environments.

Nuclear law

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 is a primary concern of NEA member countries. Those which signed the Protocols to amend the Paris and Brussels Supplementary Conventions in 2004 are actively working to implement the provisions of those protocols into their national legislation, provisions that significantly increase the amount of compensation to be made available, broaden the scope of damage for which compensation may be granted and ensure that more victims will be entitled to compensation than ever before. Half of the signatories to the 2004 Protocol to amend the Paris Convention and a majority of the signatories to the 2004 Protocol to amend the Brussels Supplementary Convention are now ready to deposit their instruments of ratification of these protocols.

In addition, several member countries which are not signatories to the above-mentioned conventions continue to modernise their third party liability regimes. Increasing the liability amounts of nuclear operators is a significant step in this process. Japan, for example, has adopted new legislation, to enter into force on 1 January 2010, under which its operators will be liable for a considerably higher amount than was previously the case, with the increase having been largely inspired by the revised international nuclear liability conventions. Canada is on its way to substantially revising its 1985 Nuclear Liability and Compensation Act, including increasing its operators' liability amount to a level that is reflective of that called for under the revised conventions. Furthermore, Poland plans to ratify shortly the 1997 Protocol to amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage.

On a regional level, a legal study was published on the impact of the different nuclear liability regimes in Europe in an effort to determine whether a uniform European Union liability and compensation regime is both feasible and desirable, and whether the European Atomic Energy Community should accede to the Paris Convention.

Efforts to establish a global regime for nuclear liability and compensation are also continuing. The 1988 Joint Protocol, which establishes a link between the Paris and Vienna Conventions, now counts 26 contracting parties following the accession of Uruguay in 2009. The 1997 Convention on Supplementary Compensation for Nuclear Damage has now been ratified by four countries (the United States, Argentina, Morocco and Romania). It will enter into force 90 days after the date on which at least five states with a minimum of 400 000 "units" of installed nuclear capacity (or roughly 400 000 MWth of installed capacity as defined in the convention) have done the same.

For the first time since the inception of the European Community in 1957 and after two unsuccessful attempts, the Council of the European Union adopted EU-wide binding requirements in respect of nuclear safety. The goal of the "Council Directive establishing a Community framework for the nuclear safety of nuclear installations" is to maintain and to promote the continuous improvement of nuclear safety and to ensure that a high level of nuclear safety is provided by EU member states to protect workers and the general public against the dangers arising from ionising radiation.

Many countries are considering relaunching their nuclear power programmes, and to that end have started preparing new or revised legal and regulatory frameworks; Sweden and the United Kingdom are two such examples. Also of note is Italy's adoption of a new legislative and regulatory framework more than 20 years after a government decision to suspend nuclear power generation in that country. An important feature of this framework will be the establishment of a new nuclear regulatory body, the *Agenzia per la sicurezza nucleare*.