Nuclear Power in 2008

Nuclear energy development

At the end of 2008, a total of 345 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 2008, no new reactors were connected to OECD country grids, one was shut down (the Bohunice-2 reactor in the Slovak Republic was closed on 31 December 2008 as a condition to the country's accession to the European Union) and the first concrete was poured for two reactors under construction in the Republic of Korea.

Nuclear energy policies vary widely in OECD countries, and range from official moratoria or phase-out policies (e.g. Austria, Belgium, Germany and Spain) to clear commitments to maintain nuclear power as a significant component of the energy mix (e.g. France, Japan and the Republic of Korea). Nuclear power's ability to enhance security of energy supply and to provide competitively priced, base-load electricity that is essentially free of greenhouse gas emissions led, in 2008, to several developments to either replace soon-to-be-retired capacity or to increase nuclear generating capacity in several OECD countries:

- In Canada, the Government of Ontario launched a competitive procurement process to select a preferred supplier of two new reactors. Bruce Power launched an environmental assessment (EA) of a plan to build two reactors at the Nanticoke site in Ontario, and work on the company's EA of a proposal to add four reactors to the existing Bruce site continued. Hydro-Quebec announced that it would refurbish the province's sole reactor (Gentilly-2) to extend the reactor's operating life to near 2040. A feasibility study in Saskatchewan concluded that 1 000 MWe of nuclear generating capacity could contribute to the province's energy mix by 2020.
- In Finland, the national government approved a new climate and energy strategy that gives priority to the construction of electricity generating capacity with low carbon emissions, but limits new nuclear capacity to that required for domestic purposes only. By November 2008, environmental impact assessment reports of plans for three new reactor construction projects had been submitted. Construction of the Olkiluoto-3 European pressurised water reactor (EPR) continues, but the completion date has been pushed back to 2012.
- In France, construction of the Flamanville-3 EPR in the Basse-Normandie region continues and the President of France announced Penly as the site for a new EPR construction project.
- In Italy, the newly elected national government announced an energy plan that includes a return to nuclear energy, and introduced legislation to overturn the existing moratorium.
- In the Republic of Korea, the national government announced a new "National Energy Basic Plan" calling for an increase in nuclear generating capacity to about 60% of the country's total electricity generation by 2030; to do so requires the commissioning of 10-12 new nuclear power plants in addition to the 8 units that are already planned or under construction.
- In the Slovak Republic, a project was launched to complete the construction of two reactors at the Mochovce power plant, halted in 1992. The Czech power company CEZ was selected to form a partnership to build an additional nuclear power source at the existing Bohunice site.
- In Switzerland, the Atel energy group submitted plans to the government to build a new nuclear power plant near the existing Goesgen station, and it was confirmed that the Axpo Group and BKW FMB Energy would be submitting applications to build two new reactors at the existing sites of Beznau and Muhleberg.
- In Turkey, the national government called for bids to build the country's first nuclear power plant (total capacity of

2008 Nuclear Data Summary (as of 31 December 2008)

	Operational reactors	Installed capacity (GWe net)	Uranium requirements (tonnes U)	Nuclear share of electricity production (%)
Belgium	7	5.8	1 030	53.8
Canada	20	12.7	1 900	14.5
Czech Republic	6	3.6	637	32.4
Finland	4	2.7	460	29.9
France	59	63.3	8 150	76.2
Germany*	17	20.4	3 400	23.2
Hungary	4	1.9	422	37.7
Japan*	55	47.5	5 792	25.6
Mexico	2	1.4	161	4.0
Netherlands	1	0.5	60	4.0 *
Republic of Korea*	20	17.0	3 200	35.2
Slovak Republic	4	1.7	380	54.9 *
Spain	8	7.5	1 513	18.3
Sweden	10	9.2	1 574	42.0
Switzerland*	5	3.2	318	39.9
United Kingdom	19	11.0	951	13.2
United States	104	100.6	16 424	19.7
Total (OECD)	**345**	**310.0**	**46 372**	**21.6 ***

* 2007 data. Operational = connected to grid.

about 4 000 MWe) and is evaluating the sole bid received from Atomstroyexport of the Russian Federation.

- ➢ In the United Kingdom, the national government continued to express support for the construction of new reactors by private industry. Électricité de France made a (successful as of 9 January 2009) bid to acquire British Energy, committing to build four new nuclear reactors in the United Kingdom.
- ➢ In the United States, the Department of Energy announced that it had received loan guarantee applications from 17 utilities, reflecting intentions to build a total of 21 new nuclear reactors at 17 different facilities. The Nuclear Regulatory Commission (NRC) received 17 Combined Construction and Operating License (COL) applications for a total of up to 26 potential new reactors, and approved 10 power uprates amounting to an addition of 726 MWe of capacity to the US fleet.

As governments continue to develop these and other nuclear energy initiatives, the ongoing global financial crisis threatens to at least delay some of them due to credit shortages and concern about potential financial risks.

In non-OECD countries, no new units were commissioned in 2008, but the construction of eight reactors (six in China and two in the Russian Federation) was initiated in support of plans for a robust expansion of nuclear electricity generating capacity in these two countries. India and South Africa have also expressed similar ambitions. The completion of a nuclear safeguards agreement with the International Atomic Energy Agency and a decision by the Nuclear Suppliers Group to approve nuclear trade with India brought the country closer to realising these plans. In contrast, South Africa postponed the selection of a successful bidder in its tender to build new nuclear generating capacity, citing concerns about the magnitude of the investment. Elsewhere, Bulgaria and Romania formed joint venture partnerships to increase nuclear generating capacity in their countries, and consideration to either increase existing capacity or introduce nuclear energy continues in a number of other non-OECD countries, including Argentina, Brazil, Indonesia, Jordan, Kazakhstan, Lithuania, some Persian Gulf States and Vietnam.

Uranium production, conversion and enrichment

Preliminary data indicate that in 2008 uranium was produced in seven OECD countries, three of which (France, Germany and Hungary) contributed only small amounts as part of mine remediation activities. Australia (19%), Canada (20%) and the United States (3%) together accounted for a significant share of world production. Production in OECD countries amounted to approximately 19 350 tonnes of uranium (tU) in 2008 (a decrease of almost 4% from 2007) accounting for roughly 40% of uranium requirements in the OECD area. Remaining requirements were met by imports and secondary sources (material derived from dismantling warheads, excess commercial inventories and reprocessed uranium).

Beginning in 2001, the spot price of uranium began to rise from historic lows of about USD 18/kgU to levels not seen since the 1980s, reaching a peak of USD 354/kgU in June 2007. By early 2008, the spot price had declined to USD 235/kgU and continued a general decline throughout the year, retreating to about USD 138/kgU in December 2008. The price decline in the latter half of 2008 is thought to be at least in part the result of the global financial crisis as some investors were forced to sell uranium holdings in order to raise capital. However, despite the recent decline, uranium spot prices remain several times higher than prices in the 1990s owing to increased demand combined with reduced inventories. In response to higher prices, uranium exploration and mine development activity has increased substantially. However, the unfolding global financial crisis has already caused some uranium mine development projects to be delayed.

During 2008, uranium conversion facilities continued to operate in Canada, France, the United Kingdom and the United States, while construction of additional capacity continued in France. Cameco and Kazatomprom announced the creation of a joint venture partnership and the initiation of the first stage of a feasibility study to assess plans to build a 12 000 tonnes/year conversion facility in Kazakhstan. In late 2008, Cameco announced that it had suspended production at its plant in Canada until mid-2009 owing to a contract dispute with its sole supplier of hydrofluoric acid.

In terms of uranium enrichment, construction moved ahead on schedule at two new centrifuge plants using URENCO technology: AREVA's Georges Besse II facility in France, where development was accelerated in 2008, and Louisiana Energy Services' National Enrichment Facility (NEF) in the United States, where a second phase of development is due to double capacity by 2015. Elsewhere in the United States, the US Enrichment Corporation continued development of its new plant using the American centrifuge design; AREVA filed an application with the NRC to build and operate a centrifuge facility in Idaho using URENCO technology; and GE-Hitachi Global Laser Enrichment development continued as an NRC licence for the construction of a test loop facility was obtained and Cameco purchased a 24% stake in the company. In 2008, China signed an agreement with the Russian Federation to increase capacity of its domestic centrifuge enrichment facilities.

Nuclear safety and regulation

In 2008, 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 their initial design life is increasing and licence renewal continues to be an approach adopted by many OECD countries. The NEA continues to support regulatory authorities in their review of the adequacy of plant ageing management methods.

At the same time, several countries are licensing new reactors and OECD 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.

Overall, the general consensus remains 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.

Radioactive waste management

With the US Department of Energy's application for a construction licence, the world's most substantial geological repository project for high-level, heat-generating radioactive waste and spent nuclear fuel at Yucca Mountain, Nevada, entered a decisive new phase. The licensing authority, the NRC, has a three-year period, starting in September 2008 and with a possible one-year extension set by the US Congress, to decide whether to grant a construction authorisation for the repository. It is expected that multiple hearings regarding the Yucca Mountain application will be organised by the NRC's Atomic Safety and Licensing Board as part of the licensing procedure. The start of the review was marked by the release of a new radiation standard for Yucca Mountain by the Environmental Protection Agency (EPA) that also established a dose limit for the time period beyond 10 000 and up to 1 million years to be consistent with recommendations of the National Academy of Sciences (NAS).

In spite of this very positive development, the planned schedule for a construction licence for the repository still faces some uncertainties due to possible funding problems and legal challenges for the licensing review. In addition, policy decisions on the future development of nuclear energy in the United States and the required repository capacity may lead to project delays.

The procedures and decisions to identify appropriate sites for radioactive waste disposal continue to be high priorities for national programmes. At a procedural level, the waste agencies in Canada and in the United Kingdom launched public consultation processes. The Canadian effort aims to design a process for identifying and selecting an informed and willing community to host a deep geological repository. The UK consultation will establish a framework for public and stakeholder engagement in geological disposal. The UK Government also issued a white paper inviting local communities to express interest in discussions on hosting a geological repository.

Several other programmes took important steps towards siting disposal facilities. The Swiss national waste agency Nagra announced three geographical areas in which further investigation into geological disposal of high-level waste will be focused, and three additional areas which may be suitable to host geological repositories for low- and intermediate-level waste. The selection of these areas was based so far solely on scientific-technical criteria; a final site decision is expected in about ten years and will involve the local population, municipalities and cantons in a transparent procedure.

In France, the French national radioactive waste agency Andra issued a call in June for volunteer communities to identify suitable candidate sites for the implementation of a disposal facility for graphite and radium-bearing waste stemming from graphite-moderated, gas-cooled reactors and from the rehabilitation of industrial sites contaminated with radium. Andra will select a short list of two or three sites for further studies. The final objective is to select a suitable site by the end of 2010, with a view to submitting the application for the implementation licence of the disposal facility by the end of 2013 and to commissioning the actual facility in 2019.

Radiological protection

With the approval of the new International Commission on Radiological Protection (ICRP) general recommendations (ICRP publication 103), the radiological protection community is now turning towards its implementation. It should be noted that recommendations on public and worker dose limits have not changed, and that the three fundamental ICRP principles (justification of exposure-causing activities and of protective actions; optimisation of protection; and limitation of exposures) also remain. The key change in the new recommendations is, however, its emphasis on the optimisation of protection in all exposure situations, be they planned, emergency or existing situations. This new focus stresses the importance of the prevailing circumstances of the exposure situation, and of the process followed in order to identify and to implement the protective actions. It also stresses the judgemental nature of radiological protection decision making, and the need for transparency in optimisation and decision processes. In general, this new approach reflects an extension of the successful use of ALARA (as low as reasonably achievable) in reducing exposures from planned situations to the public and workers, to also address exposures caused by nuclear or radiological emergencies (such as at a nuclear power plant or industrial facility) and in existing situations (for example exposure from radon in dwellings or from post-accident, long-term residual contamination).

The new approach promotes flexibility in designing and implementing radiological protection, but at the same time somewhat complicates decisions in that numerical standards, either national or international, may be taken more as a starting point for discussions rather than as predetermined end points. Implementation of a "modern" approach to radiological protection is now being developed in the form of new international Basic Safety Standards (BSS) to replace the 1996 version issued by the International Atomic Energy Agency (IAEA) and co-sponsored by the OECD Nuclear Energy Agency (NEA), the International Labour Organisation (ILO), the World Health Organisation (WHO), the Pan-American Health Organisation (PAHO) and the Food and Agriculture Organisation (FAO). The new version seeks to expand the standards, and hopes to include the European Commission (EC) and the UN Environment Programme (UNEP) as co-sponsors. Significant progress was made on the draft text for the new BSS during 2008, moving towards incorporating the new philosophy of the ICRP, experience from the implementation of the 1996 BSS, and bringing the document more in line with the current IAEA Safety Series documents and structure. However, several key issues remain to be resolved before the new BSS can be approved by IAEA member states, and subsequently by the constituencies of the other co-sponsoring organisations. First, the identification of what are truly the "basic" requirements is under way, as is the discussion of how detailed the expression of necessary requirements should be. The detail with which the new

BSS follows the new ICRP recommendations is also under discussion. These issues reflect the complexity posed by the previously mentioned trend of flexibility that comes with the new focus on judgemental optimisation of protection.

Another trend that emerged strongly in 2008 was renewed regulatory focus on radiological protection in the areas of medical exposures and domestic exposure to radon. Average annual medical exposure has, for the first time in several countries, exceeded average annual exposure to natural radiation. This trend, broadly resulting from significant increases in the use of CT scans and other radiological imaging techniques, has been accompanied by discoveries of medical over-exposure cases in some countries that suggest a need to improve the optimisation of radiological protection. However, while the radiological protection community tends to view these increases with some concern, the medical community tends to consider them as generally beneficial in terms of the medically valuable information provided by the images obtained. As such, the regulatory challenge is to define, with both the medical and radiological protection communities, a path forward to ensure public protection. As regards domestic radon, the renewed focus is not due to increases in exposures, but rather due to new epidemiological studies that suggest a statistically significant incidence of lung cancers at radon concentrations that are lower than most international, and some national, recommended action levels. While the risk of radon-induced lung cancer estimated in these studies is consistent with previous understanding, the level at which statistically significant effects are being noted, in smokers and non-smokers, has pushed the regulatory community to reconsider its approach to protection.

Nuclear science

The trends observed in recent years in the area of nuclear science continue to prevail. For example, the development of advanced nuclear fission reactors depends to a large extent on the availability of advanced structural materials, as well as suitable nuclear fuel, which have to withstand severe conditions, such as high temperatures, intense neutron irradiation and, in some cases, strongly corrosive environments. Since experimental studies of irradiation effects in materials are very expensive, requiring dedicated, long-term experiments in research reactors, it is important to develop a sound theoretical approach to help understand material behaviour on a long-term basis. Important efforts are therefore being pursued to develop numerical tools to model, for example, irradiation effects in structural materials and fuels.

Another important issue in the development of advanced reactor systems is the availability of well-documented experimental information to help assess new concepts. To this end, a number of efforts to preserve information from previously performed experiments in a suitable and easily accessible form have been undertaken, covering many different subject areas, such as reactor physics, nuclear criticality, fuel behaviour and radiation shielding.

Methodologies have been established and/or are being developed in many countries to quantify computational biases and their associated uncertainties when performing benchmark exercises to validate different reactor parameters. To assist this process, nuclear data library producers are making efforts to include uncertainty information in their data libraries, especially for the minor actinides, which are less well known and of importance when considering transmuting these elements in fast reactors or accelerator-driven systems (ADS). These efforts to propagate uncertainty information throughout the calculations are driven by a need to obtain a better estimation of safety margins, for example, as a better understanding of and confidence in these margins could have a significant economic impact.

Nuclear law

Harmonising legislation governing the peaceful uses of nuclear energy and minimising legal impediments to the safe use of nuclear energy will lead to better understanding, appreciation and confidence among countries in the use of this technology. One of the primary aims of the legal community in this regard is to ensure 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 continue working to implement the provisions of these protocols in their national legislation. Several of these countries are searching for solutions to overcome nuclear operators' inability to obtain private insurance coverage for certain third party liability risks that they are legally obliged to assume under these conventions. By ratifying the 1997 Convention on Supplementary Compensation for Nuclear Damage (CSC), the United States became a contracting party to one of the international nuclear liability conventions. Several other countries that have not yet joined the international nuclear liability regime prepared new national legislation that is based on its principles, such as Canada and Japan. The European Commission assessed the impact of different nuclear liability regimes in Europe to determine whether a uniform EU regime on nuclear third party liability is both feasible and desirable. Currently 13 EU member countries (Belgium, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Portugal, Slovenia, Spain, Sweden and the United Kingdom) are party to the 1960 Paris Convention, 9 EU member countries (Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and the Slovak Republic) are party to the 1963 Vienna Convention, with one of them (Latvia) also being party to the 1997 Vienna Convention, whereas 5 EU member countries (Austria, Cyprus, Ireland, Luxembourg and Malta) as well as the European Community itself do not belong to any convention.

Many countries that are considering launching a nuclear power programme have begun preparing a legal and regulatory framework. In this regard, Turkey has adopted key legislation on the construction and operation of nuclear power plants and updated the existing set of national nuclear safety regulations.

Other key issues in the development of nuclear law concern the impact of international conventions outside the nuclear field on nuclear activities; ensuring that small training and research reactors as well as nuclear installations that are being decommissioned are not subject to an overly burdensome liability and compensation regime; identifying legal and economic factors that may impact nuclear emergency decision making; and assisting selected countries in adopting domestic nuclear legislation based upon internationally accepted principles.