2011 NEA Annual Report

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NUCLEAR ENERGY AGENCY

2011 NEA Annual Report

NUCLEAR ENERGY AGENCY
Organisation for Economic Co-operation and Development

The NEA in Brief

Governing body: the Steering Committee for Nuclear Energy

30	member countries (23 in the Data Bank)
53	years of international service
7	standing technical committees
21	international joint projects funded by participants
69	professional and support staff (NEA and the Data Bank combined)
560	national experts participating in NEA committees and expert groups
4 500	experts participating annually, on average, in policy and technical meetings organised at OECD headquarters
€ 10.4	million budget for the NEA in 2011, supplemented by voluntary contributions
€ 3.0	million budget for the Data Bank in 2011, supplemented by voluntary contributions
30	publications produced in 2011

The NEA and its mission

The Nuclear Energy Agency (NEA) is a semi-autonomous body within the Organisation for Economic Co-operation and Development (OECD), located in the Paris area in France. The objective of the Agency is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes.

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The European Commission (EC) takes part in the work of the NEA. A co-operation agreement is in force with the International Atomic Energy Agency (IAEA). The NEA also maintains contacts with several non-member countries as well as the nuclear industry and a number of civil society organisations.

Message from the Director-General

2011 was a pivotal year for the NEA and its member countries. First of all, our condolences go to all those who suffered from the 11 March Tohoku earthquake and tsunami which led to widespread damage in north-eastern Japan and to the loss of approximately 19 000 lives. It is clear that these combined natural disasters were also at the origin of the Fukushima Daiichi nuclear power plant accident, with the earthquake having resulted in the loss of offsite power and the tsunami in the loss of onsite emergency power necessary to keep the cooling systems functioning. While the accident itself was not responsible for any casualties, it has affected the lives of thousands of displaced Japanese citizens and caused considerable environmental damage in the surrounding area.

Following the accident, a number of initiatives were undertaken internationally to learn from it, to share approaches on key follow-up actions and to implement lessons learnt to improve nuclear safety so as to better protect the public and the environment. At the NEA, monitoring of the accident began immediately as well as working with all members to fully ascertain the technical and regulatory lessons that could be learnt.

In that context, on 7-8 June 2011, the NEA hosted in co-operation with the French Presidency of the G8, a ministerial seminar on nuclear safety and a regulatory forum to discuss insights and approaches. The insights gained during the forum have strongly influenced the work of the NEA and also provided valuable input to the IAEA ministerial conference and subsequent action plan.

At present, the three NEA standing technical committees most involved in Fukushima follow-up work are the Committee on Nuclear Regulatory Activities, the Committee on Radiation Protection and Public Health, and the Committee on the Safety of Nuclear Installations. A number of activities are underway in the areas of nuclear regulation, nuclear safety and research, crisis communication, radiological protection, decontamination and recovery. Furthermore, third party liability aspects of the accident are being examined by the Nuclear Law Committee, and the accident's impact on the future of nuclear power is being investigated by the Nuclear Development Committee.

In parallel, the NEA has devoted significant efforts to directly support the technical needs of the Japanese government, with this assistance primarily focusing on 1) the recovery of land and decontamination, 2) the development and implementation of national reviews and stress tests, and 3) enhancements to the regulatory infrastructure. Several NEA missions of experts from member countries have already been sent to Japan, and the Agency has actively participated in the organisation of, and discussions which took place at, various meetings and symposia.

While many countries have begun to resume their nuclear power development programmes, the importance of the Fukushima Daiichi nuclear accident should not be underestimated. It clearly marks a turning point in terms of reviewing how nuclear safety is evaluated and ensured, and in particular examining specific site locations and designs associated with those sites. I therefore believe that it is the role of international organisations like the NEA to help member countries in carrying out in-depth analyses of the lessons learnt, and in applying those lessons to all reactors in operation as well as to new designs. The future of nuclear power is going to depend on this, and I can confirm that the NEA is making corresponding efforts and activities its top priorities in the near term.

Luis E. Echávarri
NEA Director-General

The Fukushima Daiichi Accident and NEA Follow-up

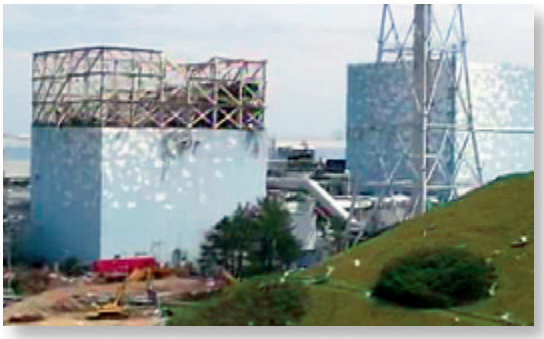
On 11 March 2011, Japan endured one of the worst natural disasters in its history when a massive earthquake of magnitude 9.0 on the Richter scale jolted its eastern coast. The earthquake's epicentre was situated 150 km north-east of the two Fukushima nuclear power plants (Daiichi and Daiini) operated by the Tokyo Electric Power Company (TEPCO). The Onagawa nuclear power plant, operated by the Tohoku Electric Power Company, was the closest at approximately 80 km. Eleven operating reactors affected by the earthquake shut down immediately, including the three operating reactors at the Fukushima Daiichi site. The other three Fukushima Daiichi units were not operating when the earthquake struck. The earthquake damaged the electrical grid that provides offsite power to nuclear power plants when shut down. An hour after the earthquake, a 14-15 m tsunami, as estimated at the Fukushima Daiichi site, hit the Pacific coastline and led to a terrible loss of lives (approximately 19 000 people died or remain unaccounted for). It also led to the loss of all onsite power sources resulting in serious accidents at the three operating Fukushima Daiichi units, which were classified by the Japanese authorities as level 7 on the International Nuclear and Radiological Event Scale (INES).

The accidents at Fukushima Daiichi Units 1, 2 and 3 were the result of the loss of offsite power caused by the earthquake, coupled with the loss of onsite power and the ultimate heat sink caused by the tsunami. Without a source of electrical power, the systems and components used to keep the fuel in the reactors cooled were not able to function. Although the operator attempted to implement alternative measures to cool the fuel, ultimately they were unsuccessful in preventing the fuel from overheating and melting. The molten fuel relocated to the bottom of the reactor vessels, melted through the latter and dropped into the lower portion of the primary containments. Based on preliminary analyses, it appears that most of the fuel in Unit 1 relocated to the primary containment. While there appears to have been breaches in the Unit 2 and 3 reactor vessels, the amount of fuel relocated to their primary containments does not appear to be as large as at Unit 1. In addition, hydrogen generated during the accidents collected within the reactor buildings and caused explosions in the upper portions of the Unit 1, 3 and 4 reactor buildings, with significant damage to the top floors and exposure of the spent fuel pools to the environment.

Following the accident, there were several reviews of nuclear power programmes as part of countries' existing energy supply and of programmes to build new capacity. As a result, one European country announced an accelerated phase-out of nuclear energy, another announced a phase-out but without defined timelines to date and a third voted in a referendum not to reintroduce nuclear power (see page 10). In the majority of countries, there was a reconfirmation of stated intentions to introduce new nuclear plants or a restatement of the value of nuclear energy as part of a diverse energy mix. Overall, however, it is clear that there will be a slowdown in nuclear reactor construction rates and that previous high growth targets will not be achieved.

CRIEPI, Nuclear Information Center

Fukushima Daiichi NPP before the accident.



TEPCO, Japan

Fukushima Daiichi NPP after the accident.

TEPCO, Japan

Installation of panels to cover the damaged reactor building.

Public confidence has been significantly affected and re-establishing trust will be a long and challenging task. It is not straightforward though how extensive this period of reconsideration will be given that major growth is expected in countries where low-carbon alternatives are not available on a sufficient scale.

The accident has led the NEA's standing technical committees to alter their work priorities to assess the accident and to identify safety lessons. In addition, the NEA has devoted significant efforts to directly supporting the technical needs of the Japanese government, with this assistance primarily focusing on 1) the recovery of land and decontamination, 2) the development and implementation of national reviews and stress tests, and 3) enhancements to the regulatory infrastructure. Specific follow-up activities are described below as well as on the NEA Fukushima information exchange web page (www.oecd-nea.org/nsd/fukushima/).

Nuclear regulation

Immediately following the accident, the NEA began collecting information and sharing it among member countries. A web page was also established to consolidate member countries' national follow-up activities. The NEA response to the Fukushima accident is being co-ordinated among the three NEA standing technical committees – the Committee on Nuclear Regulatory Activities (CNRA), the Committee on Radiation Protection and Public Health (CRPPH) and the Committee on the Safety of Nuclear Installations (CSNI) – that address regulation and safety. After the initial development of area-specific responses, a joint meeting of the three committees' bureaus was held to establish a shared way forward. The CNRA is leading the integrated post-Fukushima co-ordination of NEA nuclear safety activities. Each committee will determine the specific direction of its work while building upon the shared mandate of protecting public health and safety, and the environment.

The CNRA established a Senior-level Task Group on Impacts of the Fukushima Accident (STG-FUKU) on 23 March 2011 to identify regulatory and safety concerns as well as activities that would benefit from international collaboration; to carry out timely exchanges of information; and to maintain awareness and co-ordination of activities in other organisations. The CSNI and the CRPPH are represented on the STG-FUKU.

The STG-FUKU has been tasked with co-ordinating and monitoring the NEA's safety-related activities in response to the accident where an issue may be within the mandate of more than one of the affected standing technical committees. This includes CSNI activities related to a reassessment of the defence-in-depth philosophy; a reassessment of accident management issues; the development of a thorough understanding of the accident progression; and a review of precursor events to identify other areas that could have a similar impact on safety as the Fukushima Daiichi accident. In addition, the CSNI will begin activities to review approaches to considering internal and external hazards; to assess plant robustness and defence-in-depth considerations; to assess safety management in view of human and organisational issues; to study the implications of severe environmental conditions on human performance during emergency response; and to conduct research on severe accident progression and management. Activities within the scope of the CRPPH include evaluating offsite emergency preparedness issues, in particular: licensee, government and regulatory body command and control linkages during emergency response; the availability of onsite or offsite equipment and measurement capabilities; the co-ordination of recommendations among countries for the protection of their citizens; the comparison of release and dose calculations; and the roles and authorities of different organisations associated with emergency preparedness activities in different countries.

On 7-8 June 2011, the NEA co-organised two days of high-level meetings on international nuclear safety in light of the Fukushima Daiichi nuclear accident. The first event, on 7 June, was an international ministerial meeting co-organised by the French Presidency of the G8 and the NEA, with 37 countries in attendance. It enabled important discussions on how to reinforce international co-operation and international legal frameworks on nuclear safety. On 8 June, the nuclear regulatory authorities of the G8, NEA member countries and other associated countries (Brazil, Bulgaria, India, Romania, South Africa and Ukraine) participated in the Forum on the Fukushima Accident: Insights and Approaches. Participants discussed initial insights gained in relation to the accident and decided on appropriate follow-up actions at the international level.

N. Kosciusko-Morizet and L. Echávarri at the 7 June 2011 ministerial seminar.

OECD/NEA, F. Vuillaume

The 8 June 2011 Forum on the Fukushima Accident.

Nuclear safety and stress tests

Following the accident, every country with operating nuclear power plants conducted initial assessments of the continued safe operation of its plants. The reviews found that short-term actions taken by licensees provided assurance of the continued safe operation while more thorough evaluations of the accident and the impact on safety were implemented. In many countries, the longer-term, more thorough evaluations have been called "stress tests".

Stress tests in the European Union (EU) were performed according to the specifications elaborated by the Western European Nuclear Regulators' Association (WENRA) and adopted by the European Nuclear Safety Regulators' Group (ENSREG). In addition to EU members, Switzerland and Ukraine have participated fully in the EU stress-test process. Croatia has participated as an observer and has a special status in relation to the nuclear power plant in Slovenia, which it co-owns. Armenia and the Russian Federation agreed to carry out stress tests as well. Belarus and Turkey, which have plans to develop nuclear power, are following the process and have participated in co-ordination meetings between the European Commission and neighbouring countries. While other countries have

not directly adopted the EU stress test methodology, their national assessments use similar assumptions, for example those that have been or are being carried out in Canada, Japan, Mexico, the Republic of Korea and the United States. In the case of Japan, the stress tests are also being used as a condition to restart the reactors that have been shut down since the accident.

These efforts are a targeted reassessment of the safety margins of nuclear power plants in light of the severe external events that occurred at Fukushima Daiichi. They consist of evaluations of the responses of a nuclear power plant to severe external events (single and multiple), and a verification of the measures chosen to prevent or mitigate an accident using a defence-in-depth logic that considers the initiating events, the consequential loss of safety functions and severe accident management. It is assumed that there is a sequential loss of the lines of defence following a deterministic methodology regardless of the probability of this loss. The reassessment examines the response of the plant, the effectiveness of preventive measures, the identification of weak points and cliff-edge effects. It also includes an evaluation of the robustness of the current defence-in-depth approach by looking at the adequacy of current accident management measures and then identifying the potential safety improvements, both technical and organisational, that should be considered to improve the capability of the plants to withstand accidents that may be caused by severe external hazards.

The EU stress tests started on 1 June 2011. Licensees submitted final reports to the regulators by 31 October 2011. The latter reviewed the licensees' reports and provided final national reports to the European Commission (EC) by 31 December 2011. In the first quarter of 2012, these reports will be subject to external peer reviews. A report consolidating all EU member national reports will be prepared by the EC and presented to the EU Council during its June 2012 meeting.

In terms of NEA support to the Japanese authorities on nuclear safety issues, in November 2011 an NEA team of international experts met in Tokyo with the Japanese Nuclear and Industrial Safety Agency (NISA) and the Japan Nuclear Energy Safety Organisation (JNES) to foster a better understanding by NISA and JNES of other NEA member countries' post-Fukushima national stress tests, international guidance and review methodologies. The mission included a technical experts' meeting for sharing information on national reviews, an international seminar on stress tests with the Japanese nuclear industry and public, and a meeting with an advisory committee supporting the regulatory reviews of licensee analyses as part of the Japanese stress tests. The NEA team included experts from Japan, Finland, France, the Republic of Korea, the United Kingdom and the United States. The International Atomic Energy Agency (IAEA) also participated in the meetings.

Crisis communication

A significant challenge encountered by both the Japanese authorities and the broader international community was effective communication during the accident, including with the public. For regulators, the NEA has a Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC). The WGPC held a special meeting in September 2011 to follow up on lessons learnt from the Fukushima Daiichi accident and to prepare for a Crisis Communication Workshop to be held in Madrid on 9-10 May 2012. The focus of the WGPC workshop is to bring together senior-level regulators and other stakeholders to identify efficient approaches and practices to improve crisis communications, to take into account the lessons learnt from the accident, and to collect insights for future guidance on international aspects of regulators' crisis communication programmes. The results from this workshop will be used to strengthen the international dimension of the WGPC's Roadmap for Crisis Communication.

TEPCO, Japan

Emergency Response Headquarters for the Fukushima Accident on 15 April 2011.

International intergovernmental communications are an essential part of developing appropriate national responses to almost any nuclear or radiological emergency situation, and these communications certainly played a key role in responding to the Fukushima accident. To assist governments in communicating more effectively, the NEA, through the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE), collected government decisions (e.g. recommendations for foreign nationals in Japan and recommendations concerning airlines flying to or from Japan) for posting on the IAEA's Incident and Emergency Centre (USIE) website. To maximise learning from this event, the NEA will perform an analysis of these decisions, not with respect to the national decisions taken but rather to the types of decisions taken, in order to better understand the quality of information that is needed by governments, and when.

Radiological protection

As of the end of 2011, Japanese authorities estimated that the Fukushima Daiichi accident released approximately 20 PBq of caesium-137 and 200 PBq of iodine-131 (the two most radiologically significant isotopes) into the environment. The majority of radioactive releases from the plant are estimated to have taken place before 19 April 2011. This represents 12% of the activity released by the Chernobyl accident. Because the Japanese government quickly recommended the evacuation of the 78 000 people living within 20 km of the plant, the sheltering of those living between 20 and 30 km from the plant, and the evacuation of a further 10 000 people living

to the north-east of the plant in what was determined to be the most contaminated area, health-significant population exposures were avoided.

© AFP Photo / Jiji Press

Residents of Kawauchi village, located in the 20-km evacuation zone, were allowed to return to their homes briefly to pick up their personal belongings on 10 May 2011.

A health survey among 1 500 residents of three towns near the Fukushima Daiichi nuclear power plant carried out by Fukushima prefecture estimated external exposures received between 11 March and 11 July 2011. This survey showed that most residents received less than 10 mSv of exposure, with the highest values, for only a few individuals, being on the order of 14 mSv. Somewhat higher doses were received by individuals performing recovery work in these towns during this time period, with the highest doses reaching 37 mSv for nine workers. In addition to this estimate of public doses, so far there have been approximately 19 000 workers participating in response activities at the Fukushima Daiichi nuclear power plant, with those who were there in March and April receiving the highest exposures. To date, 171 workers have received over 100 mSv; the highest doses received were by two workers with approximately 650 mSv each.

The final exposures to the public will be determined as time passes, and the Japanese government has initiated a long-term health programme to provide regular surveillance of those exposed. The NEA will provide the experience of its other member governments to assist the Japanese authorities with this health surveillance programme. It has established an Expert Group on Radiological Aspects of the Fukushima Accident (EGRPF) to manage the Agency's work in this area and to co-ordinate with other international organisations to ensure compatible and non-redundant efforts. It began providing its members' experience through the support of and participation in conferences and workshops held in the affected areas in Japan aiming to explore approaches to stakeholder involvement. Two such conferences took place with NEA support in 2011 (in September and November), and two more are planned in early 2012.

There have been no cases of immediate radiation sickness in workers. This is as expected based on current scientific understanding, as such effects appear only after exposures of greater than 1 000 or 2 000 mSv. Through its Information System on Occupational Exposure (ISOE), the NEA is collecting operating utility experience with working in high-radiation areas. This information will be provided to TEPCO and the Japanese government to help best protect the workers who will continue to undertake investigations of the damaged reactors with a view to removing all damaged fuel.

Decontamination and recovery

The most significantly contaminated areas are mostly in Fukushima prefecture, although contamination can be measured in many areas of Japan. The Japanese government has initiated a vast programme of decontamination and recovery, focusing on those areas where estimated doses to people living there would exceed 1 mSv in a year. The Japanese central government itself is taking charge of areas where people have been evacuated (where estimated annual doses would be greater than 20 mSv). Municipalities, with support from the Japanese government, will develop and implement decontamination programmes where the populations still living in the areas are estimated to be exposed at a rate of between 1 and 20 mSv per year. Although technically challenging, the rehabilitation of living conditions in these affected areas is achievable, but only through extensive involvement of the exposed populations themselves in identifying local priorities, customs and needs.

Ministry of the Environment, Japan

Environmental remediation activities in Japan.

The NEA has been supporting Japanese recovery efforts through a series of workshops and seminars intended to provide examples of extensive experience in stakeholder involvement to the Japanese government from other NEA member country governments, in particular those which have been addressing the consequences of the Chernobyl accident for the past 25 years. In October 2011, the government of Japan, in co-operation with the NEA, the IAEA, the Japan Atomic Energy Agency (JAEA) and the Japan Nuclear Energy Safety Organisation (JNES), held an International Symposium on Decontamination – Towards the Recovery of the Environment, in Fukushima, Japan. The objective of the symposium was to share experience and best practices in the remediation of land contaminated with radioactive materials, and to contribute to the planning and effective management of decontamination activities in Japan.

Nuclear Power in 2011

Nuclear energy development

The 11 March 2011 accident at the Fukushima Daiichi nuclear power plant in Japan was without doubt the most significant event of the year. Although there were no casualties directly caused by the nuclear accident and the accident itself resulted from an extraordinary earthquake and tsunami, it has had strong impacts both locally and internationally. In addition, while subsequent safety checks undertaken for all operating plants outside of Japan have revealed no serious issues, regulatory and policy responses have led to several reviews of nuclear power programmes and delays in nuclear reactor construction.

At the end of 2011, a total of 329 reactors were connected to the grid in NEA countries (not including three reactors under refurbishment in Canada), a sharp reduction from the 342 in 2010 as four reactors were rendered inoperable at Fukushima Daiichi and shut down, and eight reactors were shut down in Germany in response to the accident. One unit in the United Kingdom was also closed in 2011 as it had reached the end of its operational life. No new plants were connected to the grid and no new construction was initiated. Nonetheless, nuclear capacity in NEA countries constituted about four-fifths of the world's total nuclear electricity generating capacity and about one-fifth of the total electricity supply in NEA countries.

Other significant developments that occurred in NEA member countries in 2011 were as follows:

- In the Czech Republic, the state power company ČEZ forged ahead with a tender process to build two additional reactors at the Temelin site and as many as three other new reactors on other sites, with the winning bidder expected to be announced by the end of 2013.
- In Finland, the Fennovoima nuclear power consortium announced that it would build a new reactor in the northern municipality of Pyhajoki, with a supplier to be chosen in 2013 and construction expected to begin in 2015.
- In Germany, in addition to permanently shutting down eight of the country's older reactors, the government amended the Atomic Energy Act in order to close the remaining nine reactors in a stepwise fashion and to eliminate electricity production with nuclear power by 2022.
- In Italy, in a June 2011 national referendum voters overwhelmingly rejected legislation that would have allowed the construction of new nuclear reactors.
- In Japan, the Fukushima Daiichi accident prompted a reconsideration of the role of nuclear power in the country's energy mix, putting plans to build more than 20 reactors by 2030 on hold.
- In Poland, legislation was approved and site selection began for the construction of nuclear power plants, with the goal of the first unit being in operation in the 2020 time frame.

2011 nuclear data summary (as of 31 December 2011)

	Operational reactors	Installed capacity (GWe net)	Uranium requirements (tonnes U)	Nuclear share of electricity production (%)
Belgium	7	5.9	1 080	51.2*
Canada	17	12.1	1 600	15.0*
Czech Republic	6	3.7	840	33.0
Finland	4	2.7	510	31.6
France	58	63.1	8 000	77.7
Germany	9	12.1	1 700	17.6
Hungary	4	1.9	435	43.2
Japan	50	44.2	6 400	29.2*
Mexico	2	1.4	410	4.2
Netherlands	1	0.5	60	3.2*
Republic of Korea	21	18.7	4 300	32.7
Slovak Republic	4	1.8	390	52.9*
Slovenia	1	0.7	170	41.7
Spain	8	7.4	1 320	19.5
Sweden	10	9.3	1 645	38.1*
Switzerland	5	3.3	235	38.0*
United Kingdom	18	9.9	1 000	20.0
United States	104	100.7	19 995	20.3*
Total (OECD)	**329**	**299.4**	**50 090**	**21.8***

* 2010 data. Operational = connected to grid.

Shares of uranium resources and production			
	Resources (%)*	Production (%)**	Production (tU)**
Australia	31.0	11	6 135
Canada	9.0	17	9 100
United States	3.8	3	1 535
Namibia	5.3	7	4 070
Niger	5.0	7	4 000
South Africa	5.5	1	600
Kazakhstan	12.1	35	19 450
Russian Federation	8.9	6	3 400
Uzbekistan	2.1	4	2 400
Ukraine	1.9	2	875
Others	15.4	7	3 495
Total	**100.0**	**100**	**55 060**

* Identified resources recoverable at less than USD 130/kgU (2009 data). ** 2011 estimates.

- In the Republic of Korea, the government reaffirmed its commitment to increasing nuclear power generation, earmarked USD 922 million to improve safety at existing reactors and reaffirmed its goal to become a leading international supplier of reactors.
- In Switzerland, the parliament voted in favour of prohibiting the construction of new nuclear power plants, moving the country closer to a phase-out of nuclear power by 2034, the year in which the last of the currently operating units will in principle reach the end of its operational life.
- In Turkey, the Prime Minister reaffirmed plans to move ahead with the construction of nuclear power plants, beginning with the four units at the Akkuyu site on the Mediterranean coast which will be built, operated and financed by the Russian Federation.
- In the United Kingdom, National Policy Statements for Energy were ratified by parliament and EDF Energy submitted an application to the Infrastructure Planning Committee to build a two-unit 3 260 MWe nuclear power plant at Hinkley Point.
- In the United States, the Tennessee Valley Authority approved the USD 4.9 billion completion of the construction of the Bellefonte-1 nuclear reactor by 2020, and Southern Company is expected to begin construction of two new reactors at Vogtle in Georgia.

While these developments reflect the wide range of policy approaches to nuclear power in NEA member countries, the continuing economic downturn and low natural gas prices, combined with the Fukushima Daiichi nuclear accident, have delayed firm commitments for new build activities in countries with favourable policies towards nuclear power. Other contributing factors included concerns that electricity market restructuring in the United Kingdom and the loan guarantee programme in the United States may be insufficient to stimulate private investment in new nuclear power plants. In addition, regulatory responses to rigorous tests being carried out on the safety of the existing fleet of reactors are expected to increase development and operating costs.

The pace of development activities in non-NEA member countries also slowed in the wake of the Fukushima Daiichi accident, notably in China. A total of five reactors were connected to the grid (one each in China, India, Iran, Pakistan and the Russian Federation), and construction was initiated on two reactors (one each in Pakistan and India). These developments brought the total number of reactors under construction in the world to 64, of which 12 are located in NEA member countries.

Uranium production, conversion and enrichment

Preliminary, unofficial data indicate that global uranium production rose by about 4% in 2011, once again principally owing to increased output in Kazakhstan. Uranium was produced in seven NEA member countries, although France, Germany and Hungary contributed very small amounts as part of mine remediation activities. Australia (11%), Canada (17%), the Czech Republic (<1%) and the United States (3%) together accounted for a significant share of world production. NEA member countries produced approximately 17 040 tonnes of uranium (tU) in 2011 (a decrease of less than 3% from 2010), accounting for roughly 34% of their uranium requirements. Remaining requirements were met by non-NEA country production and secondary sources (material derived from dismantling warheads, excess commercial inventories and reprocessed uranium).

After peaking at USD 189/kgU (USD 73/lbU_3O_8) in early 2011, the uranium spot price started to decline, accelerating after the Fukushima Daiichi accident and then recovering slightly to about USD 136/kgU (USD 52.50/lbU_3O_8) in December 2011. Long-term price indicators declined gradually throughout the year from USD 189/kgU (USD 73/lbU_3O_8) in early 2011 to USD 164/kgU (USD 63/lbU_3O_8) in late 2011. Global uranium exploration and mine development activity continued in several countries, although deteriorating market prices and challenging financial conditions combined with technical and licensing issues, in particular in NEA member countries, slowed development.

Uranium conversion facilities continued to operate in Canada, France, the United Kingdom and the United States in 2011, and construction of additional conversion capacity continued in France, with first production scheduled in 2012. However, in September 2011 AREVA announced that it would suspend production at its conversion facilities in November and December 2011 due to reduced demand resulting from the Fukushima Daiichi accident. In parallel, Cameco announced that it had terminated negotiations with Springfields Fuels Limited to extend its ten-year toll conversion agreement beyond 2016.

Construction of two new high-efficiency uranium centrifuge enrichment plants [AREVA's Georges Besse II facility in France and Louisiana Energy Services' National Enrichment Facility (NEF) in the United States] was completed and both began commercial operations in 2011. Commissioning issues at NEF have caused some delays in bringing additional capacity on line. AREVA Enrichment Services received a construction and operation licence for its Eagle Rock Enrichment Facility, a centrifuge plant it proposes to build in the United States at Idaho Falls. Development of the US Enrichment Corporation's American Enrichment Plant slowed pending a US Department of Energy (DOE) loan guarantee decision. The GE-Hitachi Global Laser Enrichment project continued with engineering design activities ahead of a decision to proceed with the construction of a commercial production facility.

Nuclear safety and regulation

As described earlier in this report, a number of activities have been undertaken by the international community to identify and to address the lessons learnt from the Fukushima Daiichi accident. Preliminary safety assessments were promptly conducted by every regulatory authority in countries with established nuclear power programmes to evaluate the safety of their operating nuclear power plants under similar severe conditions. These preliminary safety assessments concluded that the existing nuclear power plants were safe for continued operation while longer-term programmes were implemented to assess safety enhancements to improve the protection of public health and the environment. The lessons learnt have emphasized the importance of continuing to enhance the safety of nuclear power plants by, for example, ensuring the robustness of their designs to withstand severe natural phenomena and other hazards; applying defence-in-depth approaches to ensure that mitigative strategies are in place to address the loss of electrical power and ultimate heat sink; developing and sustaining strong safety cultures in operating organisations and regulatory bodies; and understanding the importance of effective communication during a crisis. Accordingly, NEA member countries have been actively engaged in establishing programmes to assess the lessons learnt and in developing comprehensive approaches for regulatory bodies to consider as they enhance their regulatory framework in response to the Fukushima Daiichi accident.

In parallel, as the number of existing nuclear power plants that are entering or preparing for long-term operation (LTO) is increasing, regulatory authorities are reviewing the adequacy of LTO and ageing management methods. Additionally, related issues such as component obsolescence during the lifetime of a facility and the oversight of contractors and subcontractors are challenges that regulatory authorities are addressing through international efforts. As more installations move to long-term operation, it is critical to understand the safety implications of changes in plant configuration, operational modes and the maintenance of ageing components. NEA member countries believe that safety can be maintained, and even enhanced, through the use of operating experience, analysis, research and various tools such as probabilistic safety assessments (PSA) to gain insights that are not available from deterministic analyses. They also agree that advanced safety assessment methods and approaches 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.

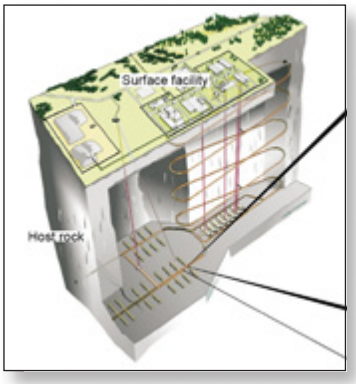
At the same time, several countries are also licensing and constructing new reactors. A number of initiatives have been undertaken to share experience related to the regulation of new reactors, including the continuing Multinational Design Evaluation Programme (MDEP), to improve the efficiency of the design review of new nuclear power plants. International collaborative efforts are yielding improvements in regulatory practices and enhanced knowledge and understanding of new technology. The initiatives are seeking to reinforce nuclear safety worldwide, by promoting convergence on safety practices and combining the expertise of participating regulatory authorities, while improving and expediting the safety review of new designs. The lessons learnt from the Fukushima Daiichi accident will also impact the design requirements of new reactors.

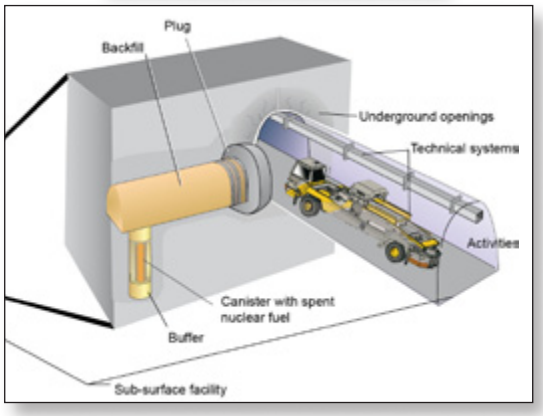
New approaches, new concepts and new technology often present new issues for safety. The development and validation of new analytical tools and research is necessary to support the identification and resolution of new or unique safety issues based on the technology of advanced designs. Regulatory and safety practices for advanced designs have the greatest potential for international harmonisation and should be pursued to the extent practical. Likewise, international collaborative projects and cost-sharing have significant potential for mutual gains.

Radioactive waste management

In addition to the Fukushima Daiichi accident drawing worldwide attention to nuclear safety issues, the question of radioactive waste management, and in particular spent nuclear fuel (SNF) and high-level waste (HLW), continues to be an important aspect of public and political confidence in the use of nuclear energy. The general consensus that geological disposal should be the endpoint for long-term management of SNF and HLW was recently confirmed by the new European Union Waste Directive as well as the first draft reports released by the US Blue Ribbon Commission on America's Nuclear Future. On the other hand, however, the current impasse in the US disposal programme as well as limited onsite storage capacities in some countries have raised international interest in intermediate storage.

In this context, the cancellation of the Yucca Mountain project and the review of US policy regarding SNF and HLW management have raised concerns among many actors in this field worldwide. Actual repercussions stemming from the delays in US disposal have nonetheless been limited at the international level. The geological disposal





SKB, Sweden

Diagram of the engineered barrier system to be used for geological disposal in Sweden.

programmes in Finland, France and Sweden, considered to be the most advanced, are moving forward according to schedule. The Swedish implementer decided to pursue a general license application for a deep geological repository at the Forsmark site in Östhammar as well as for the construction of a spent fuel encapsulation facility in Oskarshamn, a municipality that was also a candidate for the repository.

In Canada and in the United Kingdom, important milestones were reached in siting procedures. After agreeing through broad stakeholder involvement processes on general procedures for siting, both countries began a voluntary nomination process offering an open dialogue with interested communities as a first step. Such processes based on voluntarism and active application from interested municipalities are not always simple, however, and can prove to be lengthy as shown by the Japanese programme whose siting and dialogue process was reorganised and intensified after more than two years of unsuccessful calls for interest.

On the European level, new impetus is expected from the waste directive establishing a Community framework for the responsible and safe management of spent nuclear fuel and radioactive waste, which was released in July 2011 by the Council of the European Union as a legally binding text. The directive requires all 27 EU member states to present national programmes that indicate *inter alia* how they will proceed to construct and manage final repositories. Also, the principles laid down in internationally agreed safety standards released by the International Atomic Energy Agency (IAEA) will become the legal references in the European Union.

In Germany, exploratory work at the potential repository site in Gorleben was restarted, and a preliminary safety case for the site is being prepared. In parallel, high-level talks are progressing towards an agreement between the federal government and the states *(Länder)* to create a broader societal and political consensus towards implementing a high-level waste repository during this generation. The planned agreement calls for a new framework for decision-making, which includes new federal laws determining procedural aspects of decision-making, selection of siting areas and the site selection itself.

In Spain, a municipality was designated by the national government for the centralised interim storage of spent fuel. This decision is another example of inclusive decision-making in this area, which involves governmental, institutional and non-institutional stakeholders.

Radiological protection

The most significant radiological protection events of 2011 were clearly those caused by the accident at the Fukushima Daiichi nuclear power plant. An overview of the accident's consequences is provided on page 6, but their impact on the system of radiological protection is still being assessed.

The International Commission on Radiological Protection (ICRP) provides the scientific and conceptual basis for radiological protection worldwide. Its two 2009 recommendations addressing the protection of people in emergency exposure situations and during post-accident recovery (Publications 109 and 111 respectively) have been implemented in the new International Basic Safety Standards (BSS), which were approved by the IAEA in September 2011 and have been co-sponsored by the NEA and five other international organisations. Although the lessons from the Fukushima Daiichi accident had not yet been fully assessed, the consensus was that the BSS were sufficiently mature and relevant to approve, and that the international community should actively work to identify appropriate Fukushima-driven modifications for later incorporation.

One of the key new focuses of the ICRP recommendations and BSS requirements is that optimisation of protection has become a much more central concept for the identification and implementation of protective actions. While both the old and the new approaches involve the implementation of countermeasures (for example, evacuation, sheltering, use of stable iodine, etc.), the new approach more directly uses achieving the lowest reasonable individual dose as a measure of success. In this context, the necessity to involve stakeholders in radiological protection decisions is clearly important in identifying what is optimum, and the experience emerging from the Fukushima Daiichi accident strongly supports the need for such involvement. Again, specific lessons and implications are only beginning to unfold, but there is already a broad trend towards reviewing national emergency management approaches in order to assess how they involve stakeholders in planning operations, and, should an accident occur, in consequence management processes. While it will be some time before conclusions are derived from these national and international evaluations, many countries are considering, or already making modifications to improve their readiness for large-scale radiological emergency management situations.

Nuclear science

The Fukushima Daiichi accident has reinforced the importance of longstanding programmes of continuous safety enhancement at existing nuclear power plants. In this context, it is anticipated that there may be increased interest in alternative forms of fuel matrix and cladding materials with an enhanced capability to retain radioactive nuclides following extreme events, such as those experienced by the Fukushima Daiichi reactors in March 2011. Increased activity is also expected in the area of modelling degraded core and damaged spent fuel pond scenarios to investigate issues such as the possibility of re-criticality.

Notwithstanding the current dedication of resources to Fukushima-related activities such as stress tests of existing plant designs/configurations, it is anticipated that operational considerations will continue to favour moves to increased fuel burn-up and/or extended plant lifetime. Increased fuel burn-up for current reactor designs implies an increase in the initial enrichment, which is now starting to pose a challenge to the 5% ^{235}U enrichment "threshold" applied to criticality safety cases for many existing light water reactor (LWR) fuel fabrication, transport and storage operations. More generally, increased burn-up and extended plant lifetimes would stimulate the development and validation of modelling methods for fuel and structural materials performance assessment.

Research activities in support of plans to construct a full-scale demonstration of sodium-cooled fast reactor systems are set to continue with further refinement of established design concepts over the next few years. For future reactor systems, there has been a continued trend towards the study and development of systems and fuel designs which help minimise waste arisings. Many future fuel designs include the presence of significant quantities of minor actinides as part of transmutation strategies. Given the expectation of significant changes to the fuel matrix, fuel and material performance will likely be a key issue for future nuclear power systems. With the closure of many of the world's high fluence irradiation facilities, there may be increasing reliance on detailed computer modelling of material performance, including the application of multi-scale modelling methods.

Minimisation of waste is one of the incentives for developing a closed fuel cycle, and the compatibility of new fuel designs with existing and potential reprocessing methods is seen as an important element of current research. The transition from today's mainly LWR fleet to a closed-cycle system based on fast reactors would present challenges in several areas, and research continues on various operating scenarios involving combinations of thermal and fast reactors to optimise waste minimisation while meeting production demands.

Given the trend to extend computer modelling methods into new application domains and the closure of many experimental facilities, there has been growing use of sensitivity/uncertainty analysis as part of the demonstration of the accuracy of such predictive methods. This growth has also been linked to increased computer speed and memory capability which allows the application of more rigorous techniques, such as the use of Monte Carlo sampling for the treatment of uncertainty.

Many of the technical areas referred to above have seen a steady decline in the number of technical experts actively involved in research programmes. With continued high rates of retirement, the need to train, educate and develop a new generation of technical specialists is likely to become an increasingly pressing issue.

Nuclear law

Ensuring that adequate and equitable compensation is made available to victims who suffer injury or damage as a result of a nuclear accident occurring at a nuclear installation or during the transport of nuclear substances remains a primary concern of NEA member countries. Following the Fukushima Daiichi accident in Japan, the international nuclear law community concentrated on assessing and learning from the liability and compensation issues. The accident also gave rise in several countries to a thorough review of nuclear laws and regulations, mainly regarding nuclear safety, which sometimes led to their repeal, modification or streamlining and, exceptionally, to a planned nuclear phase-out.

The NEA member countries that signed the 2004 Protocols to amend the Paris Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention) and the Brussels Convention Supplementary to the Paris Convention (Brussels Supplementary Convention) continue to work towards implementing 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. A majority of the signatories to both protocols are now ready to deposit their instruments of ratification of these protocols. It is expected that Belgium, Italy, Turkey and the United Kingdom will adopt ratification and implementing legislation in 2012. Belgium has, however, already adopted transitory legislation in 2011 which transposes the compensation levels provided in the 2004 Protocols. Some signatories, such as Spain and Finland, have adopted temporary amendments to their nuclear liability legislation which increases the existing amounts of liability while waiting for such protocols to come into force.

In addition, member countries which are not signatories to the above-mentioned conventions continue to modernise their third party liability regimes. Kazakhstan and Saudi Arabia ratified in 2011 the 1963 Vienna Convention on Civil Liability for Nuclear Damage (Vienna Convention) and the 1997 Protocol to amend the latter (1997 Protocol) while Montenegro significantly increased the operator's liability amounts by ratifying the 1997 Protocol.

The 1988 Joint Protocol, which establishes a link between the Paris and Vienna Conventions, still counts 26 contracting parties, and the 1997 Convention on Supplementary Compensation for Nuclear Damage has only been ratified by four countries (Argentina, Morocco, Romania and the United States). This convention 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.

Technical Programmes

Nuclear Development and the Fuel Cycle

Nuclear Development Committee (NDC)

The NDC continues to support member countries in economic assessments of nuclear energy, including the direct and indirect costs of nuclear power generation and the economics of the nuclear fuel cycle, as well as in the reliable application of nuclear technology and the examination of nuclear power's potential to mitigate greenhouse gas emissions and enhance security of supply.

Highlights

- *Carbon Pricing, Power Markets and the Competitiveness of Nuclear Energy* was published mid-year and considers the role of nuclear energy in a liberalised electricity market with carbon pricing, from the viewpoint of a private investor. Its scenarios indicate that the competition for new investment would be between gas and nuclear, with nuclear favoured by carbon pricing in a moderate range, high electricity or gas prices, or progress in reducing overnight costs for Generation III plants.
- *Trends towards Sustainability in the Nuclear Fuel Cycle* was released in December and analyses the evolutionary changes in the industry and their impact on sustainability. Despite these changes and continual research, it shows that there has been little progress in closing the fuel cycle, mainly due to the ready availability of uranium, and highlights the importance of the initiatives underway within the Generation IV International Forum.
- The final report of the first two-year mandate of the High-level Group on the Security of Supply of Medical Radioisotopes was issued. It details the necessary policy approach to establishing a sustainable supply chain in the market. In April, the NEA Steering Committee for Nuclear Energy endorsed a corresponding statement that was sent to all relevant ministers in OECD countries.
- Other reports and documents included *Nuclear Energy Data*, "Technical and Economic Aspects of Load Following with Nuclear Power Plants" and "Current Status, Technical Feasibility and Economics of Small Nuclear Reactors".

Policy and strategic issues

The Agency has closely followed member country responses to the Fukushima Daiichi nuclear accident, as well as those of other key non-member countries. In general, while four countries (Belgium, Germany, Italy and Switzerland) have opted to phase out or not to reintroduce nuclear power, a larger number have reaffirmed their commitment to continuing or increasing its use. During 2011, several presentations on the post-Fukushima perspectives of nuclear power were given by the NEA Secretariat at Eurelectric (Brussels), COP-17 (Durban), UNCTAD (Geneva) and internally at the OECD.

Overall, the situation post-Fukushima is not the same as for previous accidents, since the economic circumstances are very different globally and in developing countries demand for energy and energy security continues to spur interest in developing nuclear power as a vital part of the energy mix, while limiting greenhouse gas emissions. Indeed, calculations in the 2011 *World Energy Outlook* show that the cost of providing low-carbon energy would be more expensive without nuclear power and may not be possible in some countries. However, public opinion remains greatly affected by the Fukushima Daiichi accident and restoring confidence in countries wishing to pursue the nuclear option will be a major challenge.

Strains on human resources still remain high in the nuclear industry. With few major breakthroughs in addressing the demographic downturn of an ageing workforce, concerns regarding the availability of sufficient skilled manpower and adequate infrastructures still prevail. An NEA study due to be published shortly provides a qualitative characterisation of human resource needs and appraises instruments and programmes in nuclear education and training initiated in different countries. In this context, the study also examines current and future uses of nuclear research facilities for education and training purposes and, focusing more on the nuclear training component of workforce competence, it outlines an approach to developing a job taxonomy which describes training needs related to the different categories of the nuclear workforce.

The NEA also participated in the IEA in-depth energy policy reviews of the Republic of Korea, Switzerland, Ukraine and the United Kingdom in 2011. NEA involvement brings expertise on nuclear energy to the teams conducting the reviews, thus ensuring that they are as comprehensive as possible. The Agency also provided input and review to the *World Energy Outlook, 2011* and the revision of the energy technology programme roadmaps, to be released in 2012.

Security of supply of medical radioisotopes

The NEA continued its efforts related to improving the security of supply of molybdenum-99 (^{99}Mo) and its decay product, technetium-99m (^{99m}Tc), the most widely used medical radioisotope. The first two-year mandate of the High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) was completed in June 2011 with the release of its final report entitled *The Supply of Medical Radioisotopes: The Path to Reliability.*

This report includes the full findings from the HLG-MR assessment of the key areas of vulnerability in the supply chain and a comprehensive policy approach to ensure the long-term security of supply of these important medical radioisotopes. It describes the essential steps to be taken by governments, industry and the health community to address the vulnerabilities, including changing an economic structure that does not support reliable supply.

In June 2011, the HLG-MR also released its study on *The Supply of Medical Radioisotopes: An Assessment of Long-term Global Demand for Technetium-99m.*

Recognising that continued action was required on the part of all stakeholders to implement the HLG-MR policy approach, the HLG-MR was given a second mandate from 2011 to 2013. To achieve implementation, actions will be undertaken to maintain transparency on global developments, to continue communication with the supply chain and end users, to evaluate progress towards implementation and to provide additional information and analysis where necessary. A study has also been launched to assess the economic and supply impacts of converting to the use of low enriched uranium targets for ^{99}Mo production.

Economics and financing

The Working Party on Nuclear Energy Economics (WPNE) provided advice on key economic issues that merit investigation on an international level. It is currently advising on a large "system effects" study and the interaction of nuclear energy and renewables in low-carbon electricity systems. The system costs of a power generation technology are the total costs above plant-level costs to supply electricity at a given load and given level of security of supply. They include items like grid reinforcement, extension and connection as well as balancing costs and the need for back-up capacity.

System costs are increasingly capturing the attention of electricity industry experts and decision-makers due to the large system costs of decentralised, intermittent renewables such as wind and solar. While nuclear power has some system costs of its own, notably in terms of grid reinforcement and specific requirements for the reliability of external power supplies, its key role in this context relates to its interaction with intermittent renewables in decarbonising electricity systems. On the one hand, nuclear energy can provide back-up and balancing services due to its good flexibility and ability to follow changes in electrical load. On the other hand, nuclear is affected by intermittency in terms of reduced load factors and overall depressed prices due to the supply of renewables with very low short-term variable costs. The system costs study, to be published mid-2012, aims at refining the notion of system costs, at better understanding the contribution of nuclear power to provide balancing services and capacity, and at providing quantitative estimates of system costs on the basis of its innovative NEA methodology.

Ulchin NPP, Rep. of Korea

The WPNE is examining the interaction of nuclear energy and renewables in low-carbon electricity systems.

Two other important studies were launched in 2011 on the economics of the back end of the fuel cycle and the economics of long-term operation. The first meetings of the working groups have taken place and the work is expected to be completed by the end of 2012.

Data and resources

A new project on Managing Health and Environmental Impacts of Uranium Mining began in 2011, with the first ad hoc expert group meeting held in September. This project, whose final report is expected to be released in late 2012, aims to illustrate the difference between mining practices today and those that created uranium mine and mill legacies in the past, as well as documenting regulatory practices in all uranium-producing countries.

Nuclear Energy Data 2011 was published. This annual publication aims to keep member countries abreast of the latest nuclear power developments in OECD countries.

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Nuclear Safety and Regulation

Committee on Nuclear Regulatory Activities (CNRA)

The CNRA contributes to developing a consistent and effective regulatory response to current and future challenges, addressing in particular operational experience feedback, inspection practices, the regulation of new reactors and public engagement concerning safety in the use of nuclear energy.

Highlights

- The CNRA set up a senior task group to co-ordinate NEA activities to investigate lessons from the Fukushima Daiichi accident.
- The CNRA issued a new regulatory guidance booklet on *The Nuclear Regulator's Role in Assessing Licensee Oversight of Vendor and Other Contracted Services*, as well as an update of *Improving Nuclear Regulation*, a compilation of all 14 regulatory guidance booklets.
- Crisis communication and transparency were important areas of focus for identifying key programme elements for nuclear regulatory organisations.
- The CNRA continued to place emphasis on identifying and applying lessons learnt and commendable practices in the areas of operating experience and inspection practices.

Regulatory impacts of the Fukushima Daiichi accident

A task group of senior-level regulators was formed in late March 2011 to provide a dedicated forum for the timely and efficient exchange of information on national activities and safety reviews in response to the Fukushima Daiichi accident. It was also asked to identify areas of concern for member countries which would benefit from an international collaborative effort. Several activities have been undertaken in this context (see page 7 for further details).

Operating experience

The Working Group on Operating Experience (WGOE) focuses its activities on follow-up actions regarding national trends and lessons learnt from national events submitted to the joint NEA/IAEA International Incident Reporting System for Operational Experience (IRS). The IRS is the only international system providing regulators with information about lessons learnt from safety-significant events at nuclear power plants (NPPs). The group completed reports on regulatory activities concerning "Large, oil-filled transformer failures" and "Counterfeit, fraudulent and suspect items". The WGOE also held a workshop in co-operation with the Working Group on Inspection Practices addressing the utilisation of operating experience in the regulatory inspection programme and of inspection findings in the national operating experience programme, as well as recent operating experience and inspection insights from the non-conformance of spare parts.

Regulation of new reactors

The Working Group on the Regulation of New Reactors (WGRNR) is reviewing regulatory activities concerning siting, licensing and oversight of new commercial NPPs. Given that sharing information about the licensing process, construction experience and inspection practices will be helpful to all countries, a construction experience programme (ConEx) has been developed. The ConEx objectives are to identify deficiencies associated with NPP design and construction, to assess the adequacy of, and to supplement if necessary, regulatory activities to detect and correct such events, and to disseminate information to ensure appropriate regulatory attention is given to lessons learnt from past events. A web-based interface was fully implemented and populated during 2011 with a procedure that describes the roles, responsibilities and means to share lessons learnt promptly. The first ConEx report assessing the construction experience information from 2008-2011 was approved by the CNRA in 2011.

A report on the regulation of site selection and preparation aimed at reviewing the various practices used by regulators was finalised. The report is based on a survey covering different aspects of the regulation of nuclear sites. In 2011, the WGRNR also discussed a potential follow-up activity related to new plant siting including changes or enhancements as a result of the Fukushima Daiichi accident.

A study was undertaken on recent regulatory experiences describing licensing structures, the resources and skills needed to perform design reviews, assessments and construction oversight, the types of training needed for these activities and the various licensing processes. The first phase covers general aspects, including the licensing process, safety assessments, public participation, construction and operating oversight. A survey was also taken. The report was finalised and approved by the CNRA. The second phase was subsequently launched in 2011 on the different aspects of the design reviews performed by regulatory authorities.

Regulatory inspection practices

The Working Group on Inspection Practices (WGIP) continued its efforts on the inspection of licensee maintenance programmes and licensee emergency arrangements. Preparations were made for the eleventh international workshop on inspection practices which will be held in May 2012 in Switzerland. The workshop will address experiences from the inspection of ageing equipment and equipment qualification, the competency of operators and the licensee's oversight of contractors.

Nuclear regulators and public communication

The activities of the Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC) focused on crisis communication, which is needed whenever a nuclear event has a media impact. Based on a survey of practices in members countries, a roadmap for crisis communication of nuclear regulatory organisations (NRO) was established early 2011 describing the main aspects to be addressed before, during and after the crisis. The roadmap was assessed by NRO communicators in member countries after the Fukushima Daiichi accident and was found to be relevant in cases where the major impact of the event remained within the country. It was also found, however, that the international dimension for cases of wider impact needed further development. In this respect a new survey was prepared and a workshop bringing together senior regulators, NRO communicators and stakeholders (politicians, media, NGOs and industry) will be convened in May 2012 to address the specific needs of crisis communication on the international dimension. Other areas of WGPC work include the use of social media and the development of communication plans.

Long-term operation

A senior-level expert group was formed in 2010 to produce a guidance document on the challenges of long-term operation (LTO) of nuclear power plants, primarily addressing the implications for regulatory bodies and focusing on policy issues. The document, which was approved by the CNRA at the end of 2011, reviews the different approaches to long-term operation in member countries, including regulatory activities related to licensing and supervision of LTO, challenges with ageing management issues, design improvements and compliance with newer design requirements, and severe accident policies. The document incorporates the impacts of the Fukushima Daiichi accident on long-term operation of nuclear power plants.

Committee on the Safety of Nuclear Installations (CSNI)

The CSNI contributes to maintaining a high level of safety performance and safety competence by identifying emerging safety issues through the analysis of accidents and their management, ageing and structural integrity, fuel and fuel cycle safety, contributors to risk and human factors. The committee also facilitates the establishment of international joint research projects when useful.

Highlights

- **CSNI activities focused on follow-up to the Fukushima Daiichi accident. The committee and its working groups discussed possible new technical tasks to respond to some of the preliminary lessons learnt and closely co-operated with the CNRA and the CRPPH in a cross-committee integrated response to the accident.**
- **The Task Group on Defence in Depth of Electrical Systems and Grid Interactions Follow-up (DIDELSYS-2) completed its mandate and produced its final report.**
- **Seven new international joint projects were started in 2011 (see page 32).**

Analysis and management of accidents

The activities of the Working Group on Analysis and Management of Accidents (WGAMA) have focused on the thermal-hydraulics of the reactor coolant system; in-vessel behaviour of degraded cores; containment behaviour and protection; computational fluid dynamics (CFD); and fission product release, transport, deposition and retention. Work has also been undertaken on new and advanced reactors.

During 2011, further progress was made on best-estimate methods and uncertainty evaluations with the organisation of an international workshop in November in Barcelona, Spain. In addition, a new benchmarking activity was launched on quantifying the uncertainty of the physical models in system thermal-hydraulic computer codes.

Regarding computational fluid dynamics (CFD), work is progressing on the consolidation of best practice guidelines for CFD application to nuclear reactor safety (NRS) problems, CFD code assessment for NRS problems, CFD extension to two-phase flow problems, benchmarking activities and the organisation of workshops. The CFD benchmark on a customised T-junction experiment was completed as scheduled, and the report was issued. A new CFD benchmark exercise was undertaken on turbulent flow in a customised rod bundle with spacer grids. The results of this benchmark will be presented during the workshop on Experimental Validation and Application of CFD and Computational Multi-fluid Dynamics (CMFD) Codes to Nuclear Reactor Technology (CFD4NRS-4), which will be organised in the Republic of Korea in September 2012.

In order to assess safety analysis code capabilities, two international standard problems (ISP) were carried out on thermal-hydraulics of the reactor coolant system (ISP-50 on the Korean ATLAS facility) and on hydrogen combustion (ISP-49 based on the French ENACCEF and German THAI facilities). Both ISPs were completed in 2011, and the related reports will be issued in 2012.

Work also continued on in-vessel behaviour of degraded cores. A new activity is progressing on code benchmarking to assess the ability of computer codes to simulate in-vessel core melt progression and degraded core coolability on the basis of three severe accident sequences involving safety systems failure or delayed operation. Preparations also began late 2011 on a state-of-the-art report addressing molten corium concrete interaction and ex-vessel molten core coolability.

Finally, like the other CSNI working groups, the WGAMA organised in September 2011 a technical discussion on the Fukushima Daiichi accident in order to identify issues of relevance to the group's work and to provide proposals on how to address them.

Ageing and structural integrity of reactor components

The main topics addressed by the Working Group on Integrity of Components and Structures (WGIAGE) concern the integrity and ageing of metal components and concrete structures, and the seismic behaviour of structures and components.

In 2011, the WGIAGE finalised the report that documents the main findings and conclusions of the IRIS 2010 activity on improving the robustness of assessment methodologies for structures impacted by missiles. The activity involved a benchmark exercise with the participation of 28 teams. The purpose was to develop guidance that outlines effective methods of evaluating the integrity of structures in such circumstances.

Component fatigue is a key issue for the safety of nuclear power plants. The group continues to assess transferability of fatigue data in member countries.

In view of the increasing interest in safe, long-term operation of existing nuclear power plants, an activity is being conducted to identify technical areas of common interest concerning age-related degradation of materials in safety-related systems, structures and components (SSCs) during NPP long-term operation (60 years) and to capture operating experience associated with degradation in buried tanks and piping.

An activity is also underway to identify technical areas related to the structural integrity evaluation of piping systems using deterministic and/or probabilistic methods and the demonstration that flaws in piping systems will exhibit leaks prior to failure.

A new activity was initiated in 2011 to review current practices in member countries regarding the definition of seismic input from far- and near-field sources and its control point, and ultimately to provide recommendations regarding their harmonisation.

Risk assessment

The main mission of the Working Group on Risk Assessment (WGRISK) is to advance the understanding and utilisation of probabilistic safety assessment (PSA) as a tool to support nuclear safety decision-making in member countries. The activity on PSA knowledge transfer is progressing as scheduled, with the objective of developing an understanding of the current needs and ongoing activities in member countries on PSA knowledge transfer, including related international activities, and supporting the dissemination of lessons learnt and best practices. A comprehensive questionnaire was circulated to WGRISK members, the IAEA and the EC, and the resulting report is expected to be submitted for approval in spring 2012.

The activity on PSA for the design and commissioning of new NPPs seeks to identify and characterise current practices in this area and to identify key technical issues, current approaches to addressing them, associated lessons learnt and issues requiring further work. In addition, in order to widen the audience and the discussion, a joint workshop including PSA for advanced reactors was organised in Paris in June.

The development of best practice guidelines on failure mode taxonomy for reliability assessment of digital instrumentation and control (I&C) systems for PSA was approved by the CSNI in June with the aim of developing technically sound and feasible failure mode taxonomy for such reliability assessments, and providing best practice guidelines on the use of taxonomy in modelling, data collection and qualification of digital I&C reliability. Two workshops were organised in 2011, and the guidelines are expected to be submitted for approval in 2013.

Regarding information exchange on the use and development of PSA in member and associated countries, a report on "The Use and Development of PSA in NEA Member Countries" is being updated and is expected to be issued late 2012.

Finally, a new activity was initiated on the use of OECD/NEA data project products (stemming from the ICDE, OPDE, FIRE and COMPSIS projects described on page 36) in order to identify and characterise current uses of such products and data in support of PSA, and to ensure better interaction and co-ordination among the projects in question.

Fuel safety

The Working Group on Fuel Safety (WGFS) is addressing the systematic assessment of the technical basis for current safety criteria and their applicability to high burn-up, as well as to the new fuel designs and materials being introduced in nuclear power plants.

The group has re-examined the current status of light water reactor fuel safety criteria, which in some areas developed rapidly, in order to update a report published over ten years ago. As a result of this reassessment, the group confirmed that the current framework of fuel safety criteria remains generally applicable. However, the numerical values in the individual safety criteria may change according to the particular fuel and core design features. Some specific criteria and associated values continue to

be modified and adjusted on the basis of new experimental data and analyses. The report on *Fuel Safety Criteria Technical Review* (second edition) is scheduled to be published in 2012.

Regarding the testing and modelling of nuclear fuel behaviour during reactivity-initiated accidents (RIA), two activities are being carried out on RIA fuel rod codes benchmarking and mechanical testing of fuel cladding for RIA applications.

Human and organisational factors

The Working Group on Human and Organisational Factors (WGHOF) constitutes a unique international forum for addressing safety management including safety culture, human and organisational factors, and human performance in nuclear facilities. A joint NEA/IAEA workshop on Oversight and Influencing of Leadership and Management for Safety, Including Safety Culture was held in September in Chester, United Kingdom. The objectives of the workshop were to build upon a previous workshop held in 2007 and to advance the thinking on best practices and areas for improvement stemming from the shared experiences of overseeing and influencing leadership and management for safety within the nuclear industry. The workshop brought together over 40 representatives from regulatory bodies and licensees in 16 countries, the NEA and the IAEA.

In addition, work is continuing on a joint WGHOF/WGRISK task to investigate key attributes of human reliability analysis (HRA) in nuclear risk assessments. Both this task and the previous one on oversight and influencing of leadership and management for safety, including safety culture, will seek to provide valuable insights for international specialists in the field.

Fuel cycle safety

The Working Group on Fuel Cycle Safety (WGFCS) brings together regulatory and industry specialists to address a broad range of interests, including safety assessments, nuclear criticality safety, probabilistic safety assessment, safety management, decommissioning, site remediation and fire protection.

The joint NEA/IAEA Fuel Incident Notification and Analysis System (FINAS) is the only international system providing regulators and government bodies with information about lessons learnt from safety-significant events at fuel cycle facilities. The FINAS web-based system has been in operation since 2008. In total, 125 events have been registered with 20 additions having been made in 2011. Soon the FINAS will be migrated to the NUCLEUS system, where other IAEA databases have been brought together.

The group recently completed a technical opinion paper on *Ageing Management of Nuclear Fuel Cycle Facilities*. The paper reviews the potential impact of common ageing problems on the safety, regulation and operability of nuclear fuel cycle facilities. It also addresses specific aspects such as combined nuclear and chemical hazards, uniqueness of designs, and long operational lives with numerous evolutions/additions of equipment and processes. The paper will be published in 2012.

A workshop on Safety Assessment of Fuel Cycle Facilities – Regulatory Approaches and Industry Perspectives was organised in Toronto, Canada in September. About 60 participants from NEA member countries and international organisations reviewed the general approaches to safety assessment being used by different regulatory authorities. They also discussed how these regulations have been applied and under what circumstances deterministic and probabilistic methods have been used in front-end and back-end fuel cycle facilities.

Defence in depth of electrical systems and grid interaction

Following the July 2006 Forsmark-1 event which identified a number of design deficiencies related to electrical power supply to systems and components important to safety in NPPs, a Task Group on Defence in Depth of Electrical Systems and Grid Interaction (DIDELSYS) was established.

In 2009, the group issued its final technical report which provided information on the state of the art regarding the robustness of safety-related electrical systems (SRES), taking into account their interaction with other electrical equipment, the use of new technologies and the problems encountered when modernising existing NPPs. It also provided guidelines for improving communication and co-ordination among grid operators, nuclear safety authorities and licensees.

After the completion of the report, a follow-up activity was initiated to identify a methodology for periodically carrying out a systematic hazard review of possible voltage/frequency transients which could occur from the grid and in NPPs, and to convene a workshop to discuss progress made since the publication of the technical report. The group finalised in 2011 a technical opinion paper that reports the main findings and recommendations of the DIDELSYS activity.

Sump clogging

At the end of 2010, a Task Group on Sump Clogging was established to update the state-of-the-art report on the "Knowledge Base for Emergency Core Cooling System Recirculation Reliability", taking into account progress in relevant R&D that occurred since its initial publication in 1996. Special emphasis is being placed on chemical effects and downstream effects as well as long-term core cooling which were identified as main concerns during a joint CNRA/CSNI workshop. The report's outline has been agreed and several chapters and appendices have been prepared and reviewed. The final report is expected to be completed by the end of 2012.

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Radioactive Waste Management

Radioactive Waste Management Committee (RWMC)

The RWMC is assisting member countries in the development of safe, sustainable and broadly acceptable strategies for the long-term management of all types of radioactive waste, in particular long-lived waste and spent fuel considered as waste, and for the decommissioning of obsolete nuclear facilities.

Highlights

- A collective statement was issued on "Geological Disposal of Radioactive Wastes: National Commitment, Local and Regional Involvement".
- An international peer review was undertaken, on behalf of the Swedish government, of the industry's safety case for a deep repository for spent nuclear fuel in that country. An international peer review was also started for a low- and intermediate-level waste disposal facility in Belgium.
- A new international project was launched on the preservation of records, knowledge and memory across generations.
- The Forum on Stakeholder Confidence (FSC) held an international multi-stakeholder workshop in Sweden in May, soon after the licensing phase began for a final repository for spent nuclear fuel in the Östhammar municipality.
- The Working Party on Decommissioning and Dismantling (WPDD) completed the International Structure for Decommissioning Costing (ISDC), in a joint undertaking with the European Commission and the IAEA.

Waste management policy and regulatory issues

In 2011, preparations began for the International Conference on Geological Repositories (ICGR-12) which will be held in Toronto, Canada, on 1-2 October 2012. The conference, which is the fourth in a series of high-level conferences on this topic and which was rescheduled due to the Fukushima Daiichi accident, is being organised under the theme of National commitment – regional and local involvement. In support of the conference, the RWMC prepared a collective statement on its views on the subject drawing on practical insights from the Forum on Stakeholder Confidence and the Regulators' Forum.

The project on retrievability and reversibility (R&R) in geological disposal came to a close in late 2011 with the publication of a final report as well as a brochure summarising the project's major findings and a bibliography of worldwide literature about reversibility and retrievability. A four-page leaflet on "R&R" was also developed as an effective tool for public communication and discussion.

International peer reviews

The Swedish Radiation Safety Authority (SSM) requested the NEA to organise a peer review of the planned deep geological repository for spent fuel in Östhammar. The review, which is being performed by a team of ten experts, supplements the Swedish authority's review in the context of the license application for the construction of the repository, and covers long-term radiation safety as well as site selection. Public hearings were held in Sweden in December during which the NEA peer reviewers posed questions to the implementer. Preliminary results have been presented to the Swedish regulatory authority.

Following a similar request from the Belgian federal government, the NEA initiated a peer review of a Belgium surface disposal facility at Dessel, designed for low- and intermediate-level waste. This review will evaluate the safety assessment methodology to be used in the context of the application for a construction and operation license for this facility. It is planned that the review will conclude in July 2012 and that the results will be documented in an NEA report.

Records, knowledge and memory

As radioactive waste disposal programmes approach the siting and operational stages, the preservation of records, knowledge and memory (RK&M) across generations constitutes one of the pillars of confidence in safety and security, and a foundation for robust decisions by future generations. These aspects should thus be addressed early on in national programmes. The new RWMC initiative on RK&M developed an extensive bibliography and held a workshop which together provided a solid starting point. Representatives of institutions involved in waste management, and social scientists including philosophers, historians and archaeologists, clarified the three related areas of archiving, markers and monuments, and heritage.

Safety case for geological disposal

At its 2011 annual meeting, the Integration Group for the Safety Case (IGSC) discussed new projects to advance the development of safety cases for radioactive waste disposal repositories. It also organised a topical session to review recent research activities and results on gas migration, focusing on the impact of gases on the integrity of the host rock, which is a particularly important issue in demonstrating the long-term safety of a geological repository.

The NEA Clay Club held an international workshop on Microscopic observations and imaging techniques for clay in September. The 100+ participants discussed various important clay issues, such as pore structure and connectivity of clay, water and ion mobility in clay, and upscaling and implementation in model approaches. The project is currently planning its next annual meeting, to be held in October 2012 on the theme of Clays in natural and engineered barriers for radioactive waste confinement.

With a growing number of disposal programmes entering the industrial phase, the issues of construction and operation come to the fore. Supported by the RWMC Regulators' Forum, the IGSC organised a workshop on Preparing for construction and operation of geological repositories – challenges to the regulator and the implementer. The workshop provided a rare opportunity for regulators and implementers to discuss the challenges they have to face when preparing for a license application.

The IGSC also started preparatory work to organise the next safety case symposium in 2013, which will review progress and ongoing activities since the last symposium on this topic four years ago.

Forum on Stakeholder Confidence

The Forum on Stakeholder Confidence (FSC) held its 8th national workshop and community visit in May, in Sweden on Actual implementation of a spent nuclear fuel repository: seizing opportunities. More than 50 Swedish stakeholders, representing local, regional and national government, civil society organisations and environmental groups as well as institutions involved in the repository programme, exchanged information and experience with officials from 13 NEA member countries.

At its 12th regular meeting in September in Paris, France, the FSC delved into experiences of "early involvement" of civil society in decision making, considered approaches to the assessment of community willingness to host a repository, and recognised the need for radioactive waste management organisations to anticipate the future. For this last topic, the FSC explored the potential impact of social media on citizen involvement and decision making.

Decommissioning

The WPDD Decommissioning Cost Estimation Group (DCEG) completed the International Structure for Decommissioning Costing (ISDC) in a joint undertaking with the European Commission and the IAEA; it is an updated version of the standardised cost structure first published in 1999 as the "Yellow Book". In addition, the new report gives general guidance on developing a cost estimate for decommissioning a nuclear facility and, in particular, on using the standardised cost structure. The use of the ISDC will support greater harmonisation of reporting and facilitate comparison of different cost estimates. The group is also conducting a survey on the use of cost and schedule controls in decommissioning projects and their impact on project performance improvement.

The WPDD completed a study that provides a methodology for assessing different options for the long-term management of large components following decommissioning of a nuclear facility. Work continued on evaluating R&D needs for decommissioning. A new WPDD task group began to identify and to summarise best practice for radiological characterisation at different stages of decommissioning, an important issue for the safe decommissioning of nuclear facilities.

The International Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD) continued its work which currently covers 59 active decommissioning projects (35 reactors and 24 fuel facilities), in 12 member countries, 1 non-OECD economy and the European Commission (see page 38 for more information).

Understanding the scientific basis

The RWMC continued to support the development and maintenance of quality-assured databases and models for use in the implementation of repositories and to generally secure the scientific basis of its work.

Performance assessment exercises have demonstrated that one of the most important processes providing long-term safety is the sorption of radionuclides along their eventual migration to the surface. The NEA Sorption Project developed recommendations and guidelines to model these processes within the framework of a safety case and to guide modellers in their appropriate application to relevant systems.

The NEA Clay Club organised an international workshop on microscopic observations and imaging techniques in September in Karlsruhe, Germany. Over 100 specialists in radioactive waste management and from outside the nuclear field shared state-of-the-art methods and modelling techniques in these areas.

Copying the successful format of the NEA Clay Club, a new NEA Salt Club has been established to focus on geomechanical issues (such as rock mechanic studies, behaviour of the excavation damaged zone, backfilling, sealing and plugging of drifts and shafts) and geochemical issues (including radionuclide chemistry, and brine and gas migration) related to salt as a geological host formation.

The Thermochemical Database (TDB) Project, which is run by the NEA Data Bank under the scientific guidance of the RWMC, continued to develop its database of recommended chemical thermodynamic data for the safety assessment of radioactive waste repositories (see page 38 for further details).

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Radiological Protection

Committee on Radiation Protection and Public Health (CRPPH)

The objective of the CRPPH is to facilitate the understanding and implementation of a system of radiological protection that addresses regulator and practitioner needs, and more appropriately positions scientific radiological protection considerations within the broader context of social judgment and risk governance.

Highlights

- A preliminary programme of work was developed to address the radiological protection aspects of the Fukushima Daiichi accident, focusing on consequence management, emergency planning and stakeholder involvement.
- Following a CRPPH recommendation, the NEA Steering Committee for Nuclear Energy decided in October to co-sponsor the revised international Basic Safety Standards (BSS).
- Two international peer reviews of emergency management policy and strategy were performed.
- A study was finalised on "Dose Constraints in Optimisation of Occupational Radiation Protection".
- A total of 18 countries held national emergency exercises within the framework of INEX-4, whose results will be analysed and published in 2012.

Radiological protection consequences of the Fukushima Daiichi accident

Following the Fukushima Daiichi accident, the CRPPH established a framework to make its experience available to the Japanese government and at the same time, to start collecting lessons learnt from the accident. To this end, a number of activities were launched under CRPPH auspices, in particular in areas of its traditional strength, namely the evolution of the system of radiological protection, emergency management and occupational exposure. To manage the Committee's overall work programme in this area and to co-ordinate with other international organisations to ensure compatible and non-redundant efforts, it established an Expert Group on Radiological Protection Aspects of the Fukushima Accident (EGRPF).

The CRPPH also began providing its members' experience through the support of and participation in conferences and workshops held in the affected areas in Japan aiming to explore approaches to stakeholder involvement. Two such conferences took place with NEA support in 2011 (in September and November), and two more are planned in early 2012.

Evolution of the international system of radiological protection

During 2011, the CRPPH and the NEA Secretariat continued to help finalise the new international Basic Safety Standards (BSS) with the IAEA and the six other co-sponsoring organisations (EC, FAO, ILO, PAHO, UNEP and WHO). The revised BSS were approved by the IAEA Board of Governors during its September 2011 meeting. The NEA Steering Committee for Nuclear Energy agreed to co-sponsor the new BSS in October.

In order to assist NEA member countries with their implementation of the new International Commission on Radiological Protection (ICRP) recommendations, a study was published on the resources needed to implement the ICRP recommendations of 1990. The study is based on a questionnaire and a series of interviews, and captures the experience of regulatory authorities, nuclear utilities and other fields involving radiological exposure in order to extrapolate what resources may be needed to implement the 2007 recommendations.

The CRPPH also continued its efforts to provide the ICRP with practical user feedback on draft documents, analysing a new draft ICRP recommendation on Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste, in co-operation with the NEA Radioactive Waste Management Committee (RWMC).

International peer reviews

The NEA Secretariat organised two peer reviews of national emergency management policy and strategy documents following requests from the French and Finnish regulators. Experts from the Working Party on Nuclear Emergency Management (WPNEM) participating in the review teams supplied both general comments on the approaches taken and specific comments to improve the text which were submitted. The results of both peer reviews were made available to CRPPH and WPNEM members for their information. The well-thought-out approaches of both the French and Finnish regulatory authorities were found to be extremely valuable for other members.

Radiological protection science and policy judgment

Radiological protection decisions are a combination of science and judgment, and making these two elements more transparent in decision making will most likely improve the acceptability and sustainability of decisions. The CRPPH is addressing these issues through a series of workshops. Ongoing preparations for the third workshop on Science and Values in Radiological Protection, to be held in Japan in late 2012, have been adapted in light of the new situation. While the workshop will not be on the results of the Fukushima Daiichi accident, science and values are clearly central to post-emergency decisions, and as such will be used as a framework for discussions.

Operational radiological protection from a policy perspective

In 2011, the CRPPH Expert Group on Occupational Exposure completed its study on dose constraints which has focused on collecting operational experience with the use of dose constraints in optimising protection and developing a practical understanding of these constraints. The report provides valuable information that may be used in setting dose constraints for the radiological protection of workers. In addition, the CRPPH agreed to prepare reports on the management of total risk and on radiological protection issues for itinerant worker exposure management.

NEI, United States

Radiological protection for itinerant worker exposure.

The CRPPH Expert Group on Best Available Techniques is examining practical approaches to the management of effluents for new reactors, with the objective of developing an understanding of good practice among regulatory authorities, utilities and reactor vendors. To this end, the group prepared a summary report of its work – Good Practice in Effluent Management for Nuclear Power Plant New Build – and a workshop in January 2012 to develop a consensus view of what is meant by good practice.

The Information System on Occupational Exposure (ISOE) created an expert group to prepare a report on best radiological protection management procedures for workers during severe accident initial response and recovery efforts. The objective of this work is to identify best practices and to communicate radiological protection lessons learnt from previous reactor accidents.

Radiological protection of the environment

An ad hoc expert group on the radiological protection of the environment found that some countries were considering merging, or at least linking, regulatory management of chemical and radioactive effluents. To explore this possibility, a short questionnaire was sent to CRPPH members, and a summary report of results was drafted. Twelve countries responded to the questionnaire, and of these six were expecting or planning to harmonise their regulatory systems for health effects of radioactive or chemical releases to the environment. Overall, the survey has demonstrated some trends towards unification of the regulatory implementation in both areas; however, these trends are not universal.

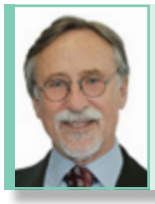
Nuclear emergency and recovery management

In terms of system evolution, the CRPPH agreed to investigate how the new ICRP recommendations for emergency management and for post-accident rehabilitation were being implemented, with a view to assist members in updating their own approaches and to provide practical feedback to the ICRP. In the area of emergency management implementation, the CRPPH agreed that its Working Party on Nuclear Emergency Matters should study approaches to improve the sharing or co-ordination of emergency management decisions, update a previous report on short-term countermeasure criteria currently used by NEA member countries, and develop an analysis of "patterns" in the government decisions that were collected following the Fukushima Daiichi accident.

The INEX-4 exercise is focusing on consequence management and transition to recovery in response to malicious acts involving the release of radioactive materials in an urban setting. The exercise began in September 2010 and has since been completed by 18 countries (including 4 non-NEA countries). National exercise summary reports will be assessed and overall conclusions will be developed in a report to be submitted to the CRPPH Working Party on Nuclear Emergency Matters for approval at its November 2012 meeting.

Occupational exposure at nuclear power plants

The sharing of operational lessons and experience, as well as the collection, analysis and exchange of occupational exposure data continue to be addressed by the Information System on Occupational Exposure (ISOE), an NEA joint project in the field of radiological protection which is co-sponsored by the IAEA. In 2011, the ISOE continued its efforts to share dose reduction experience among participants, and to co-ordinate projects to improve optimisation of worker radiological protection at NPPs by providing online data collection and analytical resources. Further details on the ISOE programme are provided on page 38.



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Nuclear Science

Nuclear Science Committee (NSC)

The aim of the NEA nuclear science programme is to help member countries identify, pool, develop and disseminate basic scientific and technical knowledge used to ensure safe and reliable operation of current nuclear systems, as well as to develop next-generation technologies. The main areas covered are reactor physics, fuel cycle physics and chemistry, criticality safety and material science.

Highlights

- The fifth workshop on uncertainty analysis in modelling LWR transients (UAM-5) was held in Stockholm, Sweden in April.
- A state-of-the-art report on "Spent Nuclear Fuel Assay Data for Isotopic Validation" was issued.
- A nuclear science electronic forum on the Fukushima Daiichi accident was set up in July.
- The third and final PWR sub-channel bundle test (PSBT) benchmark workshop was held in Toronto, Canada in September.
- The ninth International Conference on Nuclear Criticality (ICNC 2011) was held in Edinburgh, United Kingdom in September.
- A user workshop demonstrating the DICE database tool for the International Criticality Safety Benchmark Experiments Project (ICSBEP) was held in conjunction with ICNC 2011. A project to develop a similar tool for the International Reactor Physics Experiments (IRPhE) database was initiated in February.

The main objective of the NEA nuclear science programme is to validate models and data used in member countries for predicting the behaviour and performance of different nuclear systems by comparing calculated and experimental results in international benchmark exercises. In addition, it organises specialists' meetings and workshops and produces state-of-the-art reports as necessary.

Reactor physics

A significant part of NEA work related to reactor physics is devoted to the propagation of uncertainties in the modelling of coupled core neutronics/thermal-hydraulics effects in a reactor. A number of benchmarks based on measured data, such as the Russian-designed reactor (VVER-1000) coolant transient benchmark and the pressurised water reactor (PWR) sub-channel bundle test benchmark, are used to validate the models. Substantial progress was made in 2011 with the development of new methods to propagate uncertainties and the provision of new covariance and sensitivity data needed to carry out those calculations.

Several benchmark exercises devoted to advanced reactor systems are also underway covering reactor transient calculations, for example in a pebble bed modular reactor (PBMR) and a sodium-cooled fast reactor (SFR), and fuel depletion calculations in a high-temperature, gas-cooled reactor (HTGR).

In addition to the above-mentioned activities, work in this area also addresses fuel performance as well as radiation transport and shielding. The NEA has established corresponding databases containing experimental data used extensively in member countries to validate modelling codes and associated data.

The database of International Reactor Physics Experiments (IRPhE) has grown significantly in the last few years. In response, the NEA initiated a project to develop a database tool for IRPhE to improve user access, based on the DICE tool already available for accessing data contained in the International Criticality Safety Benchmark Experiment Project (ICSBEP) handbook. Demonstrations of a development version of the tool were made *inter alia* at the IRPhE technical review group meeting in October. A prototype version will be available in 2012.

Fuel cycle physics and chemistry

Potential Benefits and Impacts of Advanced Nuclear Fuel Cycles with Actinide Partitioning and Transmutation was published, providing a comparative analysis of different studies performed to assess the potential impact of partitioning and transmutation (P&T) on different types of geological repositories for radioactive waste in various licensing and regulatory environments. This report concludes that while P&T will never exclude the need for waste repositories, it has the potential to very significantly reduce the transuranic (TRU) waste masses to be stored.

An international workshop on characterisation and PIE (post-irradiation experiment) needs to support science-based development of innovative fuels was organised in June. It was concluded that existing capabilities are

not sufficient to meet the needs of a science-based approach and that safety issues and fuels behaviour during abnormal conditions will require more detailed study following the Fukushima accident. It is envisaged that some development of modelling techniques and standards is likely and this should be co-ordinated within an international framework.

Nuclear criticality safety

Following the completion of a state-of-the-art report on "Spent Nuclear Fuel Assay Data for Isotopic Validation", significant efforts are now being made to improve the spent fuel isotopic composition database (SFCOMPO). This database aims to provide fully evaluated assay data sets which are necessary for the validation of depletion codes and, by extension, for many criticality safety assessments of waste management/disposal operations.

Also important is the provision of clear guidance to the experts who will perform the independent review of the SFCOMPO data sets (which not only include the reported experimental isotopic compositions of irradiated fuel, but also all relevant operational information); such is the purpose of the guidance report for the evaluation of assay data that is currently being finalised. In this context, a restructuring of the SFCOMPO database has been undertaken. This will allow for new evaluations contributed by member countries to be fully integrated into the database and will also facilitate the use of the data.

In addition, studies related to burn-up credit criticality safety continue. Burn-up credit is the safety approach that accounts for the reduction in reactivity of spent nuclear fuel due to the change in its composition after irradiation. A summary report on lessons learnt is expected to be finalised in 2012. Other benchmark activities which concern the rigorous treatment of uncertainties in different criticality safety assessment methodologies are ongoing, and the compilation of a state-of-the-art report was completed in 2011.

The ninth International Conference on Nuclear Criticality (ICNC 2011), co-organised by the NEA, was held in September in Edinburgh, United Kingdom. It was attended by over 270 participants from 21 countries.

Material science

NEA work in the area of material science is mainly devoted to multi-scale modelling of fuels and structural materials for nuclear systems. The following five state-of-the-art reports are being prepared:

- an assessment of the possibilities and limits of numerical methods applied to multi-scale modelling of materials and the means to link them;
- a critical review of recent progress and bottlenecks for future development of fuels;
- an assessment of the use of a multi-scale modelling approach to describe the changes induced by irradiations in structural nuclear materials;
- a validation and benchmark of multi-scale modelling methods;
- an assessment of primary radiation damage characterisation and the limitations of the Norgett Robinson and Torrens (NRT)-dpa standard to propose a new parameter to better describe radiation damage.

Integral experiments for minor actinide management

The main objectives of this activity are to assess the availability of minor actinide nuclear data, to evaluate the target accuracies of these data in applications such as transmutation in light water, fast and accelerator-driven subcritical reactors, and, if appropriate, to make recommendations on additional differential and integral experiments needed to meet the target accuracies. A review of existing nuclear data and integral experiments for minor actinide management has been performed, as well as an assessment of the accuracy of the available data. A discussion of the need for further measurements is ongoing, with the final report due to be issued in 2012.

Knowledge preservation

In order to assist member countries in the development of new nuclear facilities, and in the context of marked change in the composition of their skills base as a generation of highly experienced nuclear scientists and engineers retires, the NEA Nuclear Science Committee launched, some years ago, a programme of establishing well-structured and highly accessible databases to preserve and evaluate information from reactor physics (IRPhE), criticality safety (ICSBEP), shielding (SINBAD), fuel performance (IFPE) and isotopic composition of spent fuel (SFCOMPO). The maintenance and updating of these databases are performed in close collaboration with the NEA Data Bank.

The contents of the above-mentioned databases were as follows in 2011:

- the IRPhE handbook contained 53 series of reactor physics experiments performed at 31 reactor facilities;
- the ICSBEP handbook contained nearly 4 416 critical or subcritical configurations;
- the SINBAD database contained 45 radiation shielding, 31 fusion neutronic shielding and 23 accelerator shielding experiments;
- the IFPE database contained information on 1 452 rods/samples from various sources, comprising BWR, AGR, PHWR, PWR and VVER reactor systems;
- the SFCOMPO database contained 246 samples from 14 commercial reactors and is being restructured to improve user access to the data.

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Data Bank

The Data Bank operates as an international centre of reference for its member countries with respect to basic nuclear tools, such as computer codes and nuclear data, used for the analysis and prediction of phenomena in the nuclear field. It provides a direct service to its users by acquiring, developing, improving and validating these tools and making them available upon request.

Highlights

- Slovenia joined the Data Bank as a member country.
- Approximately 120 participants from 19 countries and 2 international organisations attended the workshops and training courses organised by the Computer Program Services.
- A new version of the nuclear data display program, JANIS 3.3, was made available online through Java Web Start.
- Three Working Party on International Nuclear Data Evaluation Co-operation (WPEC) reports – on the uranium-235 capture cross-section in the keV to MeV energy region, on the assessment of the unresolved resonance treatment for cross-section and covariance representation, and on the assessment of existing nuclear data adjustment methodologies – were issued.

Computer program services

In line with its general mission, the Data Bank acts, in most of its member countries, as a focal point for the collection, validation and dissemination of computer codes and integral experiments. In order to provide rapid and reliable service to members, the Data Bank strives to employ the most modern computer technology and electronic communication techniques.

The main users of the Data Bank computer program services are national laboratories (50%); nuclear industry, vendors and utilities (25%); and universities (25%). During 2011, the Data Bank distributed some 2 230 programs and integral experiments upon request. About 130 of these programs and integral experiments were sent to authorised non-OECD countries according to a special co-operative agreement with the International Atomic Energy Agency (IAEA).

The Data Bank also tested and added 89 new or new versions of programs and integral experiments to the collection, which contains over 2 500 in total covering all nuclear energy applications. The areas of application that attracted most interest in 2011 were reactor safety analysis and radiation shielding.

Detailed information about material available from the computer program services can be accessed via the NEA website at www.oecd-nea.org/dbprog/. News about updates are provided in an electronic newsletter.

Knowledge transfer

As part of the Data Bank services, training courses on the utilisation of the most popular computer programs are organised regularly. During 2011, six workshops and training courses were organised by the Data Bank. The areas covered were computational radiation physics, uncertainty analysis in dosimetry and radiation transport using Monte Carlo codes. Approximately 120 participants from 19 countries and 2 international organisations attended in all.

Preservation of information from integral experiments

In close co-operation with other parts of the NEA, the Data Bank has established a number of databases containing information from integral experiments. These data are especially important for the validation and benchmarking of computation methods and programs used in member countries to model different nuclear systems. The databases maintained and updated by the Data Bank are:

- SINBAD (integral shielding experiments);
- IFPE (International Fuel Performance Experiments);
- ICSBEP (International Criticality Safety Benchmark Evaluation Project);
- CCVM (CSNI Code Validation Matrix for LWR LOCA and transients);
- IRPhE (International Reactor Physics Benchmark Experiments).

New editions of the SINBAD, IFPE, IRPhE and ICSBEP databases were issued in 2011.

More than 1 000 copies of these databases were distributed in 2011. The most popular of the databases was SINBAD with almost 400 experiments distributed, followed by IFPE and the CCVM.

Nuclear data services

The nuclear data services are to a very large extent provided through direct online access to the EVA, EXFOR and CINDA databases containing evaluated, experimental and bibliographic data respectively. Users can also access these data using the Java-based nuclear information software (JANIS), which facilitates the visualisation, comparison and manipulation of such data.

The updated JANIS version 3.3 implements new features such as searches over ranges of nuclide Z and A numbers; the possibility to save plots in PDF format; the display of the radioactive nuclide production index from the ENDF File 8; the display of neutron and proton drip lines; and automatic detection of the file format to open or import. It also includes improvements in ergonomy, memory usage and plot aspects. The new version is available on the JANIS web page: www.oecd-nea.org/janis.

As part of the international network of Nuclear Reaction Data Centres (NRDC), the Data Bank is responsible for the compilation in the EXFOR database of experimental reaction data measured in member countries. In 2011, the NEA contributed over 220 entries for neutron- and charged-particle-induced reaction data.

The Data Bank also develops JANIS-based tools to help check the format correctness of EXFOR files. These tools are used at the Data Bank to peer review EXFOR files submitted to the NRDC as well as the EXFOR master file shared among Data Centres.

Methods developed within the WPEC Subgroup 30 framework to further improve the quality of the EXFOR database are being implemented at the Data Bank (for details, see NEA/WPEC-30 and *NEA News,* Vol. 29, No. 1, June 2011).

The JEFF Project

Following the adoption by the French nuclear industry of the latest version of the Joint Evaluated Fission and Fusion nuclear data library (JEFF-3.1.1), it was decided to continue the efforts to further improve the data by developing new versions, which should preserve JEFF-3.1.1 performance and respond to the users' needs for both fission and fusion applications, e.g. covariance data and photon production.

An update of the JEFF-3.1.1 general purpose file will be released early in 2012 as JEFF-3.1.2. It will include new evaluated files for hafnium isotopes and fission products with photon production data.

A major update of all JEFF sub-libraries is also in preparation. A test file was assembled in 2011 as a first step towards JEFF-3.2, which should be released by mid-2013.

International nuclear data evaluation co-operation

The NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC) provides a worldwide framework for co-operative activities between major nuclear data evaluation projects. In 2011, WPEC subgroups issued three reports.

Subgroup 29 was established to investigate calculated-over-experiment ratio (C/E) discrepancies in fast uranium-core integral parameters observed with all major evaluated libraries. Its final report reviews the capture cross-section of uranium-235 (^{235}U) and describes sensitivity analyses performed to better understand the influence of other nuclear data on these integral parameters. Members of Subgroup 29 concluded that there has been a possible overestimation of the ^{235}U capture cross-section in the 0.1-2.5 kiloelectron volt (keV) energy range and provided recommendations for future work in the NEA/WPEC-29 report.

Subgroup 32 reviewed and assessed the methodologies used in the unresolved resonance region for cross-section and covariance representation. Its final report describes investigations made on the use of the single-level Breit-Wigner formalism in this energy region and recommends improving the cross-section and covariance representation in the ENDF format (see NEA/WPEC-32).

Subgroup 33 is studying methods and issues in the combined use of integral experiments and covariance data with the objective of recommending a set of best, consistent practices in order to improve evaluated nuclear data files. Its first intermediate report reviews and assesses the existing nuclear data adjustment methodologies (see NEA/WPEC-33).

These reports and more information on the current work of WPEC subgroups are available at www.oecd-nea.org/science/wpec.

The Thermochemical Database (TDB) Project

The Data Bank works together with the NEA Radiological Protection and Radioactive Waste Management Division on a thermochemical database project examining the key elements required for geochemical modelling of deep geological repositories. Teams of international experts are carrying out critical reviews of bibliographic references and have set up a quality-assured database. Further details are provided in the section on Joint Projects and Other Co-operative Projects (see page 38).

In-house computer services

The Data Bank is responsible for NEA in-house computer services comprising internet and data servers connected to a fast network. In 2011, the NEA internet server registered 1.4 million visits, during which 4.1 million web pages were browsed and some 12.5 terabytes were downloaded.

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Legal Affairs

Nuclear Law Committee (NLC)

The NLC promotes the development, strengthening and harmonisation of nuclear legislation governing the peaceful uses of nuclear energy in member countries and selected non-member countries. It supports the adoption, implementation and modernisation of national and international nuclear liability regimes. Under its supervision, the NEA analyses and disseminates information on nuclear law through a regular publications programme and two education programmes (the International School of Nuclear Law and International Nuclear Law Essentials).

Highlights

- Signatories to the 2004 Protocols to revise the Paris Convention and the Brussels Supplementary Convention made good progress towards preparing for the ratification and implementation of the provisions of those protocols into their national legislation, including finding ways to financially secure those nuclear risks for which operators are unable to obtain private insurance.
- The NLC held a special session on nuclear third party liability issues arising from the Fukushima accident.
- The first session of a new educational programme, International Nuclear Law Essentials (INLE), was successfully launched in October 2011.
- Two issues of the *Nuclear Law Bulletin* (NLB) were published, including articles on the evolution of international nuclear law in the 25 years between the Chernobyl and Fukushima accidents, the regulatory and institutional framework in Japan in the context of Fukushima, the liability and compensation regime applicable to Fukushima, the legal and regulatory aspects of long-term operation of nuclear power plants in NEA member countries, the Convention on supplementary compensation for nuclear damage and the harmonisation of nuclear liability law within the European Union, the status of radioactive waste repository development in the United States and the European Council Radioactive Waste Directive.

Development and harmonisation of nuclear legislation

Ensuring adequate and equitable compensation for third party damage caused by a nuclear incident continued to attract the highest level of attention amongst member countries, especially following the Fukushima Daiichi accident. Those countries which are party to the Paris and Brussels Supplementary Conventions on nuclear third party liability worked towards implementing the 2004 Protocols amending those conventions. A few are still facing delays in implementation because, among other reasons, private nuclear risk insurers are unable to provide full coverage for certain risks which nuclear operators are obliged to assume under the revised conventions; such risks include the cost of reinstating an impaired environment and claims instituted more than ten years after the occurrence of a nuclear incident.

The NLC held a special session addressing legal aspects related to the Fukushima Daiichi accident. Mr. Toyohiro Nomura, Professor at Gakushuin University and member of the Dispute Reconciliation Committee for Nuclear Damage Compensation, and Mr. Taro Hokugo, Deputy-Director of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), attended the NEA Nuclear Law Committee and described Japan's nuclear liability system and its application to the accident at the Fukushima Daiichi nuclear power plant, providing an overview of the compensation process.

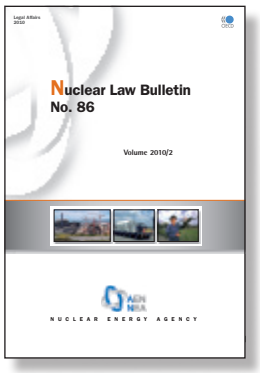
NEA Legal Affairs staff participated in the informal Third Party Liability Group which has been set up by the European Commission to analyse the potential harmonisation of national legislation regarding nuclear liability. The aim is to ensure legal coherence within the EU in line with international principles. The main objectives are to improve victims' protection in the different member states and to address the impact of diverging financial guarantee obligations. The group intends to provide recommendations for a potential Commission proposal under Article 98 of the Euratom Treaty.

Nuclear law publication programme

The 87th and 88th issues of the *Nuclear Law Bulletin* (NLB) were published. The NLB is a unique international publication for both professionals and academics in the field of nuclear law. It provides subscribers with authoritative and comprehensive information on nuclear law developments. Published twice a year in both English and French, it features topical articles written by renowned legal experts, covers legislative developments worldwide and reports on

OECD/NEA, F. Vuillaume

The 2011 INLE session was attended by 35 participants from 19 countries.



relevant case law, international agreements as well as regulatory activities of international organisations. All but the latest three editions of the NLB are freely available online at www.oecd-nea.org/law/nlb. The most recent editions are available on subscription through the OECD bookshop at www.oecdbookshop.org.

Country profiles on the regulatory and institutional framework for nuclear activities in OECD member countries are available at www.oecd-nea.org/law/legislation/. The NEA website also proposes a listing of "Latest legislative developments", which tracks recent nuclear legislative events prior to their publication in the *Nuclear Law Bulletin;* the listing can be found at www.oecd-nea.org/law/legislation/updates.html.

Nuclear law education programmes

The 11th session of the International School of Nuclear Law (ISNL), a unique academic programme organised by the NEA and the University of Montpellier 1, was held from 22 August to 2 September 2011. Over the past eleven sessions, the ISNL has provided a high-quality educational experience to more than 600 participants from around the world. This session attracted 56 participants from 33 countries who benefited from lectures delivered by 25 highly renowned experts. A special panel session focused on the impact of the Fukushima Daiichi accident on international nuclear safety, radiological protection and emergency management instruments. Participants enrolled in the ISNL have the possibility of applying for a University Diploma in International Nuclear Law recognised by the University of Montpellier 1. This diploma is also recognised within the ECTS (European Credit Transfer & Accumulation System). Further information may be obtained at www.oecd-nea.org/law/isnl/.

In October, the NEA Legal Affairs section hosted the first session of a new programme called International Nuclear Law Essentials (INLE). Some 35 participants from 19 countries participated in this one-week comprehensive course covering various aspects of international nuclear law. Built on the success of the International School of Nuclear Law (ISNL), the INLE is designed to provide focused, relevant and practical training to mid- to senior-level professionals. Renowned experts from international organisations, governments and private industry led lectures, discussions and case studies. The following 13 topics were addressed: introduction to nuclear law; international radiological protection standards; nuclear accident notification and assistance; nuclear safety; nuclear regulatory activities; management of spent fuel and radioactive waste; nuclear activities and environmental law; liability, compensation and insurance for nuclear damage; non-proliferation of nuclear weapons and international safeguards for nuclear materials; nuclear security: physical protection, illicit trafficking and terrorism; international trade in nuclear material and equipment; transport of nuclear materials and fuel; and nuclear law in context. More information is available at www.oecd-nea.org/law/inle/.

The Summer Institute of the World Nuclear University (WNU), an intensive six-week programme aimed at building future leadership in nuclear science and technology, took place from 9 July to 20 August at Oxford University in the United Kingdom. NEA Legal Affairs and the IAEA Office of Legal Affairs co-ordinated the nuclear law component.

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NUCLEAR SAFETY RESEARCH

The Halden Reactor Project

The Halden Reactor Project, operated by the Norwegian Institute for Energy Technology (IFE), was established in 1958 and is the largest NEA project. It brings together an important international technical network in the areas of nuclear fuel reliability, integrity of reactor internals, plant control/monitoring and human factors. The programme is primarily based on experiments, product prototype developments and analyses carried out at the Halden establishment in Norway. It is supported by approximately 100 organisations in 19 countries. The project benefits from stable and experienced organisation and a technical infrastructure that has undergone substantial developments over the years. Its objectives have been continuously adapted to users' needs.

In 2011, work in the fuel area included continued testing of high burn-up fuel under loss-of-coolant accident (LOCA) conditions. These are the only LOCA tests that are currently being performed in-pile worldwide, and complement the work done at laboratory scale in other institutions, notably in Japan and the United States. The tests carried out thus far have provided valuable insights and have been the basis for benchmarking exercises carried out by the Working Group on Fuel Safety on properties of UO_2, gadolinia and MOX fuels under a variety of conditions relevant to operation and licensing. Long-term irradiations have been carried out with advanced and standard nuclear fuel at high initial rating conditions. Corrosion and creep behaviour of various alloys were studied. The experimental programme on the effect of water chemistry variants on fuel and reactor internals materials has been expanded. Tests to investigate the cracking behaviour of reactor internals materials in boiling and pressurised water reactors continued, with the aim of characterising the effect of water chemistry and material ageing.

The programme on human factors has focused on experiments in the Halden man-machine laboratory, related data analyses, new control station designs, evaluations of human-system interfaces, process and instrumentation optimisation, and digital instrumentation and control (I&C). This involves *inter alia* the use of the Halden Virtual Reality Centre. Progress has been made in the area of human reliability assessment (HRA), aiming to provide data suitable for probabilistic safety assessments and to improve the validity of HRA methods.

The main results of the programme were reported at the 36th Enlarged Halden Programme Group meeting, where about 170 participants from all the project's member countries met with some 130 members of Halden staff. There were also a regular meeting of the Halden Programme Group in Hungary in May, and two meetings of the Halden Board of management in 2011. The latter approved the project's new programme of work for the 2012-2014 mandate.

The BIP-2

The Behaviour of Iodine Project (BIP), hosted by Atomic Energy of Canada Limited (AECL) and supported by 13 member countries, started in September 2007 and was completed in March 2011. The work consisted of three tasks:

- quantification of the relative contributions of homogeneous bulk aqueous phase processes, homogeneous aqueous phase processes in paint pores and heterogeneous processes on surfaces to organic iodine formation;
- the measurement of adsorption/desorption rate constants on containment surfaces as a function of temperature, relative humidity and carrier-gas composition;
- the provision of Radioiodine Test Facility (RTF) data from five RTF experiments to participants, for use in collaborative model development and validation.

The final report was approved as a CSNI public report in December 2011.

A three-year follow-up project, BIP-2, started in April 2011 with the following objectives:

- to obtain a more detailed and mechanistic understanding of iodine adsorption/desorption on containment surfaces by means of new experiments with well characterised containment paints and paint constituents and novel instrumentation (spectroscopic methods);
- to obtain a more detailed and mechanistic understanding of organic iodide formation by means of new experiments with well characterised containment paints and paint constituents and novel instrumentation (chromatographic methods);
- to develop a common understanding on how to extrapolate confidently from small-scale studies to reactor-scale conditions.

A first meeting of the steering body was held in 2011 which was devoted to discussing the test matrix for this new three-year programme.

The Cabri Water Loop Project

The Cabri Water Loop Project, which began in 2000, is investigating the ability of high burn-up fuel to withstand the sharp power peaks that can occur in power reactors due to postulated rapid reactivity insertions in the core (RIA accidents). The project participants, from 13 member countries, intend to determine the limits for fuel failure and the potential consequences of possible ejection of fuel into the coolant environment. Different cladding materials and fuel types are being studied. Project execution involves substantial facility modifications and upgrades, and consists of 12 experiments with fuel retrieved from power reactors and refabricated to suitable length. The experimental work is being carried out at the *Institut de*

radioprotection et de sûreté nucléaire (IRSN) in Cadarache, France, where the Cabri reactor is located. Programme execution can, however, involve laboratories in participating organisations, for instance, in relation to fuel fabrication and characterisation and instrumentation.

Two tests (still using the sodium loop) were carried out with high burn-up fuel cladded with zirconium-niobium material. Fuel that had been in service in Spanish and French reactors, respectively with ZIRLO and M5 cladding, and with burn-up in excess of 70 MWd/kg, was subjected to a ~100 cal/g energy injection during the transients. No fuel failure was registered.

In 2011, the reconstruction of the reactor and the construction of the water loop test facility, including the new core envelope and the security tube of the pressurised water loop, were largely finished and commissioning tests started. The resumption of the tests in the framework of the Cabri Water Loop Project is expected in 2013.

The Cabri tests are being complemented by additional reactivity-initiated accident (RIA) tests performed in Japan. These tests, which constitute the in-kind contribution from the Japan Atomic Energy Agency (JAEA) for its participation in the project, will be carried out under both cold and hot coolant conditions, and with both BWR and PWR fuel.

A meeting of the Cabri Technical Advisory Group was held in April 2011 and the meeting of the Project Steering Committee in February 2011.

The LOFC Project

The Loss of Forced Cooling (LOFC) Project started in April 2011 with seven countries participating following a recommendation of the CSNI Task Group on Advanced Reactor Experimental Facilities (TAREF) for gas-cooled reactor safety studies. The LOFC experiments to study the effects of reduction of reactor cavity cooling system (RCCS) performance are highly relevant for safety assessments of advanced reactors such as the high-temperature reactor. The experiments are to be run by the Japan Atomic Energy Agency (JAEA) in its high-temperature engineering test reactor (HTTR) in Oarai, Japan.

The objectives of the proposed project are to conduct integrated large-scale tests of LOFC in the HTTR reactor, to examine HTGR safety characteristics in support of regulatory activities, and to provide data useful for code validation and improvement of simulation accuracy. The objectives of the experimental programme are to:

- provide experimental data to clarify the anticipated transient without scram (ATWS) in case of LOFC with occurrence of reactor re-criticality;
- provide experimental data for validation of the most important safety aspects regarding reactor kinetics, core physics and thermal hydraulics;
- provide experimental data to verify the capabilities of the codes regarding the simulation of phenomena coupled between reactor core physics and thermal hydraulics.

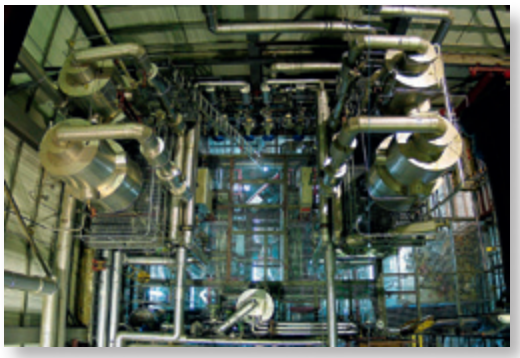
These goals will be achieved by using the HTTR to perform three test cases. The comparison of their results will provide the incremental performance availability within the vessel cooling system (VCS) range. The LOFC tests will be initiated by tripping all three helium gas circulators (HGCs) of the HTTR while deactivating reactivity control to disallow reactor scram due to abnormal reduction of primary coolant flow rate. They will address ATWS with occurrence of reactor re-criticality, and will be conducted with and without active function of the VCS.

A first meeting of the project's steering bodies was held in 2011 during which participants discussed the results of the first test. The latter will be used for benchmarking calculations by participants.

The PKL-2 Project

The PKL-2 Project, which ran from July 2007 to December 2011, consisted of eight experiments carried out in the *Primär Kreislauf* (PKL) thermal-hydraulic facility, which is operated by AREVA NP in Erlangen, Germany, together with side experiments conducted in the PMK facility in Budapest, Hungary and in the ROCOM facility in Rosendorf, Germany. The experiments investigated safety issues relevant for current PWRs as well as for new PWR design concepts, and focused on complex heat transfer mechanisms in the steam generators and boron precipitation processes under postulated accident situations.

Two meetings of the steering bodies were held in 2011. Participants discussed the preparation and the results of the counterpart test with the ROSA-2 Project addressing small break LOCA with accident management procedures. It was agreed to organise in October 2012, jointly with the ROSA-2 Project, a second and concluding analytical workshop to discuss progress in reactor coolant system (RCS) thermal-hydraulic modelling with systems codes and initial results achieved in modelling with computational fluid dynamics (CFD) codes. A proposal for a follow-up programme prepared by AREVA with side experiments at ROCOM, PMK and PACTEL (Finland) was discussed and, based on the interest expressed by most participants, a draft agreement for a new phase was prepared in December 2011 for statement of interest, with the new phase expected to start in spring 2012.



AREVA, France

Top view of the PKL facility in Erlangen.

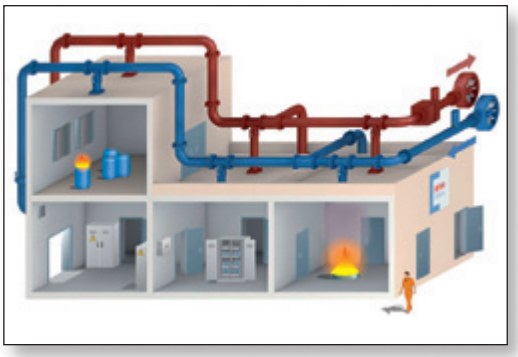
The PRISME-2 Project

Fire is a significant contributor to overall core damage frequency for both new and old plant designs. Some of the technical studies related to fire probabilistic safety analysis (PSA) that remain open are the following: the propagation of heat and smoke through a horizontal opening between two superposed compartments; fire spreading on real fire sources such as cable trays and electrical cabinets;

and fire extinction studies of the performance of various fire extinction systems.

The Fire Propagation in Elementary, Multi-room Scenarios (PRISME-2) Project (from the French *Propagation d'un incendie pour des scénarios multi-locaux élémentaires*) is a follow-on project from the PRISME project which ran from 2006 to 2011. A final report of the PRISME Project will be prepared in early 2012, and a concluding seminar will be held in Aix-en-Provence, France at the end of May 2012. The PRISME-2 Project began in July 2011 and will run until June 2016. It currently has eight participating countries. The project's objective is to answer questions concerning smoke and heat propagation inside a plant by means of experiments tailored for code validation purposes. In particular, the project aims to provide answers regarding the failure time for equipment situated in nearby rooms and the effect of conditions such as room-to-room communication and the configuration of the ventilation network. The results obtained for the experimentally studied scenarios will be used as a basis for qualifying fire codes (either simplified zone model codes or computational fluid dynamics codes). After qualification, these codes could be applied for simulating other fire propagation scenarios in various room configurations with a good degree of confidence.

The first tests for the PRISME-2 Project were carried out at the IRSN experimental facilities in Cadarache at the end of 2011. The first meeting of the PRISME-2 management board and programme review group took place in October 2011. At that time, the analytical working group of the new PRISME-2 Project met to discuss a schedule for a series of benchmark exercises needed to conduct cross-comparisons and validations of code modelling approaches.

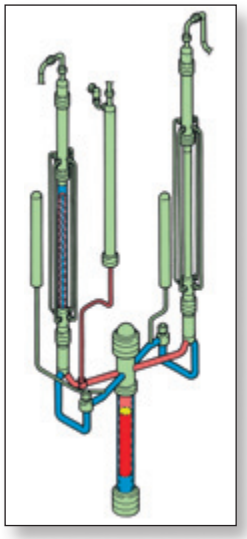


OECD/NEA, PRISME-2 Project

The IRSN DIVA facility for fire propagation studies.

The ROSA-2 Project

A first Rig-of-Safety Assessment (ROSA) Project was carried out from 2005 to 2009 to address issues in thermal-hydraulics analyses relevant to LWR safety using the ROSA large-scale test facility of the Japan Atomic Energy Agency (JAEA). In particular, it focused on the validation of simulation models and methods for complex phenomena that may occur during transients/accidents. The project was supported by safety organisations, research laboratories and industry in 14 countries, and provided an integral and separate-effect experimental database to validate the code predictive capability and accuracy of models. In particular, temperature stratification and coolant mixing during emergency coolant injection, unstable and disruptive phenomena such as water hammer, natural circulation under high core power conditions, natural circulation with superheated steam, primary cooling through steam generator secondary depressurisation, and upper-head break and bottom break LOCA were addressed by the 12 tests carried out. The project was successfully completed and the final report was released on DVD.



OECD/NEA, ROSA-2 Project

Sketch of the JAEA ROSA-LSTF facility.

A second phase of the project, called ROSA-2 and using the same large-scale test facility, started in April 2009 with the support of 14 countries. The ROSA-2 Project is to last for three years (extended by six months due to the Fukushima Daiichi accident) and initially consisting of six tests on:

- intermediate break LOCAs (for risk-informed, break-size definition and verification of safety analysis codes);
- steam generator tube rupture (SGTR) and SGTR with steam line break (for improvement and new proposals regarding accident management and mitigation/emergency operation).

All six tests have been successfully performed, including two counterpart tests with PKL. The recent participation of China, which joined as an associate member, will enable a seventh test based on an intermediate cold leg break LOCA with full availability of the emergency core cooling system.

As mentioned above, a joint PKL-2/ROSA-2 workshop will be organised in October 2012, and will include in particular presentation and discussion of the two counterpart tests and the related analytical work.

The SCIP-2

The Studsvik Cladding Integrity Project (SCIP) started in July 2004 and completed its first five-year mandate in 2009, when several power ramps and a hot cell programme addressing the various failure mechanisms were executed. The nuclear fuel failure mechanisms studied in the first phase of the project were:

- pellet-cladding interaction (PCI): stress corrosion cracking initiated at the cladding inner surface under the combined effect of the mechanical loading and chemical environment caused by an increase in the fuel pellet temperature following a power increase;
- hydride embrittlement: time-independent fracture of existing hydrides;
- delayed hydride cracking (DHC): time-dependent crack initiation and propagation through fracture of hydrides.

In December 2008, all members of the project steering bodies indicated their interest in continuing the project for another five-year period. SCIP-2 thus began in July 2009 with the participation of 13 countries (two more than in the first phase). The main objective of SCIP-2 is to generate the high-quality experimental data needed for improving the understanding of dominant failure mechanisms for

water reactor fuels and to devise means for reducing fuel failures. The major focus will be on cladding failures caused by pellet-cladding mechanical interaction, especially stress corrosion and hydrogen-assisted fracture mechanisms, as well as on the propagation of cladding cracks. Improved understanding based on experiments and analyses is needed in order to reduce the occurrence, or the risk of occurrence, of fuel failures. This understanding is to be applicable to pellet-cladding interaction conditions that can arise during normal operation or anticipated transients, as well as during long-term fuel storage. The proposed programme is intended to complement other international projects in the fuel area. Extensive analyses and theoretical modelling of the fracture mechanisms are to accompany the experimental programme.

In addition to reviewing existing Studsvik ramp data, the project will study the following fuel failure mechanisms:

- pellet-cladding mechanical interaction (PCMI), the mechanical driving force for PCI and hydrogen-induced failures;
- pellet-cladding interaction (PCI), notably when cladding fails due to stress corrosion cracking;
- hydrogen-induced failures, in particular as regards zirconium alloys, classic hydride embrittlement (HE) and delayed hydrogen cracking (DHC).

Two meetings of the project steering bodies took place in 2011, as well as a workshop on fuel rod behaviour modelling.

The SERENA Project

The Steam Explosion Resolution for Nuclear Applications (SERENA) Project was launched in 2007 with nine member countries participating to evaluate the capabilities of the current generation of fuel-coolant interaction (FCI) computer codes to predict steam-explosion-induced loads in ex-vessel reactor situations. It includes a limited number of focused tests with advanced instrumentation reflecting a large spectrum of ex-vessel melt compositions and conditions, as well as the required analytical work to bring the code capabilities to a sufficient level for use in reactor case analyses. The objective of the SERENA experimental programme is threefold:

- to provide experimental data to clarify the explosion behaviour of prototypic corium melts;
- to provide experimental data for validation of explosion models for prototypic materials, including spatial distribution of fuel and void during the pre-mixing and at the time of explosion, and explosion dynamics;
- to provide experimental data for the steam explosion in more reactor-like situations to verify the geometrical extrapolation capabilities of the codes.

These goals will be achieved by using the complementary features of the TROI (Korea Atomic Energy Research Institute) and KROTOS (French *Commissariat à l'énergie atomique*) corium facilities, including analytical activities. The KROTOS facility is more suited for investigating the intrinsic FCI characteristics in one-dimensional geometry. The TROI facility is better suited for testing the FCI behaviour of these materials in reactor-like conditions by having more mass and multi-dimensional, melt-water interaction geometry. The validation of models against KROTOS data and the verification of code capabilities to calculate more reactor-oriented situations simulated in TROI will strengthen confidence in code applicability to reactor FCI scenarios.

One meeting of the project steering bodies was held in 2011. The results of two new tests were presented and discussed, enabling a better specification of the test configurations for the last test to be performed early in 2012. In parallel, analytical activities were undertaken to prepare and to assess these tests. A benchmark on a reactor case is ongoing. A concluding seminar will be organised in the latter half of 2012.

The SETH-2 Project

The SETH-2 Project was conducted from June 2007 to December 2010 and made use of the Swiss PANDA facility and the French MISTRA facility. Nine countries participated. The project aimed to resolve key computational issues for the simulation of thermal-hydraulic conditions in reactor containments and benefited from the complementarity of the two facilities. This was a follow-up to the SESAR Thermal-hydraulics (SETH) Project, conducted from 2001 to 2007, which provided data on containment three-dimensional gas flow and distribution issues important for code prediction capability improvements, accident management and design of mitigating measures.

In September 2011, a concluding seminar of the SETH-2 Project was organised to consider the lessons learnt from this project, including the application to reactor scale. The seminar attracted 50 participants from 16 countries. The project's final summary report was endorsed by the CSNI at its December 2011 meeting. On this occasion a proposal for a new project, called HYMERES, using the PANDA and MISTRA facilities to address remaining issues regarding hydrogen mitigation in reactor containments in the case of complex situations, was discussed. A draft agreement will be circulated for comments and statement of interest early in 2012.

The SFP Project

The Sandia Fuel Project (SFP), supported by 13 member countries, began in 2009. The objective of the project is to perform a highly detailed thermal-hydraulic characterisation of full-length, commercial fuel assembly mock-ups to provide data for the direct validation of severe accident codes. Code predictions based on previous results indicate that fuel assemblies can ignite and radially propagate in a complete loss-of-coolant accident. Hence, there is a need for qualified data obtained under representative fuel configurations. The experiments should focus on thermal-hydraulic and ignition phenomena in PWR 17x17 assemblies and supplement earlier results obtained for BWR assemblies. Code validations based on both the PWR and BWR experimental results will considerably enhance the code applicability to other fuel assembly designs and configurations.

The project is scheduled to last three years and to be conducted in two phases. Phase 1 was performed in 2011 and focused on axial heating and burn propagation. Phase 2 will address radial heating and burn propagation, and will include effects of fuel rod ballooning.

Two meetings of the project steering bodies were held in June and November 2011 during which the programme of work for 2012 was approved.

The STEM Project

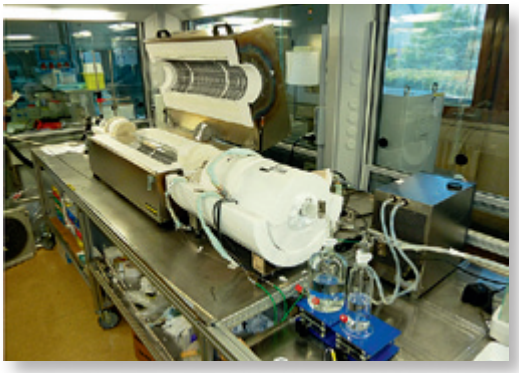
The Source Term Evaluation and Mitigation (STEM) Project was initiated in 2011 to improve the general evaluation of the source term. The reduction of known uncertainties regarding specific phenomena is expected to help:

- provide better information and tools to emergency teams enabling a more robust diagnosis and prognosis of the progression of an accident and a better evaluation of potential release of radioactive materials;
- investigate phenomena involved in possible complementary mitigation measures, natural or engineered, so as to minimise releases to the environment.

The STEM Project is a four-year programme supported by seven countries and conducted at the IRSN facilities in Cadarache, France. It will address three main issues:

- Radioactive iodine release in the mid- and long term: in complement to previous programmes, it is proposed to perform experiments to study the stability of aerosol particles under radiation and the long-term gas/deposits equilibrium in a containment.
- Interactions between iodine and paints: no experiments are planned at this stage, but a literature survey specifically focused on the effect of paint ageing will be carried out. The survey is likely to lead to the definition of experiments in a possible follow-up project.
- Ruthenium chemistry: in complement to previous programmes, it is proposed to perform experiments to study ruthenium transport in pipes.

The first meeting of the steering bodies was held in 2011 during which the overall test matrix of experiments to be performed was discussed.



OECD/NEA, STEM Project

Study of ruthenium deposition in piping at IRSN Cadarache.

The THAI-2 Project

Phase 2 of the Thermal-hydraulics, Hydrogen, Aerosols and Iodine (THAI-2) Project started in July 2011 with the support of ten member countries. It is a follow-up to the THAI Project conducted from 2007 to 2009. The new experiments will also be conducted in the THAI facility operated by Becker Technologies GmbH in Germany. The *Gesellschaft für Anlagen- und Reaktorsicherheit* (GRS) and AREVA NP also support the programme.

The objective of this follow-up project is to address remaining questions and to provide experimental data relevant to high-temperature gas reactor (HTGR) graphite dust transport issues, specific water-cooled reactor aerosol and iodine issues, and hydrogen mitigation under accidental conditions. The project will address open questions concerning the behaviour of: a) graphite dust transport in a generic HTGR geometry, b) release of gaseous iodine from a flashing jet and iodine deposition on aerosol particles, and c) hydrogen combustion during spray operation and passive autocatalytic recombiner operation in case of extremely low oxygen content. Understanding the respective processes is essential for evaluating the challenges posed for next-generation reactors (such as the HTGR), the amount of airborne radioactivity during accidents with core damage (iodine and aerosols) and containment integrity (hydrogen). The programme will generate valuable data for evaluating atmospheric flows and subsequently graphite dust transport in a generic multi-compartment geometry. Regarding fission products, the programme will focus on iodine release from a flashing jet and gaseous iodine deposition on aerosols. In terms of hydrogen mitigation, the programme will focus on hydrogen combustion during spray operation and on its effective removal by means of passive autocatalytic recombiners when approaching oxygen starvation. An analytical effort will accompany the experimental programme, mainly consisting of code calculations for pre-test assessments, result evaluations and extrapolation to reactor situations.

The first meeting of the steering bodies was held in 2011 during which the overall test matrix of experiments to be performed was discussed.

NUCLEAR SAFETY DATABASES

The COMPSIS Project

The Computer-based Systems Important to Safety (COMPSIS) Project was undertaken in 2005 by ten member countries with an initial mandate of three years. The second phase of the project ran from January 2008 to December 2011. To the extent that analogue control systems are being replaced by software-based control systems in nuclear power plants worldwide, and that the failure modes of both hardware and software in these new systems are rare, there is a considerable advantage in bringing the experience of several countries together. The project's objective was to contribute to the improvement of safety management and to the quality of software risk analysis for software-based equipment.

Work during the first part of the project concentrated on the development of the COMPSIS data collection guidelines, quality assurance and data exchange interface. Countries began submitting data in 2006; however, the total number of event records in the database at the end of the second phase remained low, with a majority of records coming from a single country. One meeting of the COMPSIS steering body was held in 2011 and the final report of the second phase was submitted to the CSNI. Based on the situation of this database after seven years of operation, the CSNI decided not to undertake a new phase and is considering other means to address the issue of computer system failures.

The FIRE Project

The Fire Incidents Records Exchange (FIRE) Project started in 2002. A third phase of the project began in January 2010 for a duration of four years. Twelve countries participate. The main purpose of the project is to collect and to analyse data related to fire events in nuclear environments, on an international scale. The specific objectives are to:

- define the format for, and collect fire event experience (by international exchange) in, a quality-assured and consistent database;
- collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention;
- generate qualitative insights into the root causes of fire events that can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences;
- establish a mechanism for the efficient feedback of experience gained in connection with fire events, including the development of defences against their occurrence, such as indicators for risk-based inspections;
- record event attributes to enable quantification of fire frequencies and risk analysis.

The structure of the database has been well-defined and arrangements have been made in all participating countries to collect and to validate data. The quality-assurance process is in place and has proved to be efficient on the first set of data provided. An updated version of the database, which now contains more than 370 records, is provided to participants every year. Two meetings of the project steering body were held during 2011 with a view to establishing the basis for increased use of the database for probabilistic risk assessments (PRAs).

The ICDE Project

The International Common-cause Data Exchange (ICDE) Project collects and analyses operating data related to common-cause failures (CCF) that have the potential to affect several systems, including safety systems. The project has been in operation since 1998, and was extended with a new agreement covering the period April 2008-March 2011. It was also agreed in 2011 to start a new project phase which will run from April 2011 to December 2014. Eleven countries participate.

The ICDE Project comprises complete, partial and incipient common-cause failure events. It currently covers the key components of the main safety systems, such as centrifugal pumps, diesel generators, motor-operated valves, power-operated relief valves, safety relief valves, check valves, control-rod drive mechanisms, reactor protection system circuit breakers, batteries and transmitters. These components have been selected because several probabilistic safety assessments have identified them as major risk contributors in the case of common-cause failures.

Qualitative insights from data will help reduce the number of CCF events that are risk contributors, and member countries use the data for their national risk analyses. Additional activities in the area of quantification are under discussion. Reports have been produced for pumps, diesel generators, motor-operated valves, safety and relief valves, check valves and batteries. Data exchange for switchgear and breakers and reactor-level measurement was completed.

In 2011, a report on "Collection and Analysis of Common-cause Failures of Centrifugal Pumps" was finalised. This report documents a study performed on a set of ICDE events related to centrifugal pumps which had been collected in the ICDE database. Organisations from Canada, Finland, France, Germany, Japan, Spain, Sweden, the United Kingdom and the United States contributed. The study examined 353 ICDE events exhibiting at least some degree of dependency and spanning a period from 1975 to 2009. The database contains general statistical information about event attributes such as impairment of the components in the observed populations, root cause, coupling factor, detection methods and corrective actions taken. The events in the study were analysed with respect to failure modes, degree of impairment, failure symptoms, failure causes and technical fault aspects. Due to the Fukushima Daiichi accident, only one project meeting was held in 2011.

The OPDE Project

The Piping Failure Data Exchange (OPDE) Project started in 2002 and finished in June 2011 after nine years of operation. In the last three-year phase of the project, 11 countries participated and contributed data on piping failures. The project collected more than 4 000 records which will be transferred to the new CODAP (see below).

The CODAP

The Component Operational Experience, Degradation and Ageing Programme (CODAP) builds on two recent OECD/NEA projects: the Piping Failure Data Exchange (OPDE) Project which ran from May 2002 to June 2011 and produced an international database on piping service experience applicable to commercial nuclear plants, and the Stress Corrosion Cracking and Cable Ageing Project (SCAP) which ran from June 2006 to June 2010 to assess, due to their implication on nuclear safety and their relevance for plant ageing management, stress corrosion cracking (SCC) and degradation of cable insulation. Twelve countries are participating in the first phase of the CODAP which started in June 2011 and will run until December 2014.

The objectives of the CODAP are to:

- collect information on passive metallic component degradation and failures of the primary system, reactor pressure vessel internals, main process and standby safety systems, support systems (i.e., ASME Code Class 1, 2 and 3, or equivalent), and components not related to safety (non-Code) but with significant operational impact;
- establish a knowledge base for general information on component and degradation mechanisms such as applicable regulations, codes and standards, bibliography and references, R&D programmes and proactive actions, information on key parameters, models, thresholds and kinetics, fitness for service criteria, and information on mitigation, monitoring, surveillance, diagnostics, repair and replacement;

- develop topical reports on degradation mechanisms in close co-ordination with the CSNI Working Group on Integrity and Ageing of Components and Structures (WGIAGE).

During 2011, two meetings of the Programme Review Group were held to define the structure and content of the CODAP database. The overall programme of work was also discussed, including the support from the project Clearinghouse.

RADIOACTIVE WASTE MANAGEMENT

The CPD

The NEA Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD) is a joint undertaking functioning under an agreement among 25 organisations actively executing or planning the decommissioning of nuclear facilities. The objective of the CPD is to acquire and to share information from operational experience in the decommissioning of nuclear installations that is useful for future projects. It has operated under Article 5 of the NEA Statute since its inception in 1985, and a revised agreement among participants came into force on 1 January 2009 for a five-year period.

The information exchange also ensures that best international practice is made widely available and encourages the application of safe, environmentally friendly and cost-effective methods in all decommissioning projects. It is based on biannual meetings of the Technical Advisory Group (TAG), during which the site of one of the participating projects is visited, and positive and less positive examples of decommissioning experience are openly exchanged for the benefit of all. Currently 59 projects under active decommissioning (35 reactors and 24 fuel facilities) are included in the information exchange.

Although part of the information exchanged within the CPD is confidential and restricted to programme participants, experience of general interest gained under the programme's auspices is released for broader use. In this context, the CPD launched a new Task Group on Site Remediation to review the experience, approaches and techniques for nuclear site restoration. The review will include not only radiological contamination but also related contamination by chemicals and hazardous materials.

The TDB Project

The Thermochemical Database (TDB) Project was initiated in 1984 by the NEA Radioactive Waste Management Committee to fulfil the need for a high-quality database for modelling purposes in the safety assessments of radioactive waste repositories. The project's current mandate runs to January 2013, following a one-year extension decided by the TDB Management Board. Sixteen organisations from 14 countries participate.

The project has so far produced 11 volumes of internationally recognised and quality-assured thermodynamic data for the major actinides and fission or activation products. Two reviews concerning tin and iron (Part I) are being finalised for publication. Three volumes are in preparation on the chemical thermodynamics of molybdenum, iron (Part II) and the ancillary data used in the TDB Project. Related activities will be conducted for the next two years. The preparation of two state-of-the-art reports concerning the use of the Pitzer model in high ionic strength systems and the cement phases will be started in 2012.

RADIOLOGICAL PROTECTION

The ISOE

Since its creation in 1992, the Information System on Occupational Exposure (ISOE), jointly sponsored by the IAEA, has been facilitating the exchange of data, analysis, lessons and experience in occupational radiological protection (RP) at nuclear power plants worldwide. It maintains the world's largest occupational exposure database and a network of utility and regulatory authority RP experts. As of December 2011, membership included 70 participating utilities from 29 countries, and 27 regulatory authorities of 24 countries.

Four supporting ISOE Technical Centres (Europe, North America, Asia and the IAEA) manage the system's day-to-day technical operations of analysis and exchange of information and experience. The ISOE occupational exposure database itself contains information on occupational exposure levels and trends at 478 reactor units in 29 countries (394 operating units and 84 under decommissioning), thus covering about 91% of the world's operating commercial power reactors. The ISOE database, publications and annual symposia, along with the ISOE Network website, facilitate the exchange among participants of operational experience and lessons learnt in the optimisation of occupational radiological protection.

In 2011, the ISOE continued to concentrate on the exchange of data, analysis, good practice and experience in the area of occupational exposure reduction at nuclear power plants, on improving the quality of its occupational exposure database and on migrating ISOE resources to the ISOE Network website (www.isoe-network.net). The four regional ISOE Technical Centres continued to support their regional members through specialised data analyses and benchmarking visits. A regional ALARA symposium held in the United States in 2011; the Asian regional symposium which was planned to be organised in Japan was cancelled due to the Fukushima Daiichi accident.

The Expert Group on Primary Water Chemistry and Source-term Management (EGWC) was created by the ISOE Management Board at its November 2010 meeting. The objective of the EGWC is to prepare a report on radiological protection aspects of primary water chemistry and source-term management in order to reflect the current state of knowledge, technology and experience in this area. The EGWC is composed of ten members who met in June and October 2011. A draft report is in preparation which includes a discussion of relevant strategies and techniques, radiation field measurement techniques (including measurement locations and indices), remediation of contamination during outages and radiological protection outcomes.

Technical Secretariat

Generation IV International Forum (GIF)

Fourth generation nuclear power plants are the next step in the development of nuclear energy. They will succeed the early prototypes from the 1950s (first generation), the first commercial reactors developed in the 1970s (second generation), and their direct descendants such as the advanced boiling water reactor (ABWR), the AP1000 or the European pressurised reactor (EPR) (all third generation). The goals of fourth generation plants are to improve sustainability (including effective fuel utilisation and minimisation of waste), economics (competitiveness with respect to other energy sources), safety and reliability (for example, no need for offsite emergency response), as well as proliferation resistance and physical protection.

After a thorough review of roughly 100 concepts in 2002, Generation IV International Forum (GIF) members selected six systems for further R&D: the gas-cooled fast reactor (GFR), the lead-cooled fast reactor (LFR), the molten salt reactor (MSR), the sodium-cooled fast reactor (SFR), the supercritical-water-cooled reactor (SCWR) and the very-high-temperature reactor (VHTR). Detailed information on these systems can be found in the "Technology Roadmap for Generation IV Nuclear Energy Systems" (2002) and in its update entitled "GIF R&D Outlook for Generation IV Energy Systems" (2009), both available on the GIF public website (www.gen-4.org).

The NEA provides Technical Secretariat support to the technical bodies in charge of the development of the six systems and the three methodology working groups. The NEA is fully compensated for its support to the GIF through voluntary, financial and in-kind contributions made by individual GIF members.

Since the GIF Charter, which established the Forum, was signed in 2001 for a period of ten years, the 13 GIF members unanimously decided in 2011 to modify and to extend the Charter for an indefinite period, demonstrating their strong will to continue their fruitful co-operation. The 13 GIF members are Argentina, Brazil, Canada, China, Euratom, France, Japan, the Republic of Korea, the Russian Federation, South Africa, Switzerland, the United Kingdom and the United States.

Following the Fukushima Daiichi accident, the Forum reaffirmed its commitment to conducting collaborative research and development on Generation IV nuclear power plants to prevent and mitigate accidents and to attain the highest degree of safety. The Forum believes that it is essential for the next generation of nuclear power plants, anticipated for commercial deployment post-2030, to be designed with the best available safety knowledge that reflects worldwide operational experience and society's expectations. The Forum is developing safety design criteria for Generation IV nuclear power plants that incorporate lessons learnt from Fukushima, with the completion of the sodium fast reactor criteria expected in 2012.

At the end of 2011, the GIF issued "An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear Systems", an update of its "Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems" and its first report on "Proliferation Resistance and Physical Protection of the Six Generation IV Nuclear Energy Systems". The three reports are available on the GIF public website.

As regards participation in research activities, in 2011 the Russian Federation joined the SCWR system arrangement and the LFR memorandum of understanding, while China, Euratom and the Russian Federation entered detailed discussions to contribute to existing SFR projects.

Participants at the 31st GIF Policy Group meeting, held in Moscow in May 2011.

Multinational Design Evaluation Programme (MDEP)

The Multinational Design Evaluation Programme (MDEP) continues to be an important forum for discussing new reactor safety issues and exploring harmonisation and convergence opportunities for new reactor regulatory practices. MDEP members are the regulators from Canada, China, Finland, France, Japan, the Republic of Korea, the Russian Federation, South Africa, the United Kingdom and the United States. The International Atomic Energy Agency (IAEA) is closely involved in generic MDEP activities to ensure consistency with international requirements and practices. The MDEP focus on safety has become increasingly important in light of the Fukushima Daiichi nuclear accident.

2011 highlights

The MDEP Policy Group set a goal to broaden its communication activities to reach more stakeholders, such as non-MDEP regulators and other regulatory organisations, reactor vendors and licensees, standards development organisations (SDOs) and key industry groups. To this end, selected MDEP products are now available on its public web pages (www.oecd-nea.org/mdep). These include three common positions on issues related to digital instrumentation and control, on design-specific concerns related to EPR digital instrumentation and control safety systems, and on technical guidelines for the large squib valves used in the AP1000 design. Also publicly available is the Vendor Inspection Co-operation Working Group (VICWG) Witnessed and Joint Vendor Inspection Protocol, which clearly defines the roles regulators play when witnessing and participating in inspections co-ordinated by the VICWG.

The MDEP Steering Technical Committee (STC) issued a paper entitled "MDEP Steering Technical Committee Position Paper on Safety Goals" that compares how MDEP regulators define safety goals. This paper and its more detailed companion, "The Structure and Application of High-level Safety Goals" were used at the 11-15 April 2011 IAEA technical meeting to discuss approaches to safety goals.

Future MDEP-related products will include a mechanical codes comparison performed by the SDOs for Class 1 components pursuant to the Codes and Standards Working Group (CSWG) activities, and a comparison of quality assurance requirements among MDEP member countries to be carried out by the VICWG, which will take into account IAEA standards and the US NRC's 10 CFR Appendix B requirements.

On 15-16 September 2011, the 2nd MDEP Conference on New Reactor Design Activities was held at the OECD Conference Centre. Among the 120 participants were representatives of 24 national regulatory authorities and technical support organisations, major reactor vendors and licensees, the IAEA, the Western European Nuclear Regulators' Association (WENRA), the NEA Committee on Nuclear Regulatory Activities (CNRA), the European Commission (EC), the World Nuclear Association (WNA) and the World Association of Nuclear Operators (WANO). This conference was a successful step towards communicating MDEP activities to important stakeholders.

During 2011, the Policy Group also discussed the expansion of MDEP membership. The national regulatory authorities of India, the Netherlands, Turkey, the United Arab Emirates and Vietnam, among others, are interested in becoming members of the programme. India's request to become a full member is currently being reviewed. The growing interest in MDEP work is a reflection of its ability to meet its member countries' needs by comparing safety reviews, regulatory practices and licensing requirements with a view to ensuring the safety of the new reactor fleet worldwide.

2nd MDEP Conference on New Reactor Design Activities, 15-16 September 2011.

General Information

Information and Communications

Nuclear energy decision making and stakeholder participation need to be based on knowledge and understanding. The NEA seeks to provide member governments and other interested parties with a large array of information resulting from the Agency's activities, thereby enhancing awareness and understanding of the scientific, technical and economic aspects of the nuclear option.

Highlights

- The Fukushima Daiichi nuclear accident of 11 March 2011 influenced much of the Agency's communications during the year, in particular in the months immediately following the accident.
- A ministerial seminar and a high-level regulators' forum on nuclear safety and the Fukushima Daiichi nuclear accident were organised on 7-8 June 2011 in co-operation with the French Presidency of the G8-G20. Largely attended press conferences were held on both occasions.
- Five official press releases were issued in 2011, of which three were in relation to nuclear safety.
- Web 2.0 networking channels were used extensively throughout the year to communicate the Agency's latest news and events.
- The Agency produced 30 publications in 2011, of which 10 were put on sale and 20 were distributed free of charge. Overall dissemination and downloads were very strong.

The NEA is an intergovernmental agency specialised in studying the scientific, technical and economic aspects of nuclear energy. It strives to provide high-quality, factual information in a timely manner to its member countries as well as to other interested parties wishing to learn about nuclear energy's multiple aspects and the results of the Agency's work.

Public affairs and relations with the media

Relations with the media were marked in 2011 by the Fukushima Daiichi nuclear accident. In the days following the accident, a team of nuclear safety, radiological protection and communications specialists was highly mobilised daily to answer requests from the press, to help the Japanese authorities transmit information to their counterparts in NEA member countries and to provide up-to-date information on the public website. Approximately 100 interviews were organised with NEA senior staff. Significant efforts were also employed to ensure efficient internal and external co-ordination and communication, including with the OECD, the International Energy Agency (IEA) and the International Atomic Energy Agency (IAEA).

On 7-8 June 2011, the NEA co-organised two days of high-level meetings on international nuclear safety in light of the Fukushima Daiichi nuclear accident. The first event, on 7 June, was an international ministerial seminar co-organised by the French Presidency of the G8-G20 and the NEA, with 37 countries in attendance. On 8 June, the nuclear regulatory authorities of the G8, NEA member countries and other associated countries (Brazil, Bulgaria, India, Romania, South Africa and Ukraine) participated in the Forum on the Fukushima Accident: Insights and Approaches.

OECD/NEA, F. Vuillaume

Forum on the Fukushima Accident press conference of 8 June 2011.

These meetings helped establish a consensus among the participating countries on a number of key issues and provided input to the IAEA ministerial meeting held on 20-24 June. The NEA Director-General, Luis E. Echávarri, responded to questions from the press at both days' press conferences.

Five official press releases were issued in 2011, primarily covering nuclear safety and regulation in follow-up to the Fukushima Daiichi accident, but also on the security of supply of medical radioisotopes and the accession of Slovenia to the NEA. Access to a global database of journalists and media was put in place to ensure wider and more targeted dissemination of NEA news items.

Publications

In 2011, the Agency produced 30 publications, of which 10 were put on sale and 20 were distributed free of charge. The list of these publications is provided on page 50. Best sellers included the *Nuclear Law Bulletin,* followed by

Carbon Pricing, Power Markets and the Competitiveness of Nuclear Power and Nuclear Energy Data 2011. NEA publications on sale are also made widely available via the OECD/NEA Nuclear Energy iLibrary.

All free NEA reports are made available in pdf format on the NEA website. The most accessed reports during the course of the year included *Nuclear Fuel Behaviour in Loss-of-coolant Accident (LOCA) Conditions: State-of-the-art Report* (165 693 downloads), *PENELOPE-2008: A Code System for Monte Carlo Simulation of Electron and Photon Transport* (81 209 downloads), *Nuclear Fuel Behaviour under Reactivity-initiated Accident (RIA) Conditions: State-of-the-art Report* (58 514 downloads) and *Chernobyl – Assessment of Radiological and Health Impacts* (55 908 downloads).

NEA News is the Agency's specialised journal, published twice a year in English and French, which endeavours to keep NEA correspondents and other interested professionals abreast of significant findings and advances in the Agency's programme of work. It provides feature articles on the latest developments in the nuclear energy field, as well as updates on NEA work, news briefs, and information about NEA publications and forthcoming events. In 2011, both issues included special articles related to the Fukushima Daiichi nuclear accident. The first provided an overview of the accident and NEA activities undertaken in follow-up, while the second addressed liability and compensation issues. The journal is available free of charge on the Agency's website at www.oecd-nea.org/nea-news/.

Internet-based communication

The NEA's online presence plays a key role in communicating the work and accomplishments of the Agency. Website traffic was up about 10% in 2011 with an average of nearly 4 000 visitors per day or 1.4 million visits on an annual basis. The website sections that attracted the most views were, in order of magnitude: the NEA press room, nuclear safety, nuclear science, nuclear law and the NEA Data Bank's Java-based nuclear information software, JANIS.

Web 2.0 networking channels are playing an increasingly import role in communicating NEA activities. After establishing a Facebook profile in 2010, the Agency has begun using Twitter, LinkedIn and YouTube to increase visibility of NEA results, publications and events.

Subscriptions to the *NEA Monthly News Bulletin* has remained constant with approximately 22 000 subscribers. Distributed free of charge, the bulletin includes monthly updates on NEA work and newly released reports. A sign-up form is available at www.oecd-nea.org/bulletin.

Online interaction with NEA delegates continues to expand. Most NEA committees and their working groups rely extensively on electronic communication such as password-protected extranet pages, e-mail discussion lists or online collaborative work spaces.

The Delegates' Area on the NEA website also continues to provide an important service for many NEA committees and working groups. This section of the website provides authorised users with official NEA documents, information on forthcoming NEA meetings, contact details for other committee members, as well as access to the presentations and background notes prepared for the Steering Committee policy debates.

NEA visibility in international fora

The NEA co-sponsored several international events during 2011, of which the main ones included:

- 2011 ISOE North American ALARA Symposium/EPRI Radiation Protection Conference, Weston, Florida, United States, 10-12 January;
- 2011 Public Information Materials Exchange (PIME) Conference, Brussels, Belgium, 13-16 February;
- International Conference on Radioecology and Environmental Radioactivity, Hamilton, Canada, 19-24 June;
- 9th International Conference on Nuclear Criticality Safety (ICNC 2011), Edinburgh, United Kingdom, 19-22 September;
- 8th International Symposium on Radiation Safety Management (ISRM), Gyeongju, Republic of Korea; 2-4 November;
- 21st International Conference on Structural Mechanics in Reactor Technology, New Delhi, India, 6-11 November.

The NEA also organised publications and information stands at the OECD Forum in Paris in May, at the two high-level nuclear safety and regulation meetings in Paris in June (see the section on Public affairs and relations with the media for details regarding the meetings), the IAEA General Conference in Vienna in September, and the American Nuclear Society (ANS) Winter Meeting in Washington DC in October-November. Several hundred copies of NEA reports and information material were provided at other events.

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Nuclear Energy and Civil Society

Nuclear regulators and the public

Information officers from regulatory bodies meet once a year under the auspices of the Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC) to exchange information and experience related to communication with the public and to carry out related studies. In 2011, the main activity of the WGPC consisted of finalising a report on crisis communication in the case of high media interest. Based on this report, a roadmap for crisis communication was prepared. Following the Fukushima Daiichi accident, the WGPC undertook an assessment of the roadmap and decided that it would be useful to extend it to events having an international dimension. This will be the topic of an international workshop with senior regulators, regulatory communicators and stakeholders from civil society to be held in May 2012.

Radioactive Waste Management Committee (RWMC) Forum on Stakeholder Confidence (FSC)

In May 2011, the FSC held its 8th workshop and community visit in Östhammar, Sweden, on "Actual Implementation of a Spent Nuclear Fuel Repository: Seizing Opportunities". The workshop, attended by 90 participants, was timely: after a site selection process involving two municipalities for well over a decade, Östhammar was retained in 2010 as the site for Sweden's high-level radioactive waste repository and the application to begin construction was submitted by the SKB waste management organisation just six weeks before the workshop. Delegates reviewed how the environmental impact assessment (EIA) was employed over the years as an "umbrella process" for information exchange and civil society participation. The unique Swedish funding systems were examined as well. The Waste Fund has supported competence-building by local and regional stakeholders as well as ONGs. In the repository licensing phase and beyond, local economic development is assured through the innovative Added Value Programme. The workshop facilitated exchanges and comparisons with international counterparts and helped identify issues requiring attention as the licensing phase unfolds. The workshop proceedings will be available online at www.oecd-nea.org/fsc/.

At its 12th regular meeting in Paris in September 2011, the FSC considered experiences of "early involvement" of civil society in decision making. Long a primary recommendation by practitioners, and promoted in international and national law, early involvement in radioactive waste management may be accomplished using various intensive or extensive procedures. Also discussed were two academic studies: one on siting and the other on assessing community willingness to host a repository. A final area of discussion reflected the need for radioactive waste management organisations to anticipate the future. In this connection, the FSC explored the potential impact of social media on citizen involvement and decision making. Challenges for a long-term management and decision process stem from the different standards of transparency, accountability and responsibility that may frame stakeholders' interventions in virtual fora. The topical discussions at the meeting also allowed delegates to refine entries in a growing compendium of terminology and concepts studied over the past 11 years. A glossary is currently in preparation for online release.

Participants at the 8th FSC workshop in Östhammar, Sweden.

Radiological protection

The importance and implications of stakeholder participation in radiological protection decision making have been addressed by the NEA Committee on Radiation Protection and Public Health (CRPPH) since the early 1990s, beginning with the Committee's 1994 collective opinion, continuing through three stakeholder involvement workshops in 1998, 2001 and 2003, addressing the balance of science and values in radiological protection in two workshops in 2008 and 2010, and specifically looking at stakeholder involvement in post-nuclear emergency management at a workshop also in 2010.

The CRPPH had planned to continue this work in 2011 by holding the 3rd Science and Values workshop to be hosted by the Japanese government, but the Fukushima Daiichi accident prevented its effective organisation. As a result, the CRPPH reconsidered the workshop programme and decided that it should be held in late 2012 in Japan. In the context of the Fukushima Daiichi accident, and the extensive national and international efforts that are already being made to learn lessons and share experience, the CRPPH decided not to have this workshop focus on the accident per se, but will use some of the key consequence management decisions and situations to explore how the relevant science and values on which decisions are or will be made can best be understood and expressed in a transparent fashion.

Organisational Structure of the NEA

The Nuclear Energy Agency (NEA) is a semi-autonomous body of the Organisation for Economic Co-operation and Development. OECD member countries wishing to participate in the activities of the Agency must make a formal request to join. Of the 34 OECD member countries, 30 are members of the NEA:

Australia	Germany	Mexico	Spain
Austria	Greece	Netherlands	Sweden
Belgium	Hungary	Norway	Switzerland
Canada	Iceland	Poland	Turkey
Czech Republic	Ireland	Portugal	United Kingdom
Denmark	Italy	Republic of Korea	United States
Finland	Japan	Slovak Republic	
France	Luxembourg	Slovenia	

The NEA is governed by the **Steering Committee for Nuclear Energy**. This committee is primarily made up of senior officials from national atomic energy authorities and associated ministries. It oversees and shapes the work of the Agency to ensure its responsiveness to member countries' needs, notably in establishing the biennial programmes of work and budgets. It approves the mandates of the seven standing technical committees.

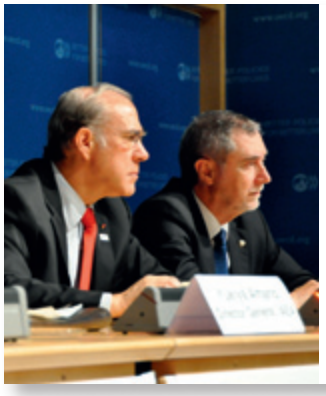
The members of the **Bureau of the Steering Committee** for Nuclear Energy are (as at its autumn 2011 meeting):

- Mr. Richard STRATFORD (United States), Chair
- Ms. Marie-Elise HOEDEMAKERS (Netherlands), Vice-Chair
- Dr. Kwang-Yong JEE (Republic of Korea), Vice-Chair
- Mr. Frédéric MONDOLONI (France), Vice-Chair
- Mr. Kazuo SHIMOMURA (Japan), Vice-Chair
- Ms. Marta ŽIAKOVA (Slovak Republic), Vice-Chair

The standing technical committees are primarily composed of member country experts and technical specialists. These committees constitute a unique feature and important strength of the NEA, providing flexibility for adapting to new issues and helping to achieve consensus rapidly. Their main areas of work are listed in the chart on the next page.

The Steering Committee for Nuclear Energy and the Agency's seven standing technical committees are serviced by **the NEA Secretariat,** composed in 2011 of 69 professional and support staff from 18 countries. Professional staff are often specialists from national administrations and research institutes, bringing their experience to the Agency for two to five years on average.

Participation in the work of the Agency by **non-member countries** is an established practice. The Russian Federation holds regular observer status in all the Agency's standing technical committees and their working groups and applied for NEA membership in 2011. Experts from selected other countries, including China and India, take part in NEA activities on a more ad hoc basis.



OECD Secretary-General A. Gurría with NEA Director-General L. Echávarri; OECD headquarters.

NEA Committee Structure in 2011

Steering Committee for Nuclear Energy

Committee on the Safety of Nuclear Installations — CSNI

- CSNI Programme Review Group (CSNI PRG)
- Working Group on Risk Assessment (WGRISK)
- Working Group on Analysis and Management of Accidents (WGAMA)
- Working Group on Integrity of Components and Structures (IAGE)
- Working Group on Human and Organisational Factors (WGHOF)
- Working Group on Fuel Safety (WGFS)
- Working Group on Fuel Cycle Safety (WGFCS)
- Task Group on Sump Clogging (SC)

Committee on Nuclear Regulatory Activities — CNRA

- Senior-level Task Group on Impacts of the Fukushima Accident
- Senior-level Task Group on Challenges in Long-term Operation at Nuclear Power Plants – Implications for Regulatory Bodies
- Working Group on Inspection Practices (WGIP)
- Working Group on Public Communication of Nuclear Regulatory Organisations (WGPC)
- Working Group on Operating Experience (WGOE)
- Working Group on the Regulation of New Reactors (WGRNR)

Radioactive Waste Management Committee — RWMC

- RWMC Regulators' Forum (RWMC-RF)
- Integration Group for the Safety Case (IGSC)
- Forum on Stakeholder Confidence (FSC)
- Working Party on Decommissioning and Dismantling (WPDD)

Committee on Radiation Protection and Public Health — CRPPH

- Expert Group on Radiological Protection Aspects of the Fukushima Accident (EGRPF)
- Expert Group on the Implications of ICRP Recommendations (EGIR)
- Expert Group on Occupational Exposure (EGOE)
- Expert Group on Best Available Techniques (EGBAT)
- Working Party on Nuclear Emergency Matters (WPNEM)
- Expert Group on the Implementation of International Recommendations for Emergency Situations (EGIRES)

Nuclear Science Committee — NSC

- Expert Group on Integral Experiments for Minor Actinide Management
- Working Party on International Nuclear Data Evaluation Co-operation (WPEC)
- Working Party on Scientific Issues of the Fuel Cycle (WPFC)
- Working Party on Multi-scale Modelling of Fuels and Structural Materials for Nuclear Systems (WPMM)
- Working Party on Nuclear Criticality Safety (WPNCS)
- Working Party on Scientific Issues of Reactor Systems (WPRS)

Executive Group of the NSC (Data Bank Management Committee)

- The Scientific Co-ordination Group of the Joint Evaluated Fission and Fusion (JEFF) Data Project

Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle — NDC

- High-level Group on the Security of Supply of Medical Radioisotopes
- Joint NEA/IAEA Group on Uranium (UG)
- Working Party on Nuclear Energy Economics (WPNE)
- Ad hoc Expert Group on the Economics of the Back End of the Nuclear Fuel Cycle
- Ad hoc Expert Group on the Economics of Lifetime Extension and Management
- Ad hoc Expert Group on Managing Environmental and Health Impacts of Uranium Mining

Nuclear Law Committee — NLC

NEA Secretariat Structure in 2011

Luis Echávarri
Director-General

Janice Dunn Lee
Deputy Director-General

Uichiro Yoshimura
Deputy Director
Safety and Regulation

Thierry Dujardin
Deputy Director
Science and Development

Serge Gas
Head
Central Secretariat, External Relations and Public Affairs

Ricardo Lopez
Head
Management Support Unit

Julia Schwartz
Head
Legal Affairs

Javier Reig
Head of Division
Nuclear Safety

Hans Riotte
Head of Division
Radiological Protection and Radioactive Waste Management

Ron Cameron
Head of Division
Nuclear Development

Jim Gulliford
Head of Section
Nuclear Science

Kiyoshi Matsumoto
Head
Data Bank

NEA Publications and Brochures Produced in 2011

General interest

Annual Report 2010
ISBN 978-92-64-99159-0. 52 pages. Free: paper or web.

Rapport annuel 2010
ISBN 978-92-64-99160-6. 52 pages. Gratuit : versions papier ou web.

NEA News, Volumes 29.1 and 29.2
ISSN 1605-9581. Free: paper or web.

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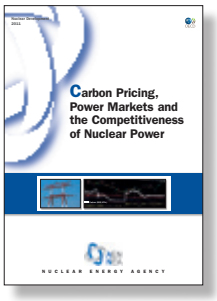

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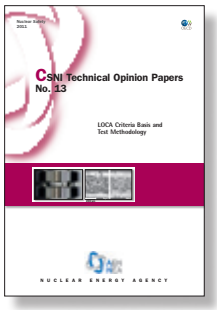

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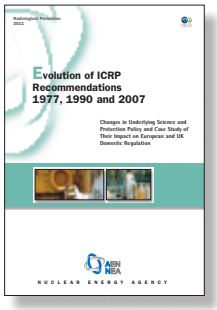

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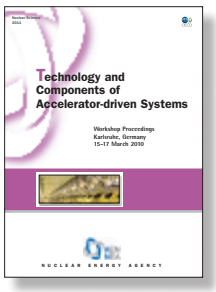

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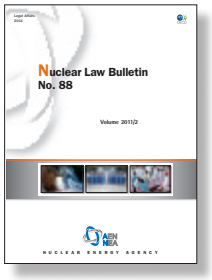

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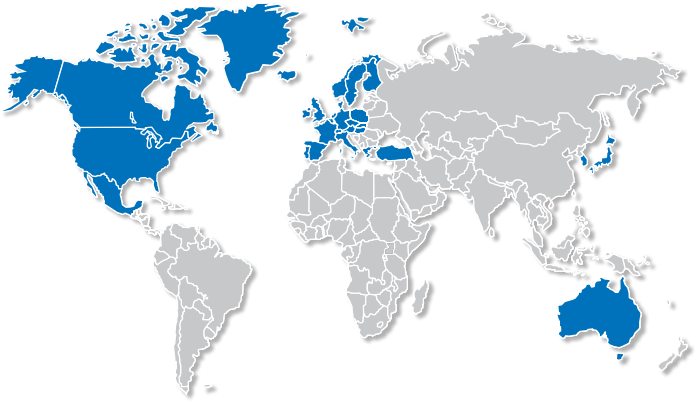

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