

Nuclear Safety Review for the Year 2012

GC(56)/INF/2

Nuclear Safety Review
for the Year 2012

IAEA/NSR/2012

Printed in the IAEA in Austria
July 2012

Foreword

The *Nuclear Safety Review for the Year 2012* contains an analytical overview of the dominant trends, issues and challenges worldwide in 2011 and the Agency's efforts to strengthen the global nuclear safety framework. This year's report also highlights issues and activities related to the accident at the Fukushima Daiichi nuclear power plant. The analytical overview is supported by the Appendix at the end of this document, entitled: *The IAEA Safety Standards: Activities during 2011*.

A draft version of the Nuclear Safety Review for the Year 2012 was submitted to the March 2012 session of the Board of Governors in document GOV/2012/6. The final version of the *Nuclear Safety Review for the Year 2012* was prepared in light of the discussions held during the Board of Governors and also of the comments received.

Table of Contents

Executive Summary	1
Analytical Overview.....	8
A. Reviewing the accident at the TEPCO Fukushima Daiichi nuclear power plant.....	8
A.1. Background [5].....	8
A.2. The Agency's response [4].....	11
A.3. Site Safety.....	15
A.3.1. Site hazard assessment	15
A.3.2. Design qualification and re-evaluation against external hazards.....	17
A.3.3. Evaluating for safety: multiple hazards on multi-unit sites	20
A.4. Severe accident management	21
A.5. Regulatory Effectiveness.....	23
B. Managing emergency preparedness and response.....	27
B.1. Trends and issues.....	27
B.2. Activities.....	28
B.3. Future challenges.....	29
C. Reviewing the safety aspects and long term management of ageing nuclear power plants and research reactors.....	31
C.1. Trends and issues in managing the safety of ageing nuclear power plants.....	31
C.1.1. Activities.....	33
C.1.2. Future challenges.....	33
C.2. Trends and issues in managing the safety of ageing research reactors.....	34
C.2.1. Activities.....	35
C.2.2. Future challenges.....	36
D. Preparing emerging nuclear energy countries	36
D.1. Trends and issues.....	36
D.2. Activities	37
D.3. Future challenges.....	38
E. Reviewing the safety of future reactor designs	39
E.1. Trends and issues.....	39
E.2. Activities.....	39
E.3. Future challenges.....	40

F.	Limiting radiation exposure	40
F.1.	Trends and issues	40
F.2.	Activities	42
F.3.	Future challenges	43
G.	Ensuring nuclear transport safety	44
G.1.	Trends and issues.....	44
G.2.	Activities	45
G.3.	Future challenges.....	46
H.	Working towards decommissioning, remediation and waste solutions.....	46
H.1.	Trends and issues.....	46
H.2.	Activities	47
H.3.	Future challenges.....	47
I.	Civil liability for nuclear damage.....	47
I.1.	Trends and issues	47
I.2.	International activities.....	48
I.3.	Future challenges	49
J.	Key reference documents	50
	Appendix	51
A.	Summary	51
A.1.	Long term structure and format for the IAEA safety standards	51
A.2.	Strategies and processes for the establishment of IAEA safety standards	52
A.3.	Synergies and interface between the IAEA safety standards and the Nuclear Security Series	52
A.4.	Review of the IAEA safety standards in light of the Fukushima accident	53
B.	The current status of IAEA Safety Standards.....	54
B.1.	Safety fundamentals.....	54
B.2.	General safety standards (applicable to all facilities and activities)	54
B.3.	Specific Safety Standards (applicable to specified facilities and activities).....	55
B.3.1.	Nuclear Power Plants.....	55
B.3.2.	Research Reactors.....	56
B.3.3.	Fuel Cycle Facilities	57
B.3.4.	Radioactive Waste Disposal Facilities.....	57
B.3.5.	Mining and Milling.....	58
B.3.6.	Applications of Radiation Sources	58
B.3.7.	Transport of Radioactive Material.....	58

Executive Summary

The *Nuclear Safety Review 2012*¹ focuses on the dominant nuclear safety trends, issues and challenges in 2011; it is organized and divided into these major sections:

- The Executive Summary provides a condensed version of the contents of the report;
- Section A provides a summary of the progression of the accident at the Tokyo Electric Power Company (TEPCO) Fukushima Daiichi nuclear power plant (hereinafter referred to generally as “the Fukushima accident”) together with a recapitulation of the Agency’s response and a review of the preliminary lessons learned in specific nuclear safety areas (site safety and design considerations, severe accident management and regulatory effectiveness);
- Sections B – I cover global nuclear safety trends, issues and challenges in 2011 in these areas: managing emergency preparedness and response; reviewing the safety aspects and long term management of ageing nuclear power plants and research reactors; preparing emerging nuclear energy countries; reviewing the safety of future reactor designs; limiting radiation exposure; ensuring nuclear transport safety; working towards decommissioning, remediation and waste solutions; and, reviewing issues in civil liability for nuclear damage;
- Section J contains a list of key reference documents used to prepare this report. These documents are cited throughout the report, and are listed in this section, with links to online versions for ease of reference. Note that some documents reside on the Agency’s restricted-access GOVATOM website and some on its public website;
- The Appendix provides details on the activities of the Commission on Safety Standards (CSS), and the current status of the IAEA Safety Standards Series.

Under its mandate, the Agency is encouraged to assist and if requested to act, as an intermediary for the purposes of intergovernmental, science and technology-based challenges inherent in nuclear safety both by tackling immediate issues — as was the case in the Fukushima accident in March 2011 — and by shaping solutions to global issues that require significant time and great care to implement — as is the case with the IAEA Action Plan on Nuclear Safety recently approved by the Board. In 2011, these cross-cutting issues have drawn on nearly every aspect of the Secretariat’s capabilities and resources to improve the state of nuclear safety worldwide.

The Fukushima accident, caused by the Great East Japan Earthquake and Tsunami of 11 March 2011, brought nuclear safety to the forefront of global attention and underlined the responsibility of Member States in this crucial area. Specifically, prime responsibility for nuclear safety is borne by every

¹ The information formerly contained in accompanying Notes by the Secretariat has been redistributed: the Note by the Secretariat covering international safety-related events and activities will be found in the IAEA Annual Report for 2011, as well as in the report, Measures to Strengthen International Cooperation in Nuclear, Radiation, Transport and Waste Safety. The information contained in the previous Note by the Secretariat on safety standards activities has been incorporated into this report as an Appendix.

operator licensed to run a nuclear facility, with every Member State that utilizes nuclear technology and by every national regulatory body overseeing such facilities.

In accordance with its central role in this area, the Agency establishes standards, comprising fundamental safety principles, requirements and measures so as to achieve a high level of safety in nuclear applications. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste. The Agency facilitates the application of its safety standards through peer reviews, advisory services, capacity-building workshops, and training and education programmes, as requested by Member States.

At the end of its fourth term in December 2011 (which began in January 2008), the Commission on Safety Standards (CSS) provided the Director General with its four-year report highlighting the goals achieved and setting out challenges and recommendations for the future². The achievements included the establishment of a long-term structure for the IAEA Safety Standards Series, the development of *Strategies and Processes for the Establishment of IAEA Safety Standards* (SPSS)³, the establishment of a short term and a long term vision for addressing synergies between safety and security, and the establishment of a plan for the review of the IAEA safety standards in the light of the Fukushima accident. In this regard, in November 2011, the CSS discussed the methodology for conducting the review of the safety standards in terms of scope, prioritization, approach, process, and timeline for the review, as well as possible options for subsequent revisions of those safety standards where necessary.

A joint task force was established in 2009 by the Advisory Group on Nuclear Security (AdSec) and CSS, and met over a period of two years. The task force discussed measures to improve the review and approval processes for and enhance interaction with Member States' representatives in the development of the Nuclear Security Series guidance documents. Additionally, the task force discussed the feasibility of establishing a single series of Agency standards covering both safety and security while respecting the specific character of each; it prepared a final report on its conclusions, which was approved by a joint session of AdSec and the CSS and submitted to the Director General in November 2011.

General Safety Requirements Part 3, entitled *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (revised BSS), was approved by the Board of Governors in September 2011. The revised BSS have strengthened the requirements governing measures to protect the public and the environment from radiation exposure.

Efforts are currently under way to review and update relevant safety standards to take into account the lessons learned from the Fukushima accident, giving special emphasis to standards that cover multiple severe hazards, multiple and single-unit sites, reactor cooling and fuel storage, as well as other safety-significant areas.

In the aftermath of the Fukushima accident, the Agency conducted a number of missions to Japan at the request of the Japanese Government. In particular, a team of experts undertook a fact-finding

² *Commission on Safety Standards — Fourth Term Report 2008–2011* (issued on 7 December 2011). The report can be downloaded at:
<http://www-ns.iaea.org/committees/files/css/204/CSS4yreport2008-2011final12December2011.doc>.

³ *Strategies and Processes for the Establishment of IAEA Safety Standards (SPSS) — Version 1.1*, 10 March 2011. The document can be downloaded at:
<http://www-ns.iaea.org/downloads/standards/spss.pdf>.

mission to Japan from 24 May to 2 June 2011. The results of this mission were reported to the IAEA Ministerial Conference on Nuclear Safety held at Agency Headquarters in Vienna, Austria, from 20 to 24 June 2011.

The IAEA Ministerial Conference on Nuclear Safety was convened to direct, under the leading role of the Agency, the process of learning and acting upon lessons following the Fukushima accident to strengthen nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide. At the Conference, a Ministerial Declaration was adopted, —which inter alia— requested the Director General to prepare a draft Action Plan, building on the Ministerial Declaration, the conclusions and recommendations of the three Working Sessions, and the expertise and knowledge available therein, to cover all of the relevant aspects relating to nuclear safety, emergency preparedness and response, and radiation protection of people, society and the environment, as well as the relevant international legal framework.

A draft IAEA Action Plan on Nuclear Safety was subsequently developed through an extensive process of consultations with Member States, approved by the Board of Governors and endorsed by the 55th General Conference, in September 2011. Its aim is to strengthen nuclear safety worldwide in light of the Fukushima accident through 12 main actions, each with corresponding sub-actions, focusing on: safety assessments ('stress tests'); Agency peer reviews; emergency preparedness and response; national regulatory bodies; operating organizations; Agency safety standards; the international legal framework; countries embarking on nuclear energy programmes; capacity building; protecting people and the environment from ionizing radiation; communication and information dissemination; and research and development.

Member States, including China, India, the Republic of Korea, Turkey, United Arab Emirates and Vietnam, continue to look to nuclear energy to meet their ever growing needs for clean energy. Other countries are even accelerating their nuclear energy programmes. For example, France is building its first advanced reactor, with plans for a second already being drawn up; the Russian Federation seeks to double its nuclear energy output by 2020, with several reactors around the country currently under construction; and, the United Kingdom has plans to build additional reactor units. However, some countries, including Belgium, Germany, Italy and Switzerland, have decided to phase out and discontinue the use of nuclear power, partly as a consequence of lack of public support and in some cases—public opposition. Several other countries, such as Austria, Denmark, Greece and New Zealand, remain opposed to nuclear power. For a detailed review of the latest projections for worldwide nuclear energy, see the *Nuclear Technology Review for 2012*.

With over 14 792 reactor-years of commercial operation in 33 countries, the operational level of NPP safety around the world remains high, as indicated by safety data collected by the Agency (and incorporated into its Power Reactor Information System (PRIS) database) and by the World Association of Nuclear Operators (WANO). Figure 1 shows the total number of unplanned reactor shutdowns ('scrams'), including both automatic and manual scrams, which occurred per 7 000 hours of critical power reactor operation. This data is helpful in monitoring performance in reducing the number of unplanned total reactor shutdowns and is commonly used to gauge improvement levels in plant safety. As shown in Figure 1, steady improvements have been achieved in recent years, although there is room for further improvement.

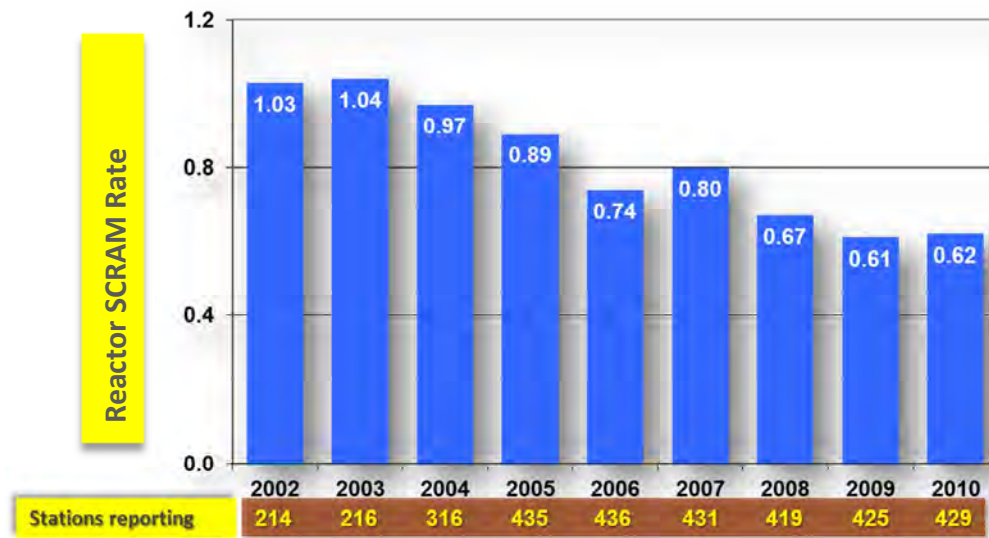


FIG. 1. Total number of unplanned reactor shutdowns ('scrams'), including both automatic and manual scrams, which occurred per 7 000 hours of critical power reactor operation.

By the end of 2011, of the 435 NPPs operating in the world, 32% were more than 30 year's old, and 5% were in operation for more than 40 years. There are growing expectations that older nuclear reactors should meet enhanced safety objectives, closer to those of recent reactor designs. Therefore, operators of older nuclear power plants need to address concerns about their ability to fulfil these expectations and to continue to economically and efficiently support Member States' energy requirements. The challenges in establishing comprehensive ageing management programmes revolve mainly around ensuring that the safety functions of all structures, systems and components (SSCs) that could be impacted by ageing effects are taken into account and addressed.

About 70% of the 254 operating research reactors have been in operation for more than 30 years, with many of them exceeding their original design life. Maintenance work on two of the five major isotope-producing research reactors in the world required long preparation and repair times, as well as a significant financial investment. As ageing research reactors become increasingly unreliable, this puts increasing pressure on the global medical isotope supply and the production capacity of the other isotopes producers.

Countries that are newcomers to nuclear energy face challenges in developing the necessary infrastructures and acquiring the necessary prerequisite skills to meet project milestones. Additionally, more than 20 Member States have initiated plans for new research reactor projects. The Agency has identified capacity building as a primary issue which Member States have to resolve, since it has found significant weaknesses in some Member States areas, such as: legislative, regulatory, technical, educational and safety infrastructures. Strong and early governmental support is required to facilitate the establishment of these infrastructures. In order to assist in this process, the Agency provides various safety standards and guidance documents — in particular, *Milestones in the Development of a National Infrastructure for Nuclear Power* (IAEA Nuclear Energy Series No. NG-G-3, Vienna, 2007) and *Establishing the Safety Infrastructure for a Nuclear Power Programme* (IAEA Safety Standards Series No. SSG-16, Vienna, published in 2012). An additional challenge for newcomer countries will be to apply the lessons learned from the Fukushima accident, when developing their nuclear infrastructures. Further to this endeavour, the Agency continues to support a number of international

knowledge networks and forums such as the Global Nuclear Safety and Security Network (GNSSN), regional networks such as the Asian Nuclear Safety Network (ANSN), the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO), the Forum of Nuclear Regulatory Bodies in Africa (FNRBA), the Arab Network of Nuclear Regulators (ANNuR) and the Regulatory Cooperation Forum (RCF).

Future reactor designs available for deployment in the near term have undergone a combination of testing and modelling to demonstrate improvements in their safety features. More innovative designs are expected to need more effort to test and demonstrate the effectiveness of their enhanced safety features. The Agency continues to investigate issues related to transportable nuclear power plants (TNPPs) with particular attention given to floating reactors, which are designed to meet the energy needs of islands or remote areas. These include an assessment of whether the current international legal framework and safety standards are applicable and appropriate for this technology. A publication on the legal and institutional issues of transportable NPPs, drafted under the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), is currently under review by the Agency.

Analyzing the results from Emergency Preparedness Reviews (EPREV) and Integrated Regulatory Review Service (IRRS) missions, weaknesses in the overall compliance with Agency's Safety Standards on *Preparedness and Response for a Nuclear or Radiological Emergency* (IAEA Nuclear Safety Series No. GS-R-2, Vienna, 2002)⁴ were found. In several Member States, weaknesses were identified in regulatory body competences, infrastructure, emergency exercise and training programmes. The challenges faced in communication with some Member States were highlighted during the response to the Fukushima accident, in which a relatively high rate of unsuccessful delivery of telefax messages occurred. To date, 63% of the 134 Member States with designated points of contact need to register in the Unified System for Information Exchange in Incidents and Emergencies (USIE) in order to receive alert messages through this system. However, in absence of being registered in USIE, Member States will receive telefax messages to their designated contact points whenever alert messages are sent by the Secretariat.

Issues related to limiting the health and environmental effects of radiation for 2011 focused on the following areas:

- Indoor radon is one of the largest contributors to the worldwide collective effective dose from all sources of radiation and is responsible for between 3% and 14% of all lung cancer cases worldwide every year. The revised BSS approved by the Board of Governors in September 2011 include strengthened requirements governing the protection of the public from radon. All Member States need to evaluate the extent of radon exposure within their national territories to determine whether additional actions are required.
- The worldwide nuclear workforce is dwindling and becoming increasingly more mobile. This poses challenges with regard to tracking and managing the cumulative dose employees receive throughout their working lives from all the sites at which they may be stationed. Additionally, radiation management and training programmes need to be implemented or strengthened; especially

⁴ The Commission on Safety Standards has approved the document preparation profile for the revision of GS-R-2 which will become General Safety Requirements (GSR) Part 7. The revision will also incorporate lessons learned from the nuclear accident at the TEPCO Fukushima Daiichi nuclear power plant. See the Appendix for specific information on this topic.

for unskilled, itinerant workers, who are currently the group of workers most at risk worldwide in terms of occupational overexposure.⁵

- Following further consideration by the International Commission on Radiological Protection (ICRP), the threshold of absorbed dose for the eye lens has been substantially reduced. These changes have been incorporated into the revised BSS, and will require careful investigation of the workplaces concerned and the development of a graded approach to implement the new limits in practice.
- As was reported in the *Nuclear Safety Review for the Year 2010*, the effective dose per capita worldwide from medical exposure for patients has doubled since the early nineties and continues to grow, especially for those patients receiving multiple computed tomography (CT) scans within a few years or even in a single year. This trend continued in 2011.⁶ For more information on these topics, see F. Limiting radiation exposure.
- Furthermore the Fukushima accident caused the release of a wide spectrum of radionuclides to the environment. As a result, a large number of people had to be evacuated from the area in order to prevent exposures above the predefined reference levels. The assessment of exposures to the population and the environment in the Fukushima area is subject to current studies of WHO and UNSCEAR respectively with support and involvement of the Agency.

Even with established safety standards for the transport of radioactive materials in place,⁷ delays and denials of shipment persisted in 2011 — partly due to fears arising from lack of information on the safe handling of radioactive materials, and also to difficulties in implementing overly complex local or national regulations. The Fukushima accident gave rise to worldwide challenges in radiation monitoring, as well as the regulation and control of transport, which served to highlight the lack of a common approach, of a fully effective regulatory system, and of general capacity. One of the conclusions to emerge from the International Conference on the Safe and Secure Transport of Radioactive Material: The Next Fifty Years of Transport — Creating a Safe, Secure and Sustainable Framework, held at Agency Headquarters in Vienna, Austria, from 17 to 21 October 2011,⁸ was that during global crises transport suffers severe repercussions, such as the disruption or closing down of major transport routes, further preventing people, products and food from reaching their required destinations. Radionuclide-contaminated sites around the world required or still require remediation. Additionally, the Fukushima accident will require extensive post-accident remediation efforts that will generate large volumes of contaminated material running into millions of cubic metres. For more information, see H. Working towards decommissioning, remediation and waste solutions.

The importance of having effective civil liability mechanisms in place to insure against harm to human health and the environment, as well as economic loss caused by nuclear damage, remains a subject of increased attention among States. The IAEA Action Plan on Nuclear Safety specifically calls for the establishment of a global nuclear liability regime that addresses the concerns of all States that might be affected by a nuclear accident with a view to providing appropriate compensation for nuclear damage,

⁵ Technical Meeting *Development of Guidance Material on the Management of the Radiation Protection Programme for Itinerant Workers*, Vienna, 21-24 November 2011

⁶ *Nuclear Safety Review for the Year 2010* (document GC(55)/INF/3 issued in July 2011). Available online at: http://www.iaea.org/About/Policy/GC/GC55/GC55InfDocuments/English/gc55inf-3_en.pdf

⁷ See the Appendix, Section B.3.7. “Transport of Radioactive Material” for more information on transport-related safety standards.

⁸ See the conference web page at: <http://www-pub.iaea.org/mtcd/meetings/Announcements.asp?ConfID=38298>.

and calls on the IAEA International Expert Group on Nuclear Liability (INLEX), to recommend actions to facilitate achievement of such a global regime.

The work of the past year, as detailed in this report, has shown that multiple international efforts and combined vigilance of all Member States and international organizations are fundamental to strengthening the Global Nuclear Safety Framework in our increasingly interconnected and interdependent world. Additionally, the role and involvement of civil society and the high expectations that it places in all stakeholders to effectively implement, monitor and strengthen concrete nuclear safety measures, now more than ever, cannot be overemphasized.

Analytical Overview

A. Reviewing the accident at the TEPCO Fukushima Daiichi nuclear power plant

A.1. Background [5]



1. Built from 1967 to 1979, the Fukushima Daiichi nuclear power plant (NPP) was constructed and operated by the Tokyo Electric Power Company (TEPCO). The Fukushima Daiichi NPP has six boiling water reactor (BWR) units. Unit 1 is a BWR-3 reactor with a Mark I containment, Units 2–5 are BWR-4 reactors with Mark I containments, and Unit 6 is a BWR-5 reactor with a Mark II containment. The total power generating capacity of the facility is 4.696 GW. The Fukushima Daiichi NPP is located near the towns of Okuma and Futaba, in Futaba County, Fukushima Prefecture, facing the Pacific Ocean on the eastern coast of Japan.

2. The individual units of the Fukushima Daiichi NPP were designed to withstand earthquakes with a design basis earthquake ground motion of 0.6g (g being the acceleration due to gravity) and a tsunami height of 5.7 m for the site.⁹ The most powerful earthquake which this plant had hitherto experienced was the Miyagi 1978 earthquake, which had a magnitude of 7.4 on the Richter scale (the ground acceleration was 0.125g for 30 seconds) and triggered only a small tsunami. All units were inspected after this earthquake, but no damage to any of the critical parts of the reactor was discovered.

3. Following the application by TEPCO in April 2010 for approval of continued operation of Unit 1 of the Fukushima Daiichi NPP, upon request from NISA, Japan Nuclear Safety Organization (JNES) confirmed the technical adequacy of Aging Management Evaluation and Long Term Maintenance Control Policy, and reported according to NISA in February 2011.¹⁰

⁹ Instead of magnitude as such, NPPs are designed to take into account the effects of vibratory ground motion caused by earthquakes, i.e. acceleration of ground motion at the free surface of the base stratum.

¹⁰ JNES annual report 2010, p 81. April 2010 – March 2011.

4. On 11 March 2011, at 05:46 UTC, an earthquake of magnitude 9.0 and subsequent tsunami with an unprecedented run-up height¹¹ of ~14 m occurred off the east coast of Honshu, Japan. According to reports provided by NISA, several nuclear power facilities were affected by severe ground motion and large multiple tsunami waves: Tokai, Higashi Dori, Onagawa, and the Fukushima Daiichi and Daini plants. The operational units at these facilities were successfully shut down by the automatic systems installed for the detection of earthquakes. However, the large tsunami waves affected all these facilities to varying degrees, with the most serious consequences occurring at the Fukushima Daiichi NPP.¹²

5. Although all off-site power was lost when the earthquake occurred, upon detection of the earthquake, the automatic systems at the Fukushima Daiichi NPP successfully inserted control rods into its three operational reactors, and all the available emergency diesel generators became operational. However, about 46 minutes after the earthquake, the first of a series of large tsunami waves reached the site and overran the 5.7 m sea wall designed to protect it.

6. The tsunami inundated the Fukushima Daiichi site, causing the loss of all power sources except for one emergency diesel generator (generator 6-B providing emergency power to be shared between Units 5 and 6). With no other significant power source available on or off site, the ability to cool the reactors was drastically reduced or even completely lost. The operators faced a catastrophic and unprecedented emergency scenario, with no power, no reactor control, almost no instrumentation, and severely affected communications systems. They had to work in darkness to secure the safety of six reactors, six associated fuel pools, a common fuel pool, and dry cask storage facilities.

7. Without backup power, venting and seawater injections could not alleviate the resulting lack of cooling to the active fuel and spent fuel pools. Reactor temperature increased and eventually led to hydrogen explosions at Units 1, 3 and 4, considerably damaging or destroying portions of these reactor buildings, fuel damage was suspected in Units 1, 2 and 3.

8. On March 12, NISA had first rated the event as Level 3 on the International Nuclear Event Scale (INES) and later, upgraded the rating at Level 5 (on March 18), and at Level 7 (on April 12). All INES ratings were provisional.

9. The nuclear accident at Fukushima Daiichi NPP caused the release of a wide spectrum of radionuclides to the environment. As a result, a large number of people had to be evacuated from the area in order to prevent exposures above predefined reference levels.

10. On 12 March 2011, many towns within 20 km surrounding the Fukushima Daiichi NPP evacuated residents. As new information emerged on the levels of environmental radioactivity in the 20-30 km zone and some of the surrounding areas beyond the 30km zone, the Government of Japan established planned evacuation zones from which residents were relocated to temporary housing. Additionally, an emergency evacuation preparedness zone was also identified in which residents were asked to be prepared should the need arise for them to evacuate; these zones extended beyond the 30

¹¹ 'Run-up height' is defined as "the vertical elevation of the most landward penetration of the tsunami wave with respect to the initial sea level" in: *Tsunami Warning and Preparedness: An Assessment of the US Tsunami Program and the Nation's Preparedness Efforts* (National Academy of Sciences, 2010), p. 38. Available online at: http://www.nap.edu/openbook.php?record_id=12628&page=38.

¹² Information received by the Agency's Incident and Emergency Centre (IEC) from NISA. See Fukushima Nuclear Accident Update (11 March 2011, 11:45 UTC) at: <http://www.iaea.org/newscenter/news/2011/fukushima110311.html>.

km radius. Figure 2 depicts a map of the restricted area and the deliberate evacuation area surrounding the Fukushima Daiichi NPP as of the date of the Nuclear Safety Review; areas recommended for future evacuations are also indicated.

11. The assessment of exposures to the population and the environment and in particular in the Fukushima area is subject to current studies of WHO and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) respectively; both studies are performed with the support and involvement of the Agency.

12. On 25 March 2011, TEPCO released to the Agency and to the public their *Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station*.¹³

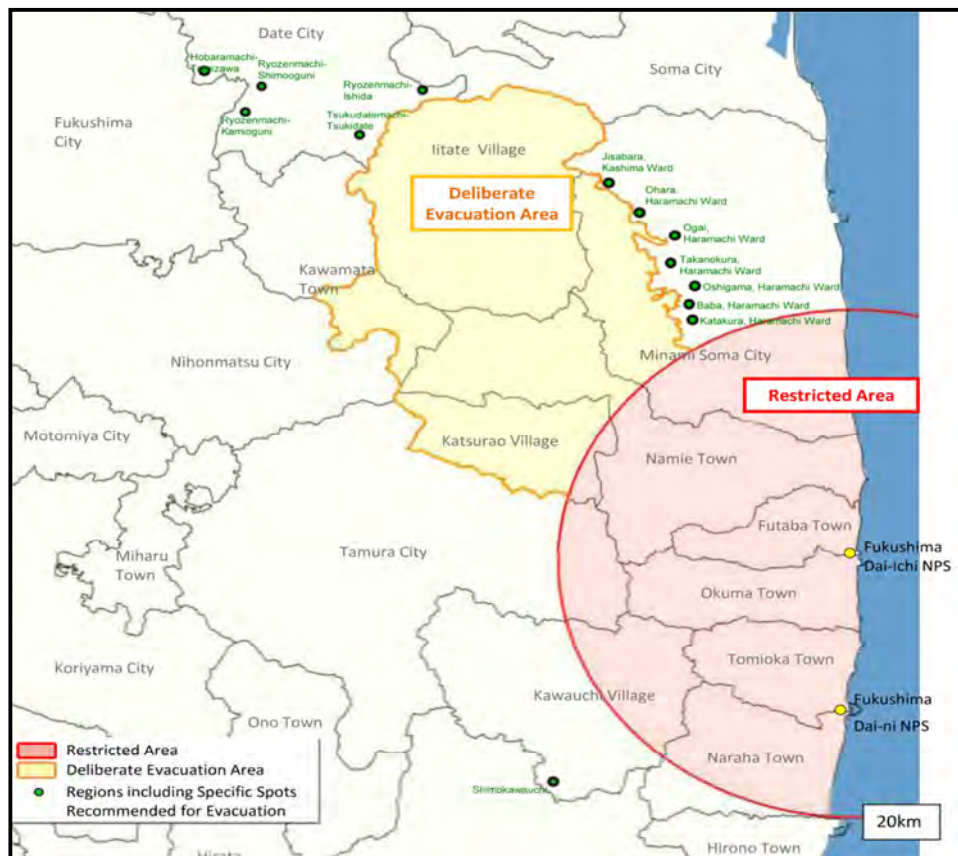


FIG. 2. Map courtesy of Nuclear and Industrial Safety Agency (NISA), Japan.

¹³ TEPCO News press release (17 April 2011). See: <http://www.tepco.co.jp/en/press/corp-com/release/11041707-e.html>.

13. On 24 May 2011, based on a decision by the Government of Japan's cabinet members, the Investigation Committee on the Fukushima accident was convened to engage in an overall assessment of the causes of the accident and the responses that occurred immediately after it. The Committee began its investigation, evaluations and interviews on 07 June 2011; it submitted an Interim Report and Executive Summary based on some of their findings to the Cabinet on 26 December 2011.¹⁴ The full report will be issued by the Committee to the Cabinet in 2012.

14. On 16 December 2011, the conditions at Fukushima NPP have improved and stabilized. Plant operators have brought the reactors into a “cold shutdown condition” defined by TEPCO and the Nuclear Emergency Response Headquarters as: “(1) keeping reactor pressure vessel bottom temperatures and temperatures inside primary containment vessel below approximately 100 degree centigrade; and (2) bringing release of radioactive materials from primary containment vessels under control and reducing the public radiation exposure by additional release (not to exceed 1 mSv/year at the site boundary as a target)”.¹⁵ TEPCO will now focus its efforts on remediation and decommissioning [3].¹⁶

15. The Agency provides the latest updates on the situation at the Fukushima Daiichi NPP on its website: <http://www.iaea.org/newscenter/focus/fukushima/>.

A.2. The Agency's response [4]



16. Less than an hour after the earthquake struck off the east coast of Honshu, Japan, and following notification from its International Seismic Safety Centre (ISSC), the Agency's Incident and Emergency System (IES) was activated. Within the next hour, the Agency's Incident and Emergency Centre (IEC) had established initial communication with Japan's official contact point, verifying information and enquiring about the safety of nuclear installations and Category I, II and III radioactive sources.

¹⁴ Executive Summary of the Interim Report Investigation Committee on the Accidents at Fukushima Nuclear Power Stations of Tokyo Electric Power Company. 26 December 2011.
See: <http://icanps.go.jp/eng/111226ExecutiveSummary.pdf>

¹⁵ See Section F, “Limiting Radiation Exposure”, for further discussion on this and other issues, activities and future challenges of worker and public radiation exposure.

¹⁶ See Section H, “Working towards Decommissioning, Remediation and Waste Solutions”, for a review of issues, activities and future challenges during this phase.

17. Shortly after this communication, the IEC was placed in ‘full response mode’¹⁷ and IES members from around the Agency were called in to discharge critical functions at the IEC — notably, liaison officers, public information officers, emergency response managers, logistics officers, technical specialists, communication specialists, and so on. Later the same day of the accident, the Agency published its first status summary report on the Emergency Notification and Assistance Convention (ENAC) website. From then on, these accident status reports on plant and radiological conditions at the Fukushima Daiichi site and surrounding areas were distributed twice daily to Member States. In accordance with the Agency’s responsibilities under the JPLAN, the Agency on 11 March 2011 promptly notified all international organizations and activated the JPLAN. The Agency initiated coordination of the inter-agency response to the Fukushima accident, with regard in particular to reaching a common understanding of the accident situation, and to coordinating public information.

18. As the Agency’s main focal point, the IEC received verified information from Japan and then alerted Member States of all significant events that occurred during the emergency.¹⁸ Moreover, these reports and the subsequent technical analysis constituted the main basis for the Member State briefings and the press briefings that were initiated by the Agency on 14 March 2011 and held routinely until 2 June 2011.

19. From the early days after the accident, the Director General has been in close contact with United Nations Secretary-General Ban Ki-Moon to ensure effective coordination among different international organizations. He has also consulted with the Director General of the World Health Organization (WHO), the Executive Secretary of Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the Director General of Food and Agriculture Organization (FAO) and the Secretary General of World Meteorological Organization (WMO) for effective coordination of activities.

20. On 15 March 2011, the first IACRNE coordination meeting was conducted (with subsequent video teleconferences thereafter) to brief relevant international organizations on the status of the situation, to exchange information among international organizations¹⁹, to reach a common understanding of the situation, to consider and coordinate response activities and to inform the public through joint press releases.

21. From 17 to 19 March 2011, Director General visited Tokyo to obtain first-hand information on the accident, to pledge the Agency’s full support and expert assistance, and to convey offers of assistance from more than a dozen countries. He met with Japanese Prime Minister Naoto Kan, the Minister of Foreign Affairs, Takeaki Matsumoto, and the Minister of Economy, Trade and Industry, Banri Kaieda, along with senior officials from TEPCO and NISA. He stressed the importance of providing timely official information to the Agency and of maintaining the highest level of transparency.

¹⁷ The IEC operated in ‘full response mode’ —24 hours a day, 7 days a week—from 11 March to 3 May 2011. The IEC drew upon staff expertise from all six Agency Departments. Agency professional staff and general service staff volunteered (230 total). Japanese staff members also assisted as accident State liaison officers and assisted with communications and translations.

¹⁸ As cold shutdown has now been achieved, the IEC will provide reports on the plant status of the Fukushima Daiichi NPP on a monthly basis.

¹⁹ Participants of the video conferences were EC, FAO, IMO, ICAO, OECD/NEA, PAHO, UNEP, UN OCHA, UNSCEAR, WHO and WMO. UNWTO and CTBTO participated as observers. In addition, the Permanent Mission of Japan attended the meetings at the IACRNE Secretary’s invitation.

22. During the first several days of the nuclear accident, it became evident that the reactors and the spent nuclear fuel could be at severe risk. In view of the accident's progression, the Agency established a number of teams (the Fukushima Accident Coordination Team (FACT), the Fukushima Nuclear Safety Team (FNST), and the Fukushima Radiological Consequences Team (FRCT)) to evaluate key issues relating to the accident, to coordinate the Agency's response, and to provide accurate and timely information to Member States, the media and the public.

23. At these meetings commonly agreed activities were assigned to specific organizations. For some issues ad hoc task groups were established, for example on transport issues²⁰ and on dose assessment issues. Joint public statements²¹ were prepared.

24. The Agency's laboratories became involved early on. The Agency's Terrestrial Environment Laboratory in Seibersdorf, Austria, provided analysis, information and methodological advice to laboratories from the ALMERA network.²² These in turn carried out spectroscopic measurements on nearly 100 samples taken in Japan during the various Agency missions. The Agency's marine environment laboratories in Monaco reviewed information regarding impacts to marine life and seafood resulting from the thousands of tonnes of radioactively contaminated water used to cool reactors at the Fukushima Daiichi NPP that had been released directly into the ocean.

25. On 4 May 2011, a delegation of major shipping lines met with the Agency and the International Maritime Organization (IMO) to discuss ways of monitoring containers at ports. Support was provided to the shipping companies through the Agency's Denial of Shipment Network.

26. By agreement with the Government of Japan, the Agency conducted a mission to establish facts and identify initial lessons to be learned from the Fukushima accident and share this information across the world nuclear community. To this end, a team of experts undertook a fact finding mission from 24 May to 2 June 2011. During the mission, the team of nuclear experts received information from many relevant Japanese ministries, nuclear regulators and operators. The Mission also visited three affected nuclear power plants: Tokai Daini, Fukushima Daini and Daiichi, to gain an appreciation of the status of the plants and the scale of the damage. The facility visits allowed the experts to talk to the operator staff as well as to view the on-going restoration and remediation work [2].

27. The results of this mission were shared and discussed with Japanese experts and officials and subsequently reported to the IAEA Ministerial Conference on Nuclear Safety held at Agency Headquarters in Vienna, Austria, from 20 to 24 June 2011.

²⁰ The IACRNE facilitated the formation of a task group to address issues relating to transport and tourism that comprised representatives of the ACI, IAEA, IATA, ICAO, IMO, UNWTO, WHO, WMO and UN. The task group met on regular telephone conference calls, starting on 17 March 2011, and has continued to meet on a regular basis throughout the event. ICAO chaired the group, and WHO provided web based document sharing to facilitate collaboration.

²¹ Joint press releases have been made by the group on several occasions, the first being on 18 March 2011, stating that there were no restrictions on travel to Japan. A further press release on 1 April 2011 responded to misleading press reports and sought to reassure the travelling public that concentrations of radioactive material were very low.

²² The ALMERA (Analytical Laboratories for the Measurement of Environmental Radioactivity) network comprises at present 122 laboratories from 77 States: <http://www.iaea.org/nael/page.php?page=2244>.

28. At this Conference, which was convened by the Agency to facilitate discussions on lessons learned and next steps following the Fukushima accident, a Ministerial Declaration was adopted, which, inter alia,

- “Request[ed] the IAEA Director General to prepare a Report on the June 2011 IAEA Ministerial Conference on Nuclear Safety and a draft Action Plan, building on the Declaration of the Ministerial Conference and the conclusions and recommendations of the three Working Sessions, and the expertise and knowledge available therein, and to promote coordination and cooperation, as appropriate, with other relevant international organizations to follow up on the outcomes of the Conference, as well as facilitate consultations among Member States on the draft Action Plan”;
- “Request[ed] the IAEA Director General to present the Report and the draft Action Plan covering all the relevant aspects relating to nuclear safety, emergency preparedness and response, and radiation protection of people and the environment, as well as the relevant international legal framework, to the IAEA Board of Governors and the General Conference at their forthcoming meetings in 2011”;
- “Call[ed] upon the IAEA Board of Governors and the General Conference to reflect the outcome of the Ministerial Conference in their decisions and to support the effective, prompt and adequately resourced implementation of the Action Plan”[6].

29. On 22 September 2011, at the 55th regular session of the Agency’s General Conference, Member States endorsed the Board’s approval of the IAEA Action Plan on Nuclear Safety. The Action Plan builds on the Ministerial Declaration, the conclusions and recommendations from the Ministerial Conference’s three working sessions, the letter report provided by the International Nuclear Safety Group (INSAG),²³ and the conclusions and lessons from the final report produced by the IAEA International Fact Finding Expert Mission. The Action Plan identifies a number of proposed measures, including 12 main actions, each with corresponding sub-actions, aimed at strengthening the global nuclear safety framework. The Action Plan requires actions by the Agency its Member States and other stakeholders [1].

30. A report by the Director General on the initial progress of the implementation of the Action Plan was issued on 10 November 2011 in advance of the Board of Governors’ meeting held from 17 to 18 November 2011. Work is currently under way on implementing the actions, and another progress report by the Director General will be published in advance of the Board meeting to be held in March 2012 [7].²⁴

31. Given that the Fukushima accident led to the radiological contamination of large areas of land, the Government of Japan began formulating a strategy for the implementation of countermeasures to remediate these areas. At the request of the Japanese Government, the Agency sent an international expert mission to Japan to help develop these remediation plans. Twelve international and Agency experts made up the team of the mission, which took place from 7 to 14 October 2011. The experts visited numerous locations in the Fukushima Prefecture, including the accident site, the area surrounding the Haramachi thermal power plant, locations in both Iitate village and the city of Date where model remediation projects are being carried out by the Fukushima Decontamination Team and

²³ *Communication dated 26 July 2011 from the Chairman of the International Nuclear Safety Group (INSAG)* (document GOV/INF/2011/11 issued on 4 August 2011).

²⁴ The Agency provides updates on its activities, missions and meetings related to the Action Plan on this section of its website: <http://www.iaea.org/newscenter/focus/actionplan/>.

the Japan Atomic Energy Agency (JAEA) as part of their efforts to test and evaluate the efficiency of a number of methods and technologies that can be used in environmental remediation strategies [8].

32. In its summary report of preliminary findings, which it provided to the Japanese government, the mission team presented, *inter alia*, the following conclusions:

- The Japanese authorities are advised to consider explaining to the public the importance of focusing on radiation doses that may actually be received by people rather than on data indicating contamination levels; and
- Japan is encouraged to continue its remediation efforts. In doing so, Japan is encouraged to take into account the advice provided by the mission. The Agency stands ready to support Japan as it considers new and appropriate criteria for such activities.

33. The mission's final report was issued to the Japanese Government on 15 November 2011 [9].²⁵

A.3. Site Safety

A.3.1. Site hazard assessment

34. The IAEA International Fact Finding Expert Mission identified issues with regard to site hazard assessment, including the adequacy of existing methodologies for assessing low probability/high consequence seismic events; the effects of successive high-magnitude aftershocks; and the impacts of tsunami-generated hydrodynamic forces on near-shoreline structures [2].

35. The current methodology for assessing seismic hazards at NPP sites relies heavily on prehistoric, historical and instrumental earthquake data. It also takes into account the geological and seismological setting of the region within which the site is situated. This site hazard model extrapolates estimates from these data to predict future earthquakes. When data are scarce, using this model to make predictions of very infrequent events results in greater uncertainty. Similar challenges exist when predicting earthquake-induced tsunamis. The severity of the tsunami hazard depends upon the magnitude of the earthquake: the larger the magnitude, the more severe the tsunami hazard. Again, when data are insufficient, extrapolating estimates to predict tsunami hazards results in greater levels of uncertainty.

36. Aftershocks are not considered in the design of NPPs because of their assumed low seismic magnitude. However, in the case of the Great East Japan Earthquake on 11 March 2011, a number of aftershocks of high magnitude (> 7.0) occurred in rapid succession after the main shock. This highlights the need to re-evaluate the effects of high-magnitude aftershocks when determining the seismic safety of an NPP site.

37. The tsunami brought with it the concurrent hazards of inundation and hydrodynamic forces, which clogged the plant's seawater intake and outfall systems with debris and sedimentation. These hazards highlighted new issues not only with regard to tsunami-induced flooding, but also flooding from other causes.

²⁵ For further information on this topic, see Section H, "Working towards Decommissioning, Remediation and Waste Solutions".

Activities

38. The IAEA Action Plan on Nuclear Safety states that the first action for Member States should be to “undertake assessment of the safety vulnerabilities of nuclear power plants in light of lessons learned to date from the accident”. Part of this assessment includes a national assessment of site-specific extreme hazards [1].

39. In 2010, the International Seismic Safety Centre (ISSC) had already begun to develop detailed guidance material on the safety of nuclear installations with regard to external hazards through its extrabudgetary programme.²⁶

40. The ISSC extrabudgetary project to promote installation safety in NPPs comprises 10 working areas, as shown in table 1. Working areas 1 and 5 (WA-1 and WA-5) had begun addressing the issues and challenges generally faced in assessing extreme seismic ground motion and tsunami hazards caused by high-magnitude earthquakes prior to the Great East Japan Earthquake.

TABLE 1. ISSC extrabudgetary project to promote installation safety in NPPs – 10 working areas.



WA1	Seismic hazards
WA2	Seismic design and qualification
WA3	Seismic safety evaluation
WA4	External events preparedness and response
WA5	Tsunami hazards
WA6	Volcanic hazards
WA7	Engineering aspects of protection against sabotage
WA8	Site evaluation and external events safety assessment
WA9	Information and notification system
WA10	Public communication, dissemination of lessons learned and capacity building

41. Working area 1 began its work in assessing issues of predicting seismic ground motion hazard caused by very infrequent external events, evaluating the adequacy of the current methodology in resolving the issues mentioned and addressing the implications of successive high-magnitude aftershocks for the seismic safety of NPPs.

42. Working area 5 began evaluating the current methodology for assessing tsunami inundation hazards.

²⁶ *Measures to Strengthen International Cooperation in Nuclear, Radiation, Transport and Waste Safety* report by the Director General, provides complete details in section D. Nuclear installation safety on this extrabudgetary programme. The document can be downloaded at:
http://www.iaea.org/About/Policy/GC/GC55/GC55Documents/English/gc55-15_en.pdf

Future challenges

43. Agency safety standards and methodologies need to be revised to take into account comprehensive seismic ground motion and tsunami hazard assessment for NPP sites. Also, the Agency's safety standards do not currently cover the assessment of ground motion hazard related to strong aftershocks and associated events following the main shock. There is also no well-established methodology for the evaluation of such a hazard. There is therefore a need to establish a design basis to take into account aftershocks (relevant parameters being their number, magnitude, interval, etc.) and thereafter to develop a methodology to evaluate it.

44. A well-established methodology exists for the assessment of inundation hazards due to tsunamis, and the Agency's safety standards also address this issue. However, the assessment of clogging of seawater intake and outfall systems by hydrodynamic forces and sedimentation/debris generated by a tsunami or any other flooding event is not covered and needs to be developed.

A.3.2. Design qualification and re-evaluation against external hazards

45. The extreme vibratory ground motion caused by the earthquake exceeded the seismic design levels at Units 2, 3 and 5 of the Fukushima Daiichi NPP. The tsunami exceeded the designed height of the protective sea walls and breakwaters. This led to the collapse of the sea wall and inundation of the majority of the plant complex, resulting in equipment failures and station blackout and the loss of the ultimate heat sink (UHS)²⁷ since the seawater intake was destroyed. The damage potential arising from the combination of correlated hazards, such as ground motion and flooding due to a tsunami, was not considered in the design safety margins of the Fukushima Daiichi site. Aftershocks became more critical as the damage to the structural system from the hydrogen explosions had significantly reduced the capacity of the buildings to deal with the impacts of subsequent seismic activity.

46. The Fukushima accident showed that NPP designs should incorporate additional safety margins to account for the maximum potential impact of external hazards, as well as to account for the combined impact of correlated hazards such as ground motion (including aftershocks and associated events) and tsunamis. According to the report of the IAEA International Fact Finding Expert Mission, it is essential "to address the issue of performance of the installation for beyond design basis earthquake ground motions in order to provide confidence that there is no 'cliff edge effect'²⁸; i.e. if an earthquake were to occur that were slightly greater than the design basis earthquake, to demonstrate that no significant failures would occur in the installation" [2].

47. The report further emphasizes that "the designer is also expected to consider beyond design basis events to see whether more can reasonably be done to reduce the potential for harm, especially where major consequences may ensue".

²⁷ An 'ultimate heat sink' is essentially an unlimited supply of water that can be used by nuclear reactors to cool vital systems and their primary containment during worst-case (design basis) accidents.

²⁸ A 'cliff edge effect' is "an instance of severely abnormal plant behaviour caused by an abrupt transition from one plant status to another following a small deviation in a plant parameter", *IAEA Safety Glossary: 2007 Edition*. See: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1290_web.pdf.

Activities

48. The IAEA Ministerial Conference on Nuclear Safety in June 2011 recommended, inter alia, systematic safety reviews of NPPs, including the design basis assumptions and the safety margins for both new and operating plants with regard to extreme external events [6].

49. Following this recommendation, the Agency began development of a document entitled “External Event Design Safety Margin Evaluation (EE-DSME) Review Programme”. This document is meant to provide guidance on the review programme for design margin evaluation of NPPs with regard to external hazards and is based on the internationally harmonized review methodologies that incorporate criteria set out in Agency safety standards, wherever available.²⁹

50. In line with the IAEA Action Plan on Nuclear Safety, a methodology for Member States to assess the safety vulnerabilities of NPPs with regard to site-specific extreme natural hazards was developed. This methodology covers site-specific hazard assessment and safety and design margin evaluation of NPPs with regard to external hazards, mainly seismic and flood-related [10].

51. Working areas 6 and 8 as shown before in Table 1 continued preparation of detailed safety guidelines for safety margin assessment with regard to external hazards. These guidelines cover the following areas: assessment of external hazards, including tsunamis, volcanic and high wind events; probabilistic safety analysis (PSA) for external events such as tsunamis, floods and heavy winds; and, risk integration to derive the overall risk or design margin of an NPP under the impact of multiple hazards.

52. In November 2011, the United States Nuclear Regulatory Commission (NRC) published *Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America* (NUREG/CR-7046),³⁰ which describes approaches and methods for estimating the design basis flood (DBF) at NPP sites, as well as conceptual models that can be used to characterize severe flooding at or near an NPP site. It also contains a brief discussion of Agency recommendations for estimating DBFs. The NRC’s Individual Plant Examination of External Events (IPEEE) programme also provides numerous insights on the safety of NPPs with regard to external events.

53. The Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) has published a number of documents on the safety of NPPs in relation to external events. Those that cover areas for which the Agency has not yet issued any separate publication of its own are especially relevant — for example, *Probabilistic Safety Analysis (PSA) of Other External Events than Earthquake* (OECD/NEA document NEA/CSNI/R (2009) 4 issued on 5 May 2009) and *Specialist Meeting on the Seismic Probabilistic Safety Assessment of Nuclear Facilities* (OECD/NEA document NEA/CSNI/R(2007)14 issued on 14 November 2007).³¹

²⁹ The relevant titles in the IAEA Safety Standards Series are *Safety of Nuclear Power Plants: Design* (NS-R-1, Vienna, 2000), *Safety of Nuclear Power Plants: Operation* (NS-R-2, Vienna, 2000) and *Site Evaluation for Nuclear Installations* (NS-R-3, Vienna, 2003), as well as the Safety Guides associated with these three Safety Requirements publications.

³⁰ The document is available online: <http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7046/>.

³¹ Both these documents are available online, respectively at: <http://www.oecd-neo.org/nsd/docs/2009/csni-r2009-4.pdf> and <http://www.oecd-neo.org/nsd/docs/2007/csni-r2007-14.pdf>.

Future challenges

54. The Great East Japan Earthquake has highlighted a number of design challenges regarding the seismic qualification, safety re-evaluation and design margin assessment of NPPs for external hazards. Two approaches through which these challenges could be met are:

- Conducting safety assessments based on Agency safety standards wherever available and using information from documents issued by other international organizations, as well as from other publications, for the areas where Agency guidance is not available. The document entitled “External Event Design Safety Margin Evaluation (EE-DSME) Review Programme” and the methodology to assess the safety vulnerabilities of NPPs for site-specific extreme natural hazards, both of which are currently being prepared by the Agency, should be useful in this respect [10];
- Preparing Agency guidance material to provide detailed guidelines for the assessment of all major external hazards, as well as for the safety assessment of NPPs with regard to these hazards and their combined effects.

55. The Agency already has a number of safety standards, guides and methodologies that deal with the safety re-evaluation of a NPP and, specifically, with design margin assessment to take into account seismic hazards. These include *External Events Excluding Earthquakes in the Design of Nuclear Power Plants* (NS-G-1.5, Vienna, 2003) and *Seismic Design and Qualification for Nuclear Power Plants* (NS-G-1.6, Vienna, 2003).³² Both deterministic (seismic margin assessment) and probabilistic methodologies are available for the re-evaluation of an NPP leading to design margin assessment for seismic hazards: they are discussed in detail in the Safety Guide *Evaluation of Seismic Safety for Existing Nuclear Installations* (NS-G-2.13, Vienna, 2009).³³ However, these safety standards, guides and methodologies do not take into account the combined impact of the main shock and the various aftershocks of an earthquake.

56. Another challenge is that no well-established methodology or Agency Safety Guide is available for safety re-evaluation or external event probabilistic safety analysis (EE-PSA) for the purposes of assessing the design margins of NPPs for other external hazards such as inundation, hydrodynamic forces and clogging. Furthermore, no design margin evaluation criteria exist for NPPs under the combined impact of correlated hazards such as ground motion and earthquake-induced flooding as a result of tsunamis or dam breaks.

57. The ‘stress test’ specification developed jointly by the Western European Nuclear Regulators’ Association (WENRA) and the European Nuclear Safety Regulators Group (ENSREG) for NPPs within the European Union also calls for design margin evaluation. The existing methodology for safety re-evaluation and/or design margin evaluation of NPPs with regard to external hazards is not comprehensive and does not cover many challenges as previously discussed. However, efforts have been initiated to develop an EE-PSA³⁴ method for non-seismic external events. Information is

³² Both these Safety Guides are available online, respectively at:
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1159_web.pdf
 and http://www-pub.iaea.org/MTCD/publications/PDF/Pub1158_web.pdf.

³³ This Safety Guide is also available online at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1379_web.pdf.

³⁴ K. Fleming, On the Issue of Integrated Risk – A PRA Practitioners Perspective, See: <http://www.nrc.gov/reading-rm/doc-collections/commission/slides/2011/20110728/fleming-integrated-risk-paper.pdf>

available in non-Agency publications on how to take into account aftershocks in the seismic probabilistic safety assessment (S-PSA) as well as on EE-PSA for combined external events.³⁵

A.3.3. Evaluating for safety: multiple hazards on multi-unit sites

58. Another critical issue highlighted by the Fukushima accident relates to the safety evaluation of a site with multiple units and other collocated nuclear installations under the impact of multiple correlated hazards. The safety evaluation of site hazards involving a single unit is challenging in itself — the task becomes even more complex when evaluating the safety of a multi-unit site for multiple hazards.

59. Site evaluation differs from safety evaluation. Site evaluation is concerned with the important safety-related and environmental considerations that need to be addressed when determining the suitability of candidate sites for NPPs or other nuclear installations. A safety evaluation provides a detailed evaluation on the overall risk and hazards associated with the proposed site/plant combination.

60. The objective of a safety evaluation of a multi-unit site for multiple hazards can be accomplished by aggregating the risk associated with all the individual units of the NPP and nuclear installations (if any) with the combined effect of multiple external hazards and taking into account any common cause failure.

Activities

61. The Agency began development of a new Safety Guide entitled *Safety Aspects in Siting for Nuclear Installations*. This publication provides needed guidance for the safe siting of new nuclear installations. It specifically considers site locations involving multiple units with respect to multiple hazards.

62. As part of the ISSC extrabudgetary projects, the working group responsible for WA-8 began writing three safety reports related to the safety evaluations of multi-unit sites (for both NPPs and nuclear installations) to take into account the impact of multiple external hazards.

63. Following the recommendations of the Ministerial Conference in June 2011, the Agency has begun preparation of a working document entitled “External Event Design Safety Margin Evaluation (EE-DSME) Review Programme”. This document, which is based on an internationally harmonized methodology, provides guidelines for reviewing the safety evaluation of a site involving multiple NPP/nuclear installation units with respect to multiple hazards. The WA-8 group is also aiming to publish it as a safety report.

³⁵ H. Tsutsumi, H. Nanaba, S. Motohashi, K. Ebisawa, “Development of seismic PSA methodology considering aftershock”, Specialist Meeting on the Seismic Probabilistic Safety Assessment of Nuclear Facilities, Nuclear Energy Agency / Committee on the Nuclear Safety Installations, NEA/CSNI/ (2007) 14.

Future challenges

64. Once the Agency has published the new safety standards and guidance material for multi-unit sites taking into account the impact of multiple external hazards, the next challenge will be to use this and further relevant knowledge from other international organizations to develop a comprehensive review programme for site safety evaluation for external hazards.

A.4. Severe accident management

65. According to the June 2011 report of the IAEA International Fact Finding Expert Mission to Japan, the extensive destruction of the Fukushima Daiichi site and its structures, systems and components (SSCs) — in addition to the actions and capabilities of the operating organization and external support to manage the accident — proved to be pivotal in the progression of the Fukushima accident. The total loss of off-site power, heat sinks and engineering safety systems; inadequate provisions to cope with multiple plant failures; and deficient and ineffective procedures and on-site radiological protection in severe accident conditions, are just some of the factors in the Fukushima accident from which lessons need to be learned with respect to severe accident management [2]. General conclusions drawn from various safety missions conducted after the Fukushima accident confirmed that some of the issues found at the Fukushima Daiichi site also exist at other NPPs.

66. Severe accident management programmes extend existing design, technical, operational, and emergency preparedness and response measures in order to facilitate the management of accidents that occur beyond the scope of a reactor's design basis — those harsh and difficult plant situations, ranging from the physical phenomena and conditions prevailing at the plant to the operational aspects that are difficult to foresee in detail.

67. Furthermore, as emphasized in the June 2011 report of the IAEA International Fact Finding Expert Mission to Japan, severe accidents can arise from a variety of causes, and the lessons learned from the Fukushima accident would apply generally to all NPPs.

68. Establishment of a severe accident management programme should ensure that workers involved in managing an accident have the training, knowledge of procedures and resources that are necessary in order to effectively:

- prevent the escalation of a reactor accident so that the reactor core does not suffer severe damage;
- mitigate the effects of an accident when the reactor core is severely damaged;
- prevent or mitigate the effects of accidental exposures of workers and the public to radioactive materials, as well as of accidental releases thereof into the environment; and
- bring the reactor into a controlled, stable and safe state as quickly as possible.

Activities

69. As part of the IAEA Action Plan on Nuclear Safety, the Agency has developed a methodology for assessing the safety vulnerabilities of NPPs with regard to site-specific extreme natural hazards [10]. This methodology provides the framework for a comprehensive assessment of severe accident management programmes addressing the specific challenges and conditions imposed by extreme hazards. Moreover, the Agency has assisted Member States in the development and implementation of their national programmes for the safety reassessment ('stress testing') of their NPPs.

70. The Review of Accident Management Programmes (RAMP) service has been modified to incorporate the methodology as applied to severe accidents caused by extreme hazards. The review of the operational aspects of severe accident management has been introduced into the Operational Safety Review Team (OSART) service as a standard and stand-alone review area. Emergency planning and preparedness will also constitute a standard core review area in future OSART missions. Furthermore, the Agency is reviewing and reinforcing its safety standards and safety services in the area of severe accident management.

71. The World Association of Nuclear Operators (WANO) is also reinforcing its peer review services in the above fields.

Future Challenges

72. At present, the combined findings from OSART and RAMP missions and from WANO peer reviews indicate that severe accident management programmes at NPPs are not sufficiently comprehensive and do not always address all the aspects required for such programmes to be truly effective. Of those NPPs that have been reviewed, the average level of preparedness and capability to mitigate severe accidents needed to be further strengthened.

73. Moreover, these missions have found that regulators had not fully implemented the Agency's safety standards covering severe accidents. As a result, plant operators were not fully familiar with them and could not follow in practice the recommendations they contained.

74. Furthermore, systematic research is needed to adequately address the situations and safety issues caused by extreme natural hazards, including:

- Availability and suitability of emergency procedures and severe accident management guidelines;
- Impact on general conditions at the plant site in terms of accessibility to the site and different plant areas, availability of infrastructure (communications, lighting, etc.), as well as the impact of radioactivity dose levels that could hamper work efforts at the site and the deployment of external support;
- Potential impact on habitability and conditions in relevant operational areas, such as the control room and technical support centre;
- Damage to or condition of SSCs that would limit the performance of equipment under accident conditions as required for the success of accident management actions, in particular the impact on the instrumentation upon which the operator relies to take actions;
- Limiting situations that might arise and impede or hamper recovery actions prior to a failure of radioactivity confinement barriers.

A.5. Regulatory Effectiveness

75. Nuclear regulators exist to ensure that nuclear activities are undertaken safely and securely for the protection of the public and the environment. In his summary and conclusions on the International Conference on Effective Nuclear Regulatory Systems held in Moscow, Russian Federation, from 27 February to 3 March 2006, the conference's President emphasized that "The Regulatory Body is effective, therefore, when it ensures that an acceptable level of safety is being maintained; when it takes appropriate actions to prevent the degradation of safety, when it takes actions to promote safety improvements; when it performs its regulatory functions in a timely and cost effective way and it strives for the continuous improvement of itself, the industry and other users of nuclear technology".³⁶

76. In this regard, the lessons learned and conclusions gathered from the Fukushima accident, as outlined in the June 2011 report of the IAEA International Fact Finding Expert Mission, paragraph 15, include:

- "Nuclear regulatory systems should ensure that regulatory independence and clarity of roles are preserved in all circumstances in line with IAEA Safety Standards";
- "An updating of regulatory requirements and guidelines should be performed reflecting the experience and data obtained during the Great East Japan Earthquake and Tsunami, fulfilling the requirements and using also the criteria and methods recommended by the relevant IAEA Safety Standards for comprehensively coping with earthquakes and tsunamis and external flooding and, in general, all correlated external events";
- "A follow-up mission to the 2007 IRRS [Integrated Regulatory Review Service] should be conducted in light of the lessons to be learned from the Fukushima accident and the above conclusions to assist in any further development of the Japanese nuclear regulatory system"[2].

Activities

77. The Third Workshop on Lessons Learned from the Integrated Regulatory Review Service (IRRS) was held in Washington, DC, on 26–28 October, 2011. Workshop participants discussed methods to strengthen the international peer review process and endorsed the incorporation of the Fukushima Daiichi-specific module as part of existing IRRS missions modules. They further stressed the need for flexibility since information on Fukushima Daiichi is still being gathered. In addition, participants suggested the need to find synergies in complementary programs that are also addressing these issues, such as the Operating Safety Review Team (OSART) missions, the Convention on Nuclear Safety, and the Joint Convention.

³⁶ The President's summary and conclusions on the conference are available online at: <http://www-pub.iaea.org/MTCD/Meetings/PDFplus/cn150/PresidentReport.pdf>.

78. Highlights of the lessons learned from the IRRS missions conducted in 2006–2010 were presented at this workshop. This report also includes data from 2011. In total, the Agency has conducted a total of 36 IRRS missions (including follow up missions) in Member States that have nuclear installations as well as radiation facilities. The chart in Figure 3 provides an annual distribution of these missions and follow-up missions through 2011.

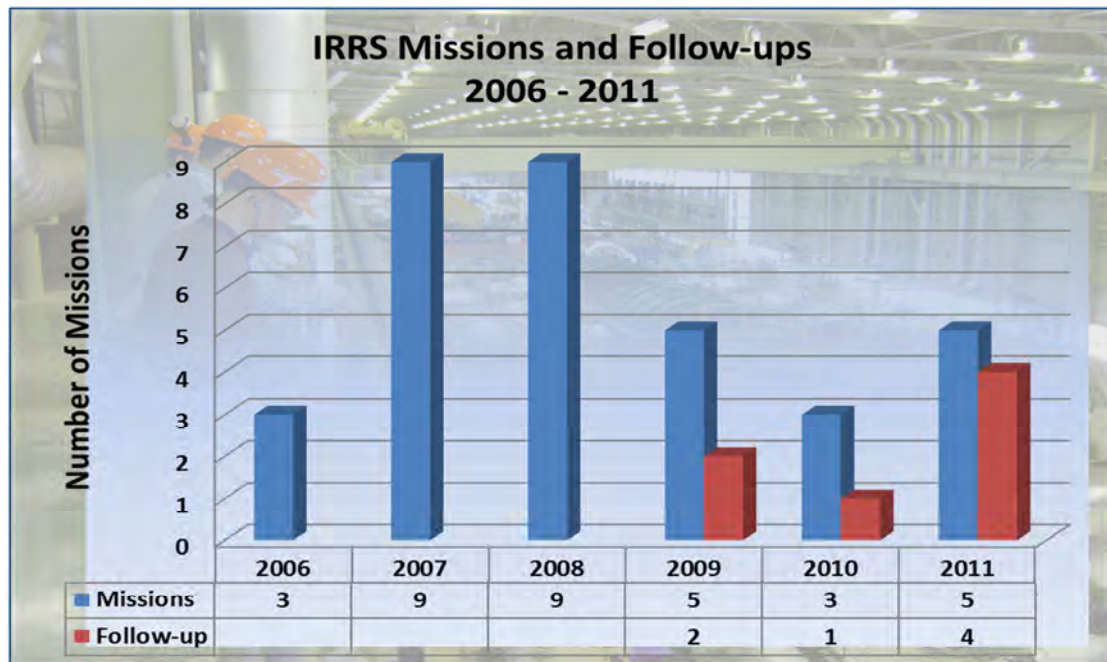


FIG. 3. Number of IRRS missions for nuclear installations, including radiation facilities, conducted from 2006 to 2011.

79. Analysis and trends from recommendations and suggestions for the core and thematic areas were also presented and discussed during the workshop. This report also includes trend information for 2011. In the course of the 36 missions conducted at NPPs, some 498 recommendations, 251 suggestions and 160 good practices were provided to regulators.³⁷ Findings and general trends are presented in Figure 4.

³⁷ In Agency peer reviews, a review team draws up 'recommendations' when it considers that a relevant aspect of an Agency safety standard is not fully met. A review team formulates 'suggestions' whenever it finds that no departure from an Agency standard was identified but that improvement could still be made. A review team highlights 'good practices' whenever it considers that these practices could be emulated by other regulators to enhance their regulatory system and that sharing these practices with other regulators will be beneficial.

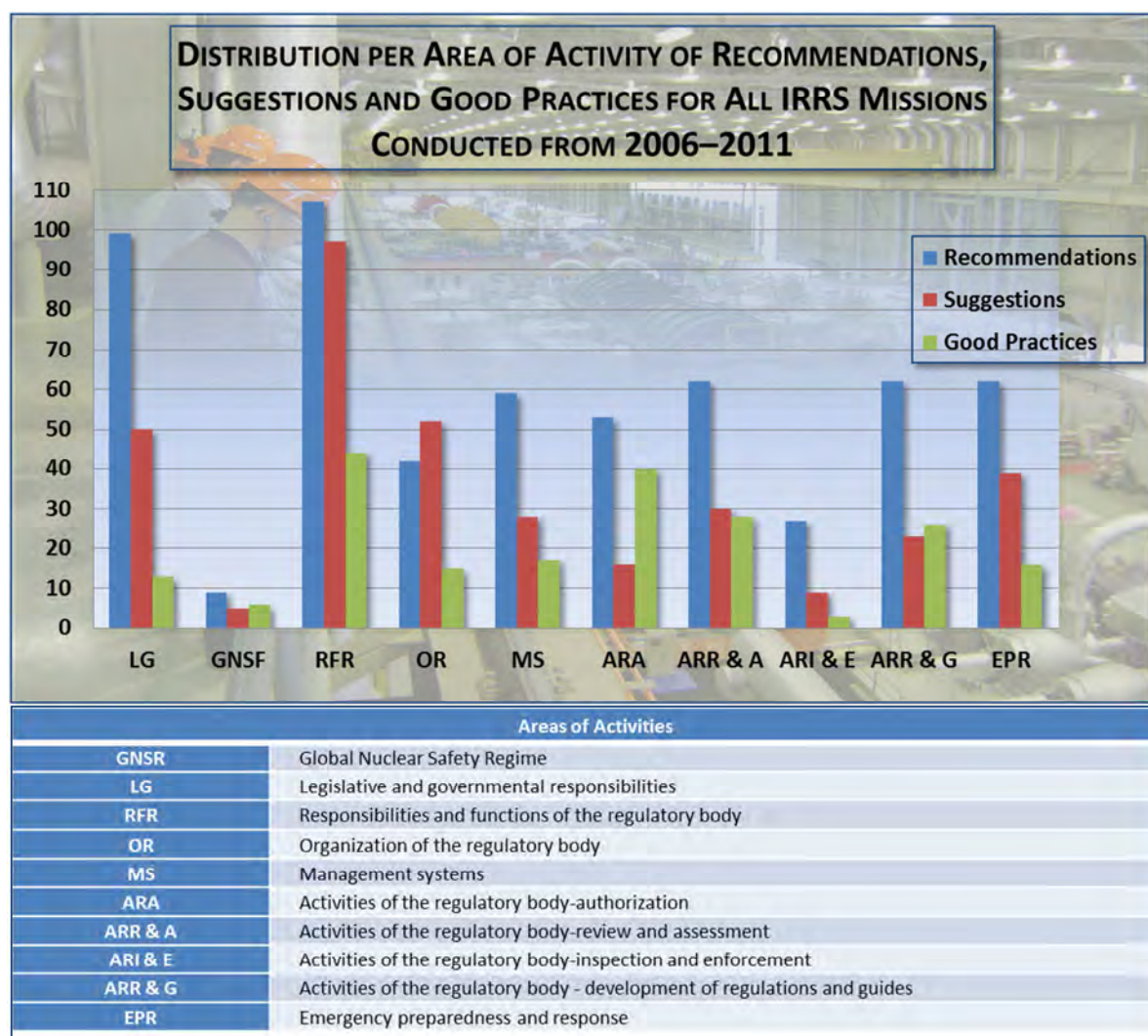


FIG. 4. General trends derived from the 36 IRRS missions conducted from 2006 to 2011.

80. The top five areas receiving the most recommendations and suggestions were: Responsibilities and Functions of the Regulatory Body (RFR); — Legislative and Governmental Responsibilities (LG); — Emergency Preparedness and Response (EPR); —Activities of the Regulatory Body – Review and Assessment (ARR & A); and Activities of the Regulatory Body – Development of Regulations and Guides (ARR & G). Areas like Activities of the Regulatory Body – Authorization (ARA), and the Management System (MS) also received significant numbers of recommendations.

81. The review missions also pointed out that nuclear regulatory systems should, in line with Agency safety standards, ensure the preservation of regulatory independence and clarity of roles in all circumstances. Since the Fukushima accident in March 2011, the Japanese Government has undertaken active efforts to strengthen and reinforce the country's nuclear safety infrastructure, to separate the regulatory body from the former governmental framework and to merge various organizations with overlapping responsibilities.

82. The IAEA Ministerial Conference on Nuclear Safety in June 2011 reinforced the IRRS findings, and concluded that the existence of credible, competent and independent regulators is an essential element of nuclear safety. All countries were encouraged to strengthen their regulatory bodies and to

ensure that they are genuinely independent, with clear roles and appropriate authority, in all circumstances, and staffed by well trained, experienced personnel.

83. In light of the Fukushima accident, as an immediate consequence of the lessons learned, the Agency extended the scope of the IRRS missions to include a specific ‘Fukushima module’ to conduct a targeted review of the national regulatory infrastructure against Agency safety standards. The review covers the actions taken by the regulatory body following the Fukushima accident, the planned longer-term actions and the implications of the lessons learned from that accident for the core activities of the regulatory body. This module has been successfully applied in the IRRS missions and follow-up missions that have been conducted since the accident occurred.

Future challenges

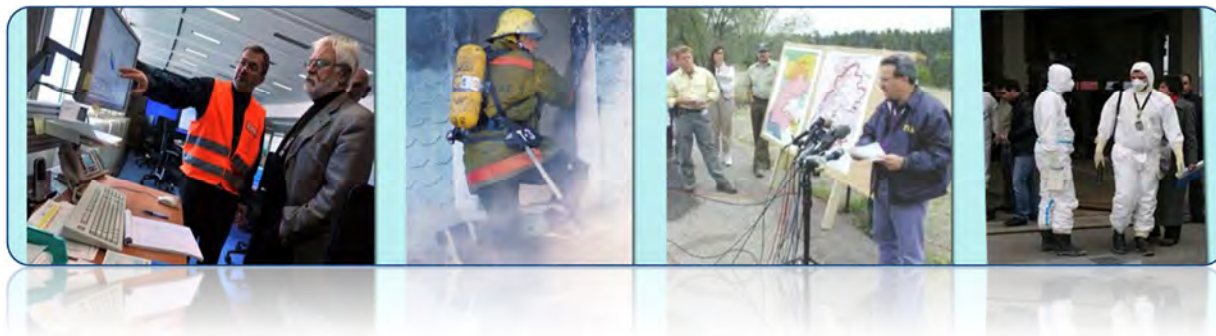
84. According to the general summary of findings from IRRS missions, nuclear regulators continue to face issues that include: (a) integrating safety and security more closely due to the changing security environment; (b) regulating the increasing use of radioactive materials (e.g. difficulties faced in regulating patient exposure for medical purposes and those arising from the way that new technology often outpaces the regulatory resource levels needed to assess and confirm its safety); (c) maintaining transparency in regulatory decision making; (d) retaining independence with regard to those organizations that are responsible for promoting nuclear energy use; and (e) ensuring that an adequate pool of competent staff is available to fulfil regulatory responsibilities. These issues cannot be resolved quickly and will require continued diligence by regulators to ensure the safe and secure use of nuclear energy.

85. Building on the conclusions and recommendations of the Ministerial Conference, the IAEA Action Plan on Nuclear Safety encourages Member States to:

- Voluntarily host, on a regular basis, an IRRS mission to assess their national regulatory framework and receive a follow-up mission within three years of the main IRRS mission;
- Conduct a prompt national review in order to, inter alia, confirm the functional independence of their regulatory bodies and to ensure adequate levels of financial and human resources (technical and scientific) so that they are able to fulfil their responsibilities.

86. Strengthening public confidence in nuclear safety goes hand in hand with strengthening public confidence in its regulators. Taking action on the lessons learned from the Fukushima accident requires national and regulatory commitment, careful planning and time to implement, and open and transparent communication with the public during the process.

B. Managing emergency preparedness and response



B.1. Trends and issues

87. *Preparedness and Response for a Nuclear or Radiological Emergency* (IAEA Nuclear Safety Series No. GS-R-2, Vienna, 2002), jointly sponsored by several international organizations sets out the requirements for Member States in the area of emergency preparedness and response. In December 2011, an analysis was completed of the results from the Emergency Preparedness Reviews (EPREV), regulatory aspects of emergency preparedness and response within the Integrated Regulatory Review Service (IRRS) missions, and the Agency's self-assessment process in the area of emergency preparedness and response, determined the following conclusions regarding the overall level of compliance with the GS-R-2 standard:

- Coordination and Cooperation: national coordination and cooperation among various Governmental entities with emergency preparedness and response responsibilities needs to be further strengthened;³⁸
- Emergency Notification and Information Exchange: in a number of Member States, weaknesses were identified in the procedures for emergency notification and information exchange with different stakeholders;
- Emergency Response Plans: emergency response plans at the local level and at times at the national level need to be improved. Additionally, some Member States do not have emergency response plans in place and do not clearly allocate or document associated responsibilities for the various response organizations;
- Regulatory Bodies: in several Member States, weaknesses were identified in their competences,³⁹ their infrastructure⁴⁰ and their emergency exercise programmes;

³⁸ e.g., among health authorities and competent authorities identified under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

³⁹ e.g., inadequacies in the following functional requirements: establishing emergency management and operations; identifying, notifying and activating; taking mitigatory and urgent protective actions; protecting emergency workers; and assessing the initial phase.

⁴⁰ e.g., inappropriate or non-existent emergency response plans and procedures, insufficient training and exercises, not enough logistical support.

- Threat Assessment: in line with the threat categories defined in Agency publication GS-R-2, many Member States have not satisfactorily performed a systematic ‘threat assessment’ of all relevant facilities;
- Training programmes: gaps in training programmes for first responders were identified; in some Member States these gaps are serious.

88. Effective communication during incidents and emergencies is crucial for the public and media perception of an event, its consequences and emergency management. In the preparedness stage, Member States should develop clear guidance on the process for incident and emergency communications and the role assumed by countries and international organizations, in line with the Convention on Early Notification of a Nuclear Accident. The Agency is implementing arrangements through which parties to the Convention on Early Notification of a Nuclear Accident and Member States are able to share and exchange information following a severe nuclear emergency.

89. The Agency guidance, Emergency Notification and Assistance Technical Operations Manual (ENATOM), has been in place and maintained for many years and has been actively promoted. The process of communications among international organizations is described in the Joint Radiation Emergency Management Plan of the International Organizations (EPR-JPLAN). These communications processes have been exercised on a regular basis over many years through the ConvEx exercises. Both documents are under current revision and will also take account of lessons learned from the Fukushima accident.

90. Member States and international organizations need to have a common knowledge and experience base to effectively exchange information, along with suitable tools and resources to implement the communication process. However, there have been cases when users of the Agency’s emergency communication systems did not have knowledge of, or ability to use, the available communication tools such as web, fax or email.

91. The International Nuclear and Radiological Event Scale (INES) is a self-reporting tool used by Member States to rate the safety significance of a nuclear or radiological event from INES Below Scale/Level 0, indicating a situation with no safety consequences to INES Level 7, indicating a major accident causing widespread contamination. The INES scale provides an assessment of a discrete incident or accident. The added complexity of assessing multiple-unit sites affected by multiple severe hazards over the course of time is not covered in the INES manual.

92. Initially and based on the knowledge available on the conditions at the Fukushima Daiichi site on 11 March, the event was rated by the by the Japanese Nuclear and Industrial Safety Agency (NISA) at level 3, “serious incident” (provisional rating). On 18 March, the INES rating on Units 1, 2 and 3 was raised to Level 5, which is described in the INES methodology as an “accident with wider consequences”. At the same time, Unit 4 was rated at level 3, “serious incident.” On 11 April, NISA rated the event at INES Level 7 by considering the entire estimated airborne radioactive release from the Fukushima Daiichi site and not considering the accident at each reactor as an individual event.

93. In the case of Fukushima Daichii NPP, involving multi-reactor releases along with other multivariate factors that occurred over the course of a few weeks, the June 2011 Ministerial Conference on Nuclear Safety concluded that “review and improvement of the INES are needed to make the scale more effective from a communications point of view”.

B.2. Activities

94. In 2011, the Agency streamlined incident and emergency communications by developing and implementing a new, web based incident and emergency communication system, the Unified System

for Information Exchange in Incidents and Emergencies (USIE). USIE represents a common platform for incident and emergency reporting and offers, in comparison to the previous web based emergency communication system, improved reporting capabilities, enhanced alert system, capabilities for direct bilateral communications and a more secure platform. USIE is fully compatible with information exchange for web services based on the International Standard for Radiological Information Exchange (IRIX) developed by the Agency and its partners. Recent developments in emergency communications, such as USIE and the Global System for Mobile communications (GSM), offer greater utilization of multiple communication channels made available through the internet.

95. The Secretariat has initiated a review of the application of the INES as a communication tool. The INES Advisory Committee provided input to this review during a meeting held at the Secretariat on 10 October 2011. The INES Advisory Committee suggested to develop additional guidance on the application of INES in severe nuclear accidents.

96. The EPREV is a service provided by the Agency to appraise preparedness for nuclear and/or radiological emergencies in Member States. In 2011, the Agency conducted six EPREV missions in Albania, Estonia, Georgia, Latvia, Pakistan and Russian Federation.

B.3. Future challenges

97. The challenges faced in communication with some Member States were highlighted during the response to the Fukushima accident, in which a relatively high rate of unsuccessful deliveries of telefax messages occurred. Registering in USIE provides Member States with diverse communication channels to receive alert message: via mobile telephone, email and telefax. Users can also browse the USIE webpage for any emergency related information the Agency provides. To date, 63% of the 134 Member States with designated points of contact need to register in the Unified System for Information Exchange in Incidents and Emergencies (USIE) in order to receive alert messages through this system as shown in Figure 5. However, in absence of being registered in USIE, Member States will receive telefax messages to their designated contact points whenever alert messages are sent by the Secretariat.

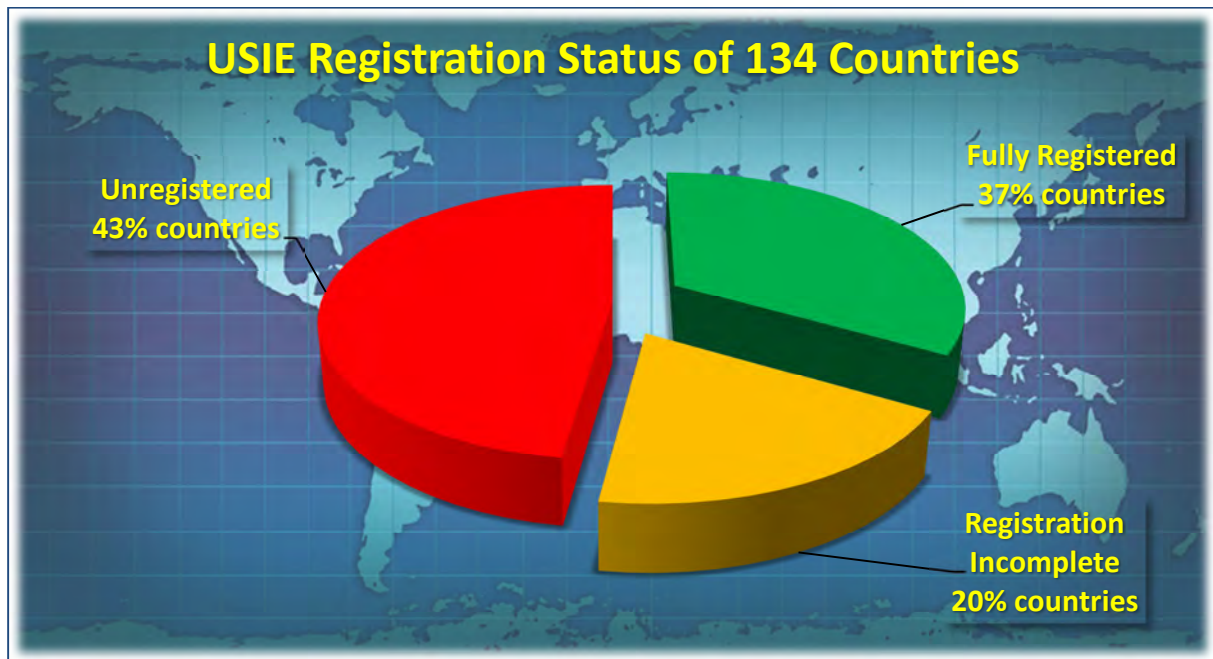


FIG 5. USIE Registration status of 01 January 2012.

98. However, no communication tool or software/hardware capability can replace training or operator experience. The training process for incident and emergency communications needs to be consolidated in many Member States and international organizations. Training is needed not only in developing countries or countries embarking in nuclear power programmes, but also in countries with experience in nuclear power programmes. This training must then be exercised by a high participation in ConvEx exercises.

99. The IAEA Self-Assessment Methodology for emergency preparedness and response is aimed to analyse national arrangements and capabilities versus international requirements in the area of emergency preparedness and response. Analysis of this information shows that Member States are steadily improving their emergency preparedness and response arrangements and capabilities; however, challenges in some of the elements continue to exist.

100. According to the IAEA Action Plan on Nuclear Safety, the Secretariat, Member States and relevant international organizations are called to review and strengthen the international emergency preparedness and response framework. The challenges lie in: 1) deriving data from self-appraisals and then globally harmonizing the results into a strengthened, cohesive widely accepted and commonly understood Emergency Preparedness and Response programme; 2) enhance the effective implementation of the legal instruments and operational arrangements in emergency preparedness and response.

C. Reviewing the safety aspects and long term management of ageing nuclear power plants and research reactors

C.1. Trends and issues in managing the safety of ageing nuclear power plants



101. Many operators around the world have begun programmes or expressed their intention to operate nuclear power plants (NPPs) beyond the original NPP design lifetimes. While the ageing nuclear fleet has provided safe, economical and reliable power, operators and regulators opting for long term operation (LTO) must thoroughly analyse the safety aspects related to the ageing factors of ‘irreplaceable’ key components. Moreover, LTO requires operators and regulators to assess and address the interrelated technical, economic, regulatory and licensing issues, which provide the foundation to quality ageing management programmes.

102. Ageing can best be described as a continuing time-dependent degradation of material due to service conditions, including normal operation and transient conditions; this can affect the capability of engineered structures, systems and components (SSCs) to perform their required function. The rate of ageing depends strongly on both the service conditions and the material sensitivity to those conditions. The ageing of NPPs could affect safety and reduce safety margins if detection or corrective action does not take place before the degradation of key SSCs, or before the loss of functional capability occurs. Ageing management, on the other hand, provides an integrated programmatic approach to planning and maintaining the performance and safety of NPPs as they age.⁴¹

⁴¹ *Ageing Management for Nuclear Power Plants* (Safety Standards Series No. NS-G-2.12, Vienna, 2009).

103. By the end of 2011, of the 435 NPPs operating in the world, 32% were more than 30 year's old, and 5% were in operation for more than 40 years. There are growing expectations that older nuclear reactors should meet enhanced safety objectives, closer to that of recent reactor designs. Therefore, operators of older nuclear power plants need to address concerns about their ability to fulfil these expectations and to continue to economically and efficiently support Member States' energy requirements.

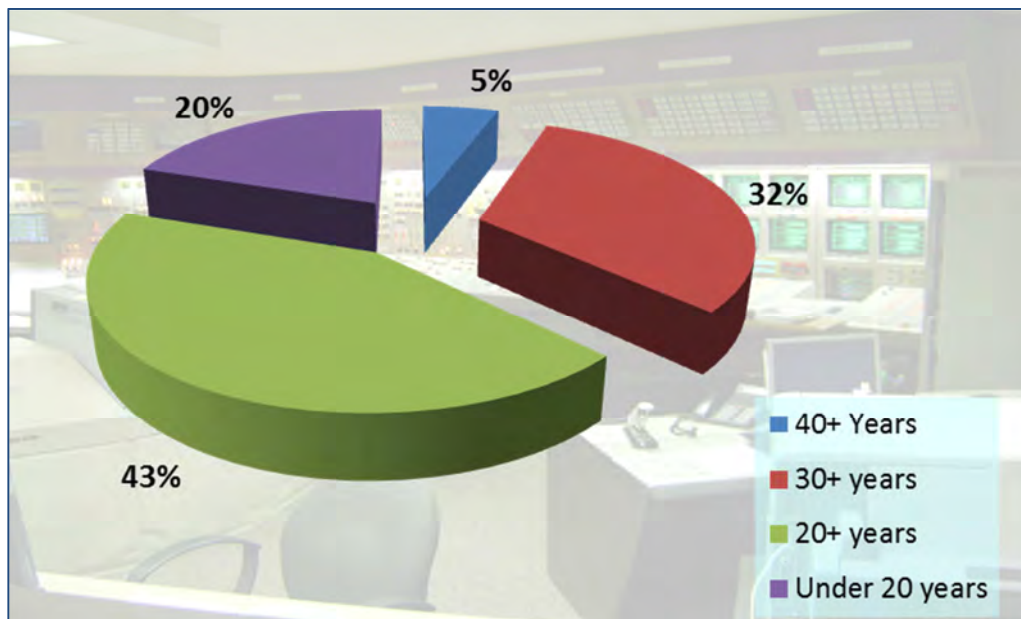


FIG. 6. The World's ageing nuclear fleet.

104. As existing nuclear facilities age, capturing and feeding back international operating experience and issues of safety significance become imperative and provide an essential, cost-effective tool to reduce escalation of or eliminate recurrence of similar safety events in other plants.

105. The International Reporting System for Operating Experience (IRS) contains reports of events that have occurred at nuclear power plants throughout the world and is jointly operated by the IAEA and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA). The aim of the IRS is to effectively facilitate the exchange of Member States' nuclear safety experiences by analysing and communicating operational safety significant events. Currently, the IRS has more than 3650 reports in its database.

106. Over the past four years, the average number of event reports submitted to the IRS from all Member States operating NPPs was 80 per year. Some significant events, such as those involving reactor shutdowns with safety system actuations, are not being reported to the system, or they are, in general, reported late, with reports having been submitted as much as one year after the event. In addition, the root cause analysis in some of these reports did not always identify the actual root causes.

107. Unreported nuclear safety events, or those not reported in a timely fashion, or those that do not provide comprehensive root cause analyses limit the ability of Member States to share, learn from and incorporate valuable nuclear safety operating experience that may mitigate potential consequences of design or operating weaknesses where such information could have prevented a similar occurrence happening at other plants.

C.1.1. Activities

108. With so many ageing NPPs becoming eligible for licence extensions, many Member States have already taken action by developing comprehensive ageing management programmes to address LTO issues. Additionally, the IAEA Action Plan on Nuclear Safety has called for plant operators worldwide to conduct stress tests as they systematically reassess safety margins to verify that they still comply with the highest safety standards.

109. The International Generic Ageing Lessons Learned (IGALL) programme was officially launched at its first steering group meeting in September 2010 with the aim of gathering the best international experience in LTO.⁴² One of the results of the meeting was a confirmed interest in establishing an IGALL report to assist Member States in controlling ageing and improving safety by providing state-of-the-art harmonized guidance on recommended ageing management approaches and strategies for regulators, operators and designers. Three IGALL working groups have been established to develop this report. The final IGALL report is expected for 2013.

110. To assist Member States with event reporting and providing root cause analysis, a number of improvements are being pursued:

- In 2011, the web-based IRS event reporting system incorporated a feature that permits Member States to record their actions as a result of an event report received from other Member States — thus allowing benchmarking and comparison to be made when other Member States are considering what actions should be taken to address a similar event.
- The *IAEA Root Cause Analysis Reference Manual* has been developed and is in the publication process. This manual will provide an easy reference guide for operating experience practitioners in Member States to conduct a comprehensive root cause analysis.
- A guide for conducting a Peer Review of Operational Safety Performance Experience (PROSPER) for regulators is being developed and will be available for use in 2013.

C.1.2. Future challenges

111. Periodic safety reviews (PSRs) of nuclear power plants are considered an effective way to obtain an overall view of actual plant safety, and to determine reasonable and practical modifications that should be made to maintain safety at a high level. Some Member States have expressed a preference for alternatives to the PSR; however, ageing management and LTO are only two of the many safety factors assessed in a PSR. Should Member States elect alternatives to the PSR, the alternative should satisfy the objectives of a PSR, as defined in paragraph 2.8 of *Periodic Safety Review of Nuclear Power Plants* (IAEA Safety Standards Series No. NS-G-2.10, Vienna, 2003).⁴³

112. Challenges to establishing comprehensive ageing management programmes centre on ensuring that safety functions of all structures, systems and components that face obsolescence, ageing effects and degradation processes are included and addressed. Therefore, it is important to provide the nuclear industry and regulatory authorities with guidance on recommended, proactive ageing management

⁴² International Generic Ageing Lessons Learned (IGALL) website:
<http://www-ns.iaea.org/projects/igall/default.asp?s=8&l=98>.

⁴³ *Periodic Safety Review of Nuclear Power Plants* (Safety Standards Series No. NS-G-2.10, Vienna, 2003).

programmes for NPPs. Such information may be used as a source for the development of a harmonized approach to addressing the various degradation mechanisms through the application of recognized ageing management programmes, as well as the establishment of a consolidated strategy for safe LTO of NPPs worldwide.

113. To operate safely and effectively during long term operation, a full and comprehensive plant-specific safety assessment is required. The Agency provides Operational Safety Review Team (OSART) missions, which include an LTO module, and Safety Aspects of Long Term Operation of Water Moderated Reactors (SALTO) missions, either of which, when conducted systematically and periodically, can be used to ensure the fulfilment of the required safety functions throughout long term operation.

114. The PROSPER service has been available to NPPs and utilities for several years as a module within all OSART missions; it has not, however, been widely requested. It is envisaged that Member States who use this review service can expect to enhance regulatory oversight of operating experience in licensees and also provide more complete reporting to the IRS.

115. The results of the ‘stress tests’, as called for in the IAEA Action Plan on Nuclear Safety, will need to be factored into ageing management and the long term operation of nuclear power plants, as well as future ageing assessments that will need to be conducted in addition to these stress tests.

116. Since the development and application of ageing management programmes differ in Member States, the support of the Agency, international organizations and Member States is needed to assess the safe, long term, continued operation of older plants and proactively share the experience obtained.

C.2. Trends and issues in managing the safety of ageing research reactors

117. Ageing research reactor facilities worldwide have raised serious concerns amongst research reactor operators, regulators and the public. Research reactor operating organizations must undertake an array of work activities to re-establish performance that has degraded over time, maintain performance in the face of changing conditions (such as obsolescence of structures, systems and components) and/or adapt to new customer or regulatory demands. Ageing may lead to an increase in failures of components and a decrease in the availability of the reactor.

118. As indicated in FIG. 7, about 70 per cent of the 254 operating research reactors have been in operation for more than 30 years, with many of them exceeding their original design life. Age-related failures of structures, systems and components continue to be one of the primary root causes of the incidents reported to the Agency's Incident Reporting System for Research Reactors (IRSRR).

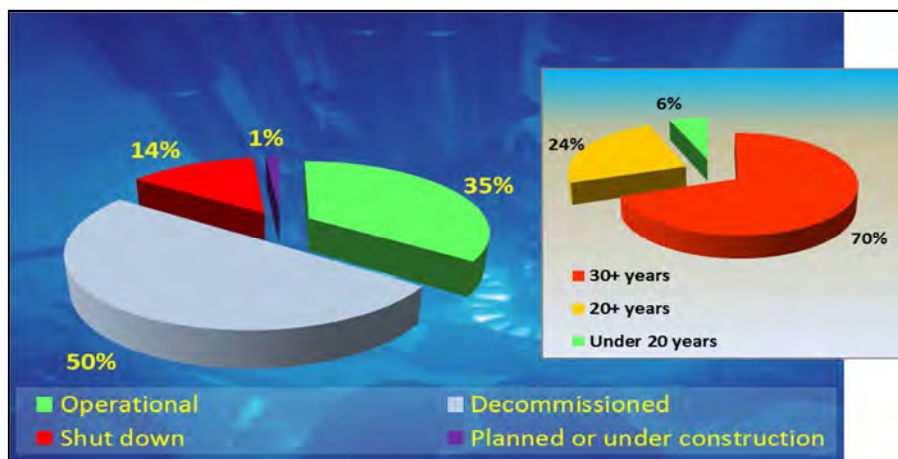


FIG. 7. 70% of the research reactors in operation worldwide are over 30 years old

119. Additionally, age-related failures and maintenance of two of the five major isotope-producing research reactors in the world was a primary cause of the worldwide shortage of medical radioisotopes in 2009 (in particular molybdenum-99). These research reactors, located in Belgium (BR-2), Canada (National Research Universal (NRU) reactor), France (OSIRIS), Netherlands (High Flux Reactor (HFR)) and South Africa (SAFARI-1) are all between 44 and 53 years old. In the last few years, all have reported age-related problems. This situation has caused unanticipated research reactor shutdowns, and has put increasing pressure on the global medical isotope supply and the production capacity of the other isotopes producers.

120. It has cost several millions of dollars to repair and refurbish these research reactors and there have been long preparation and repair times; similar situations are to be expected in the future.

C.2.1. Activities

121. The Agency continued to help Member States with the application of Specific Safety Guide No. SSG-10, Ageing Management for Research Reactors, which was published in 2010, through various training workshops provided in 2011. The Agency also finalized a publication entitled Safety in the Utilization and Modification of Research Reactors, which provides additional guidance on the safety of refurbishment and modernization projects.

122. Ageing management was one of the main topics discussed at the international meeting on the application of the Code of Conduct on the Safety of Research Reactors, held in Vienna in May 2011, and at the International Conference on Research Reactors, held in Rabat, Morocco in November 2011. These activities provided an efficient forum for sharing Member States experiences on various ageing management topics, such as: sustainability, safety and security, safety assessments after the Fukushima accident.

123. A technical meeting on *Ageing Management, Refurbishment and Modernization* was held in Vienna in October 2011, which provided an opportunity for exchanging information on the application of the recently published IAEA Safety Guide No. SSG-10: *Ageing Management for Research Reactors*, and on good practices concerning safe implementation of research reactor refurbishment and

modification projects. Additionally, ageing management was also the main topic of the safety review missions that were conducted at the research reactors in Egypt, Netherlands, Peru, Romania and Uzbekistan. These missions contributed to the effective establishment of ageing management programmes for these reactors including, for example, assessment of the physical status of the systems and components important to safety and their safe repair, refurbishment or modernization.

C.2.2. Future challenges

124. Many Member States need to establish a proactive strategy and implement a systematic approach to research reactor ageing management and the Agency needs to establish a formal process for periodic safety reviews similar to the ones established for nuclear power programmes.

125. In order to implement ageing-related activities, including refurbishment and modernization projects, a comprehensive evaluation is needed. This evaluation should focus in particular on safety categorization, safety analysis, regulatory review and assessment. Ageing-related activities have inherent economic, political and regulatory constraints and challenges that need to be addressed so that suitable criteria can be established by regulatory bodies within Member States.

126. Because of the ageing of research reactors their continuous operation may not be reliable which may affect the sustained global supply of medical isotopes in the long term.

D. Preparing emerging nuclear energy countries

D.1. Trends and issues

127. Several Member States have begun developing an infrastructure to support the introduction of nuclear power; other Member States are in the initial stages of considering the implications of adding nuclear power to their energy strategy. These Member States have had difficulty in developing the necessary infrastructures and acquiring the necessary prerequisite skills within a relatively short time frame to meet project milestones. Examples of project milestones include selecting and evaluating candidate sites, proficiently evaluating proposals and safety cases submitted by vendors, and preparing and submitting safety assessment reports to the regulatory body.

128. In addition, more than 20 Member States have initiated plans for new research reactor projects. The necessary regulatory, technical and safety infrastructures need to be in place for these Member States to support this development. The Agency provides various safety standards and guidance documents, including *Milestones in the Development of a National Infrastructure for Nuclear Power* (Nuclear Energy Series No. NG-G-3.1, Vienna, 2007) and *Establishing the Safety Infrastructure for a Nuclear Power Programme* (IAEA Specific Safety Guide No. SSG-16, Vienna, 2012) to assist in this endeavour.

129. The Agency has identified capacity building as a significant issue for Member States and provides capacity building workshops and training courses, expert missions and peer review services to countries embarking on a nuclear power programme. Results from these missions, reviews and workshops have identified weaknesses in fundamental areas, including both the development of the prerequisite national law infrastructure and a functioning, independent regulatory body. There is also a need for strong, early governmental support in connection with the establishment of the regulatory body. Other infrastructural challenges identified included an inadequate number of staff and competences in all areas related to construction, operation, and decommissioning.

D.2. Activities

130. Specific Safety Guide No. SSG-16 provides recommendations, presented in the form of sequential actions, on meeting safety requirements progressively during Phases 1, 2 and 3 of the development of the safety infrastructure. Both SSG-16 and the self-assessment tool in development will be introduced during relevant Agency activities and through the Agency website.⁴⁴

131. The Agency has prepared assistance ‘packages’ that provide guidance and tools for the establishment of an effective and sustainable national nuclear regulatory framework based on the Agency safety standards and guidance series. These assistance packages, consisting of a set of standard workshops and expert missions covering general or specific areas of the nuclear regulatory framework, are being introduced during relevant Agency activities as well as through an Agency website.⁴⁵ Although they are designed and prepared as standard packages, they can be tailored to meet specific needs.

132. Standard IRRS modules have also been tailored and redesigned to fit the conditions and needs for capacity building in embarking countries. These tailored IRRS modules will help to identify gaps and areas in need of improvement in the national capacity building infrastructure and to plan the necessary actions.

133. In relation to siting activities, the Agency offers the Site Evaluation and External Event Design (SEED) service for assistance relating to safety infrastructure and human resource development. This service covers the siting of NPPs and other nuclear installations, external hazard assessment and site evaluation, design of NPPs to withstand external events, seismic re-evaluation and seismic probabilistic safety assessment. Work has been initiated to include peer reviews of design margin evaluations of NPPs with regard to external hazards and site safety margin evaluation for external events. The site safety margin evaluation addresses the impact of multiple hazards on multiple units of an NPP and other collocated nuclear installations at a site.

134. To develop the resources required for safety assessment and to support the technical review process by operating organizations and regulatory bodies, the Agency has established and is applying safety knowledge requirements and detailed technical modules of the Safety Assessment Education and Training (SAET) Programme in its capacity building activities for embarking countries. The foundation for further development and application of these knowledge requirements and modules is being optimized through pilot programmes. As a result, SAET programme initiatives enable long term and sustainable competency building for embarking countries through the Agency’s technical cooperation programme.

135. Efforts are under way to include all newcomer stakeholders in the acquisition of essential knowledge for technical safety assessment and related practical applications. Outreach to staff of prospective owner-operators and research staff assuming technical support functions, as well as to regulatory bodies, is an integral part of the programme.

136. To address safety considerations in the design of nuclear power plants and in bid specification and evaluation, a Generic Reactor Safety Review (GRSR) methodology and training modules will

⁴⁴ See <http://www-ns.iaea.org/tech-areas/safety-infrastructure/>.

⁴⁵ Ibid.

provide newcomer countries with the methods and tools necessary for knowledgeable evaluation of vendor design safety cases.

137. For research reactors, a technical document on specific considerations and milestones for a new research reactor project is in the publication process. This document and the associated training is similar to that for nuclear power programmes. Training workshops on the establishment of a new research reactor are conducted on a national and regional basis. In 2011, a training workshop was organized on this subject in Jordan and another interregional workshop was held at the Argonne National Laboratory in the United States of America with the participation of nine countries.

138. Fact-finding missions have been conducted in Azerbaijan, Jordan, Saudi Arabia and Sudan to assist in assessing existing regulatory, safety, and technical infrastructure conditions. In the framework of these missions, the Agency has developed a self-assessment questionnaire based on the Agency's safety standards.

139. The Agency recommends that Member States develop an integrated master work plan, which will serve as a road map and coordinate the assistance provided to the Member State by the Agency and other countries to help meet the demands of building a nuclear power infrastructure. The Agency has already initiated work at the request of some countries in preparing such a plan in full harmony with their prospective nuclear power programme.

140. To assist with capacity building for nuclear installation safety, the Agency continues to support a number of international knowledge networks and forums such as the Global Nuclear Safety and Security Network (GNSSN), regional networks such as the Asian Nuclear Safety Network (ANSN), the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO), the Forum of Nuclear Regulatory Bodies in Africa (FNRBA), the Arab Network of Nuclear Regulators (ANNuR) and the Regulatory Cooperation Forum (RCF).

D.3. Future challenges

141. Regarding capacity building, there are deficiencies related to sufficient capacity in emerging countries, or inadequate or slow implementation of capacity building programmes. The challenge is to provide a comprehensive and sustainable foundation of knowledge for newcomer organizations with a curriculum covering the full range of infrastructure topics, based on the Agency's safety standards. Prompt and thorough training is also a key challenge for countries that have set stringent goals for licensing and construction of nuclear installations in the near future.

142. There appears to be a globally insufficient number of experienced and knowledgeable experts and institutions in the area of nuclear safety and security, who will provide direct or indirect assistance and guidance to embarking states. Finding host institutions/organizations for human resource development purposes, particularly for on the job training, is also another major challenge that seems difficult to solve in the short term. These challenges also extend to research reactor programmes.

143. Organizations of nuclear power countries need to be mindful that even the best people require continuous learning and updating of their expertise.

144. Some Member States are developing their own education and training programmes, including the initiation of nuclear engineering programmes in some technical universities. However, this process should be comprehensive and integrated to provide complete technical knowledge in relation to design and safety assessment. Otherwise, the risks of fragmented delivery and knowledge gaps could occur. Additionally, vital nuclear safety assessment knowledge may not be reaching all relevant stakeholders, including owner-operators and technical support groups.

E. Reviewing the safety of future reactor designs

E.1. Trends and issues

145. Enhanced safety and improved simpler designs are fundamental in future nuclear reactor development. Future reactor designs include certain small and medium size reactors (SMRs) as well as designs that are available for near and longer term deployment. Designs that are available for near term deployment have incorporated enhanced safety measures (passive systems, core catchers) that are expected to result in significant safety enhancements over existing designs. Similar and even more enhanced safety measures are expected to be employed in the more advanced designs for longer term deployment.

146. As with any new or enhanced technology, a major challenge is to demonstrate that new and innovative safety features are sufficiently tested and proven. This challenge depends on the degree of innovation. For example, improved safety features that are based on existing knowledge and experience and that are implemented in an evolutionary manner in new reactor designs require less development effort than more innovative safety features. Future designs that are available for deployment in the near term have undergone a combination of testing and modelling to demonstrate improvements in their safety features. More innovative designs are expected to need more effort to test and demonstrate the effectiveness of their enhanced safety features.

E.2. Activities

147. The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) members and the INPRO Group at the Agency along with Generation IV International Forum (GIF) held cooperation meetings in 2011 to review various safety issues with sodium cooled fast reactors (e.g, sodium coolant handling, positive void reactivity, and so on).⁴⁶ In addition, the Agency's coordinates the efforts of its Member States to facilitate the development of SMRs (the Small and Medium Size Reactors Programme) to address, inter alia, issues with safety and security, and held a workshop in December 2011 concerning the topic of Near Term Deployment.⁴⁷

148. The Agency supports several activities related to the safety of future reactors. One example is the Agency participation in the GIF Risk and Safety Working Group (RSWG), where guides are being developed to determine the safety research needs of Generation IV Nuclear Systems and to propose a methodology to evaluate the safety of these systems.⁴⁸

149. Another example includes participation in collaborative projects related to passive safety systems for which a methodology is under development to evaluate the reliability of these systems. In addition, future reactor designs can benefit from the Generic Reactor Safety Review (GRSR) service that is based on Agency safety standards dealing with safety assessment and reactor design requirements. The

⁴⁶ Second Joint GIF – IAEA/INPRO Workshop on Safety Aspects of Sodium-Cooled Fast Reactors, 30-Nov to 1-Dec 2011.

⁴⁷ For example, a workshop on “Technology Assessment of Small and Medium-sized Reactors (SMRs) for Near Term Deployment” was organized by the IAEA (5-9 Dec 2011).

⁴⁸ An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear Systems, GIF Risk and Safety Working Group (RSWG).

GRSR service provides Member States with an early evaluation of safety cases of new and innovative reactor designs against the Agency's safety standards.

150. The Agency's methodology⁴⁹ for assessing extreme natural hazards (stress test), which was developed in November 2011 in light of lessons learned from the Fukushima accident, will also benefit future reactor designs.

E.3. Future challenges

151. Innovative passive safety systems must demonstrate that they will not fail functionally as a result of unforeseen phenomena, and that their components will not be impaired by external natural hazards. Furthermore, lessons learned from the Fukushima accident will need to be factored into the designs

152. The designs for nuclear plants being developed for implementation in the coming decades contain numerous safety improvements based on operational experience in active and redundant safety systems deployed in water cooled reactors. A better understanding of future reactor designs employing coolants other than water and of failure modes of their innovative safety systems, including those caused by very low probability or unforeseen events, is needed.

153. High quality design must still deal with three major issues: nuclear waste disposal and recycling, radiation hazards, and high cost and high capacity installation over a long time frame.

F. Limiting radiation exposure



F.1. Trends and issues

154. The estimated global annual average individual effective dose from background radiation is 2.4 mSv (UNSCEAR 2008), representing 80% of an individual's annual effective dose from all sources.

155. The naturally occurring radioactive gas radon is responsible for approximately half of the collective effective dose from all natural sources (see Figure 8), with very large variability observed between individuals depending on local geology, building construction practices and environmental factors. In some extreme cases, the annual effective dose from radon can be of the order of several

⁴⁹ A Methodology to Assess the Safety Vulnerabilities of Nuclear Power Plants against Site Specific Extreme Natural Hazards. IAEA Safety Related Publications. 16 November 2011.

hundred millisievert (mSv), or greater. Currently, the best available estimate is that indoor radon exposure is responsible for between 3% and 14% of all lung cancer cases (WHO, 2009) worldwide every year.⁵⁰ According to UNSCEAR (2008), the annual average individual effective dose from radon is 1.15 mSv.

156. Proven and effective building practices exist to limit the accumulation of radon in new buildings and cost-effective corrective actions have been developed to reduce high radon concentrations in existing buildings. Thus, while radon is one of the largest contributors to the worldwide collective effective dose from all sources of radiation as shown in Figure 8, this can be reduced through the implementation of appropriate strategies.

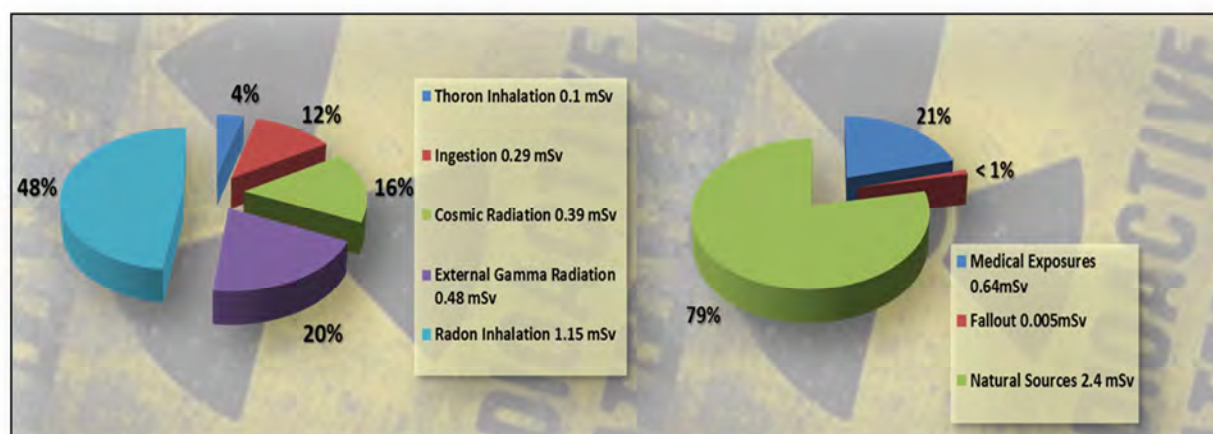


FIG. 8. Global annual per capita effective dose (UNSCEAR 2008).

157. With regard to permanent plant workers and emergency responders in light of the Fukushima accident, the principal health risks of occupational exposure during a nuclear accident remain a serious issue that need to be further reviewed.

158. Furthermore, the dwindling nuclear workforce worldwide means that there is a shortage of trained personnel who can safely work with ionizing radiation. Most of the temporary workforce at the Fukushima Daiichi site hired to aid in the clean-up efforts is unskilled, untrained and itinerant. In general, adequate occupational radiation training programmes for itinerant workers need to be developed or strengthened in many countries.

159. At the other end of the spectrum, highly skilled professional nuclear workers are also becoming increasingly mobile. Currently, no worldwide/centralized tracking system exists to manage cumulative dose rate history. Recording personal radiation exposure employer by employer does not really help in tracking and managing the cumulative dose employees receive throughout their working lives from all the sites at which they may be stationed; this applies to the entire mobile nuclear workforce worldwide, skilled or not.

⁵⁰ World Health Organization, Fact sheet N°291. Updated September 2009.

See the Fact Sheet at this web site: <http://www.who.int/mediacentre/factsheets/fs291/en/index.html>

160. The International Commission on Radiological Protection (ICRP) has reviewed recent epidemiological evidence showing a prevalence of eye opacities in staff exposed to radiation levels below the previously published ICRP threshold.⁵¹ These new data prompted the ICRP to reduce its threshold parameters to a threshold of 0.5 Gy of absorbed dose for the eye lens. Further, for occupational exposure in planned exposure situations, the ICRP now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv.

161. As was reported in the *Nuclear Safety Review for the Year 2010*, the effective dose worldwide from medical exposure for individual patients has doubled and continues to grow. Overall, an increasing number of patients have been exposed to significant doses due to repetitive, poorly regulated and often unnecessary medical procedures using ionizing radiation. In fact, computed tomography (CT) scanners were increasingly used for radiological imaging procedures throughout the world. While physicians agree that CT scanners are a life-saving diagnostic tool, there has been concern about their overutilization; and there is an increasing number of patients receiving multiple CT scans within a few years or even in a single year. This continues to be the trend in 2011.⁵²

F.2. Activities

162. The General Safety Requirements publication GSR Part 3, *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (BSS), was approved by the Board of Governors in September 2011. The revised BSS has strengthened the requirements in relation to protection of the public, inter alia from radon, over those in the previous BSS (IAEA Safety Series No. 115). This strengthening of requirements reflects the significance of radon as a source of radiation exposure and is in keeping with the high priority given to this issue by other international organizations and by several Member States.

163. A number of Member States have started activities to quantify and reduce public exposure to radon indoors. Many other Member States are only now starting to evaluate the exposure of their population to radon indoors. Conducting these evaluations is particularly important for those countries with uranium mining operations, or those countries with geological formations that favour the production and transport of radon through the soil.

164. The Agency, through its technical cooperation programme, has assisted several Member States in the past year to develop national strategies to reduce radon exposure. Workshops have also been organized to discuss radon control strategies with professionals such as architects and engineers. This work is being carried in collaboration with the WHO and the European Commission. A new Safety Guide, based on the requirements in the revised BSS, *Protection of the Public against Indoor Exposure to Natural Sources of Radiation*, is currently in development.

165. The Agency held a technical meeting on the development of guidance material for the management of radiation protection programmes for itinerant workers from 21 to 24 November 2011. Twenty participants from Member States and international organizations attended the meeting. The contributions from the participants have accelerated the development of a safety report entitled *Radiation Protection of Itinerant Workers*, which will be made available in 2013.

⁵¹ ICRP Publication 60 of 1990 and ICRP Publication 103 of 2007.

⁵² *Nuclear Safety Review for the Year 2010* (document GC(55)/INF/3 issued in July 2011). Available online at: http://www.iaea.org/About/Policy/GC/GC55/GC55InfDocuments/English/gc55inf-3_en.pdf.

166. The changes in the dose limit for the eye lens proposed by ICRP have been incorporated in the revised BSS. In the Safety Guide on occupational radiation protection that is being developed, the eye lens dose limits will also be considered. In this context, Member States have encouraged the Secretariat to publish this guidance document as soon as possible.

167. An Agency technical meeting on radiation protection for referring physicians was held in Vienna, from 26 to 28 September 2011, to address how to reduce the large number of unnecessary medical exposures. Actions to improve awareness among referring physicians (general practitioners and primary care physicians) regarding radiation exposure and the risks involved with various procedures were among some of the agreed outcomes of this meeting. Recommendations regarding actions for Member States, the Agency and professional bodies to reduce unnecessary exposures were developed.

F.3. Future challenges

168. All Member States need to evaluate the extent of radon exposure in their countries to determine if additional actions are required. Where radon concentrations of concern for public health are identified, Member States need to establish an action plan. This includes setting a national reference level, developing and implementing appropriate building codes and providing information to all interested parties. Close cooperation among national agencies is also necessary to ensure that all radiation protection and public health concerns are addressed and that resources are used effectively and protection is optimized.

169. As trained, permanent personnel decrease in number, and an increasingly unskilled itinerant workforce fills the gap, it is foreseen that both employer and itinerant worker will accept a wider range of individual risk; this raises questions as to what constitutes an acceptable dose.⁵³ Furthermore, as the nuclear workforce becomes more mobile, managing cumulative occupational dose history becomes more difficult; especially in the absence of a centralized radiation protection programme or tracking system in place to manage overall cumulative doses received.

170. The drastic reduction of the ICRP recommended limits for absorbed dose for the eye lens requires careful investigation of the workplaces concerned and the development of a graded approach to implement the new limits.

171. The goal in medical exposure is not to give the lowest dose, but to provide the appropriate dose to enable the practitioner to correctly make the diagnosis or cure the tumour. Either too large or too small of a dose can be problematic. Radiation protection programmes for the treatment of patients with ionizing radiation must be improved.

⁵³ Chapter 10 of *Radiation Risks in Perspective* (IAEA Practical Radiation Technical Manual, Vienna, 2004).

G. Ensuring nuclear transport safety

G.1. Trends and issues

172. Despite established safety standards⁵⁴ for the transport of radioactive materials, delays and denials persisted in 2011. The reasons shipments were refused ranged from suspicion and lack of information about handling radioactive materials safely to difficulties in implementing overly complex local or national regulations.

173. In the special case of the Fukushima accident, Japanese authorities reported extensive disruptions to the transport by air, sea and land of goods and people in the days directly following the earthquake, tsunami and nuclear accident. While the immediate impacts of a nuclear reactor emergency relate to aircraft travel and shipping routes within evacuation and exclusion zones, there was a realization as the nuclear accident progressed that the implications for transport were much wider.

174. Japan is the world's third largest manufacturing nation and a key producer of components for electronics, automotive, aerospace and other goods.⁵⁵ With many factories in north-east Japan affected by the combined natural disasters followed by the nuclear accident, the disruption not only to manufacturing capabilities, but also to the transport of goods badly affected the global supply chain for many weeks. Furthermore, the nuclear accident prompted States to delay or temporarily suspend flights to and from Japan amid fears of radiation. Transport of goods, food and people from Japan was further delayed as States stepped up contamination monitoring at arrival ports to screen food imports, cargo and travellers.

175. Many States had difficulties in monitoring and assessing radiation and in regulating the control of transport. This demonstrated the lack of a common approach, the lack of a fully effective regulatory system, and the lack of an effective monitoring capacity. The European Commission (EC) attempted to establish common processes in Europe through requests for specific information using the European Community Urgent Radiological Information Exchange (ECURIE) network. The EC requested information on the number of shipments exceeding specific values, thus encouraging European States to adopt the specific values they had set as a standard for acceptance.

176. The Agency was approached by a group of shipping companies voicing concerns over the safety of some monitoring activities they were being requested to undertake and their feedback suggested that only a few shipments had been returned to Japan. Information on actual levels and number of contaminated shipments was sparse and anecdotal, both from Europe and elsewhere in the world.

177. Some consignments with very low levels of surface contamination (of no safety concern) were being rejected and returned to Japan. In one reported case, vehicles were being returned to Japan because of surface contamination at or below exemption levels. The underlying issues were not related to any scientific risk, but to fear and lack of information about radiation. In a study conducted by the World Nuclear Association on the problems underlying denials of shipment, their findings identified causal relationships among fear, lack of information and denials of shipment. Overall, the situation

⁵⁴ See the Appendix, Section B.3.7., "Transport of Radioactive Material", for an update on the status of transport-related safety standards.

⁵⁵ UNIDO press announcement, 10 March 2010
<http://www.un.org/apps/news/story.asp?NewsID=33962&Cr=unido&Cr1>.

was confused, inconsistent and characterized by relatively arbitrary decision making that is continuing at the time of this report; this has been reported to the Commission on Safety Standards.

G.2. Activities

178. Under the Joint Radiation Emergency Management Plan of the International Organizations (EPR-JPLAN (2010))⁵⁶, a request was made to establish a transport working group to deal with international transport disruptions. The group was established under the leadership of the International Civil Aviation Organization, using information technology (IT) facilities provided by the WHO through their PAGNet scheme. The group involved both the United Nations and major international transport groups with a relevant interest (Airports Council International, International Air Transport Association, International Civil Aviation Organization, International Labour Organization, International Maritime Organization, World Tourism Organization, WHO, World Meteorological Organization). The group communicated via teleconference and exchanged information via the WHO IT facilities (often several times each day). They monitored concerns and responded with joint statements. They reviewed reports and circulated them — in particular, a methodology for aircraft decontamination developed by airlines in response to Chernobyl was reviewed and circulated, and information on the ease of aircraft decontamination based on experience with polonium contamination was circulated.⁵⁷

179. In 2011, the Agency organized a series of consultant and technical meetings, including regional workshops, to perform in-depth analysis of the newly issued denials and delays reports, to update regional action plans, and to develop a communication strategy and communication tools, such as brochures aimed at carriers, a simplified training course and an e-learning package on denial.

180. An analysis of the International Maritime Organization Global Integrated Shipping Information System (IMO GSIS) data showed that some 75% of air travel issues reported were air delay problems—primarily affecting radiopharmaceuticals; over 90% of maritime issues reported were denials primarily affecting Cobalt and naturally occurring ores. However, these numbers provide only partial analysis as industries continued to demonstrate reluctance in reporting problems of shipping radioactive materials, citing database confidentiality as an issue. Furthermore, some new issues (such as the potential difficulties of increased security requirements at border crossings) may increase pressure for a revised reporting and recording methodology to improve confidentiality of information.

181. Additionally, the Agency maintains a global network including regional coordinators and national focal points as liaison officers. But to date, only 69 of the Agency's 152 Member States have nominated national focal points.

⁵⁶ Sponsored by the European Commission, European Police Office, Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Criminal Police Organization — INTERPOL, International Maritime Organization, Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, Pan American Health Organization, United Nations Environment Programme, United Nations Office for the Coordination of Humanitarian Affairs, United Nations Office for Outer Space Affairs, World Health Organization, World Meteorological Organization, in cooperation with the International Civil Aviation Organization, United Nations Scientific Committee on the Effects of Atomic Radiation.

⁵⁷ Radioactive Contamination of Aircraft and Engines. 3rd Edition, Association of European Airlines (AEA), June 2002.

G.3. Future challenges

182. The transport outcomes from these developments indicate the need for improved regulatory definition and guidance, improved application of regulations, and improved information sharing. This need was confirmed later in the year through feedback at the Agency-hosted International Conference on the Safe and Secure Transport of Radioactive Material: The Next Fifty Years of Transport — Creating a Safe, Secure and Sustainable Framework, 17–21 October 2011, Vienna, Austria.⁵⁸

183. The effect on transport of most major incidents could be significant. As a result, there have been calls for strengthened relationships between UN bodies with an interest in international transport. While this is not a major area of work for the Agency, there is an interest, since a strong group could take an effective lead in dealing with problems such as denials of shipment and harmonized application of regulations as well as the obvious links with emergencies.

H. Working towards decommissioning, remediation and waste solutions

H.1. Trends and issues

184. A number of sites around the world have been contaminated with radionuclides that required or still require remediation. Some sites were contaminated by nuclear testing or reactor accidents, while others were contaminated as a result of non-regulated past practices. Contamination at these sites may cause radiation risks to humans and the environment, and therefore, the remediation of contaminated sites affects both the public and a wide variety of stakeholders.

185. Practical experience indicates that a broad acceptance by the people involved is a prerequisite for the successful recovery of affected areas. Simple, flexible, robust and transparent assessment tools to allow a comprehensive evaluation of the contaminated site are required. Providing tools and guidance how to use them, as well as ensuring effective communication, will significantly influence public confidence. How authorities use these tools to manage the situation will determine the overall success of these recovery programmes. Approaches to integrate monitoring activities for verifying the effectiveness of remedial actions also need to be developed.

186. The Fukushima accident continues to present a complex set of challenges to the surrounding population, such as the health effects of radiation-contaminated soil, which in turn contaminates crops that people rely on for food. As a consequence of the accident, about 1300 km² of land were contaminated at levels that may potentially cause exposure to the public at levels of 5–20 mSv; on about 500 km², exposure to members of the public of more than 20 mSv may occur [9].

187. For such post-accident conditions, the revised International Basic Safety Standards (BSS) recommends a reference level in the range of 1–20 mSv. Specific reference levels to be applied for each situation must be defined by taking into account the precise circumstances of an exposure situation, such as the level of activity in the environment, environmental conditions and population lifestyle. The BSS requires that any measure taken is justified to ensure that it does more good than harm and that it is commensurate with the risk.

⁵⁸ See <http://www-pub.iaea.org/mtcd/meetings/Announcements.asp?ConfID=38298>.

188. Remediation and decommissioning challenges at the Fukushima Daiichi site will clearly require the utmost vigour and determination to resolve. Post-accident remediation generates large volumes of waste that must be stored and/or disposed of within a short period of time. This is a challenge for both the regulatory body, as it will need to accelerate licensing compared to normal circumstances, and for the organization(s) responsible for carrying out the work in a safe and environmentally responsible manner [9].

H.2. Activities

189. A fact-finding mission to study the remediation of large contaminated areas off-site of the Fukushima Daiichi nuclear power plant, which took place from 7 to 15 October 2011, determined that the extensive post-accident remediation efforts required will generate large volumes of contaminated material running into millions of cubic metres [9].

H.3. Future challenges

190. Notwithstanding the fact that some reactor lifetimes are being extended, an increasing number of nuclear installations are also approaching the end of their life and need to be decommissioned and dismantled. Additionally, some countries are rethinking their energy strategy in the wake of the Fukushima accident and are moving toward decommissioning. This fact, coupled with waste issues associated with new reactor builds and increased remediation calls, requires effective technical, legal and regulatory waste solutions.

191. One of the challenges faced by operators, regulators and scientists focuses on developing harmonized and reliable methodologies to analyse and evaluate radiological monitoring data and to assess radiological impacts to the population in contaminated areas. The Models and Data for Radiological Impact Assessment (MODARIA) programme will be launched in November 2012. This is a four-year programme designed to provide an international forum to discuss these issues.

192. It should be noted that the quantity of contaminated material involved may be larger than all of the nuclear waste that will arise from the operation and decommissioning of all nuclear power plants (NPPs) in Japan. This contaminated material will need to be collected, characterized for clearance or treatment and conditioning, stored and finally disposed of. The challenges involved in processing such massive amounts of contaminated material will need to be carefully considered and swiftly resolved by the regulator, the operator and the implementing organizations.

I. Civil liability for nuclear damage

I.1. Trends and issues

193. The importance of having effective civil liability mechanisms in place to insure against harm to human health and the environment, as well as economic loss caused by nuclear damage, remains a subject of increased attention among States.

194. The IAEA Action Plan on Nuclear Safety specifically calls for the establishment of a global nuclear liability regime that addresses the concerns of all States that might be affected by a nuclear incident with a view to providing appropriate compensation for nuclear damage. In particular, the Action Plan calls on Member States to work towards establishing such a global regime and, more specifically, to give due consideration to the possibility of joining the international nuclear liability instruments as a step toward achieving such a regime. The Action Plan also calls on the IAEA

International Expert Group on Nuclear Liability (INLEX), to recommend actions to facilitate achievement of such a global regime.

I.2. International activities

195. In addition to the eleventh regular meeting of INLEX, which was held from 25 to 27 May 2011, a special session of INLEX was held from 14 to 16 December 2011, specifically devoted to the implementation of the IAEA Action Plan on Nuclear Safety.

196. At the May meeting, INLEX discussed, inter alia, developments relating to nuclear liability within the European Union (EU), a proposal to allow Contracting Parties to exclude certain small research reactors and nuclear installations being decommissioned from the scope of application of the international nuclear liability conventions, INLEX's outreach activities, the Explanatory Text for the Joint Protocol Relating to the Application of the Vienna Convention and of the Paris Convention (Joint Protocol) and the establishment of the Nuclear Law Institute.

197. As regards INLEX's outreach activities, the Group reviewed its previous activities, with special reference to the fifth Workshop on Civil Liability for Nuclear Damage which was held in Moscow, on 5-7 July 2010, for countries of Eastern Europe and Central Asia, and the International Workshop on the Convention on Supplementary Compensation for Nuclear Damage which was organized by the IAEA with the Republic of Korea and held in Seoul on 10-11 February 2011. There were also discussions on future INLEX's outreach activities.

198. With regard to the Explanatory Text for the Joint Protocol, the Group endorsed the revised version which was presented by the Secretariat, and requested that it be published as part of the IAEA International Law Series with the same status as the Explanatory Texts for the 1997 Vienna Convention and the 1997 Convention on Supplementary Compensation.

199. INLEX also had an initial informal discussion on the liability and compensation arrangements which would apply to the Fukushima Daiichi nuclear accident and the related legal issues in connection with the application of the relevant Japanese legislation. Issues discussed revolved around the channelling of liability to the operator, the government indemnity in the case of earthquake or tsunami and the concept of exemption from liability in the case of damage caused by a "grave natural disaster of an exceptional character".

200. At the special session held in December 2011, the Group specifically discussed its role in the implementation of the IAEA Action Plan on Nuclear Safety. In particular, the Group agreed on activities to be carried out before the next regular meeting in May 2012, and had a preliminary discussion, based on the work already done by INLEX in the past, notably on ways and means whereby a global nuclear liability regime that addresses the concerns of all States can be established.

201. As regards activities to be carried out before its next regular meeting, the Group agreed that IAEA/INLEX missions should be carried out in specific target States relevant for establishing a global nuclear liability regime. These missions should first target States operating nuclear installations that are currently not covered by any nuclear liability convention. The Group also noted that, in addition to the IAEA/INLEX missions, the Secretariat would continue its informal consultations with Member States of interest at IAEA Headquarters, and agreed that the Secretariat would organize a nuclear liability workshop at IAEA Headquarters for diplomats and experts from Member States, in conjunction with the regular meeting of INLEX in May 2012. Finally, the Group agreed that presentations on nuclear liability should be made at relevant IAEA meetings during 2012.

202. During the preliminary discussion on the recommendations on ways and means whereby a global nuclear liability regime can be established, the Group also considered a number of possible recommendations to be further discussed at its next regular meeting in May 2012.

I.3. Future challenges

203. The main challenge for the future is the establishment of a global nuclear liability regime as called for in the IAEA Action Plan on Nuclear Safety. This is highlighted by the comparatively low number of Contracting Parties to the existing nuclear liability conventions, in particular those adopted under IAEA auspices, after the 1986 Chernobyl accident, in order to modernize the regime.

204. The Action Plan specifies that the global regime to be established should be one that addresses the concerns of all States that might be affected by a nuclear accident, with a view to providing appropriate compensation for nuclear damage, and specifically calls on States to give due consideration to the possibility of joining the international nuclear liability instruments as a step toward achieving such a global regime. INLEX will assist in this regard through its enhanced activities, as described above.

J. Key reference documents

205. This section provides a list of the key reference documents that were used in the preparation of this report. They have been compiled in this section along with their links for ease of reference and accessibility. Some documents reside on the Agency's restricted-access GOVATOM website and some on its public website.

1. *Draft IAEA Action Plan on Nuclear Safety* (document GOV/2011/59-GC(55)/14; the Board's approval of the Action Plan was endorsed by General Conference on 22 September 2011)
2. *IAEA International Fact Finding Expert Mission of the Nuclear Accident Following the Great East Japan Earthquake and Tsunami: Preliminary Summary* (mission summary issued on 1 June 2011)
3. *Fukushima Daiichi Status Report* (Agency report issued on 22 December 2011)
4. *IAEA Activities in Response to the Fukushima Accident* (document GOV/INF/2011/8 issued on 3 June 2011)
5. *Report of Japanese Government to IAEA Ministerial Conference on Nuclear Safety - Accident at TEPCO's Fukushima Nuclear Power Stations* (transmitted by Permanent Mission of Japan to IAEA, 7 June 2011 and 12 September 2011)
6. *Declaration by the IAEA Ministerial Conference on Nuclear Safety in Vienna on 20 June 2011* (document INFCIRC/821 issued on 20 June 2011)
7. *IAEA Ministerial Conference on Nuclear Safety 20–24 June 2011* (document GOV/INF/2011/13-GC(55)/INF/10 issued on 5 September 2011)
8. *Initial Progress in the Implementation of the IAEA Action Plan on Nuclear Safety* (document GOV/INF/2011/15 issued on 10 November 2011)
9. *Summary Report of the Preliminary Findings of the IAEA Mission on Remediation of Large Contaminated Areas Off-site the Fukushima Dai-ichi NPP 7–15 October 2011, Japan* (report issued on 14 October 2011)
10. *Final Report of the International Mission on Remediation of Large Contaminated Areas Off-site the Fukushima Dai-ichi NPP. 7–15 October 2011, Japan* (Agency report issued on 15 November 2011)
11. *A Methodology for Member States to Assess the Safety Vulnerabilities of Nuclear Power Plants against Site Specific Extreme Natural Hazards* (Agency document issued on 16 November 2011)
12. Appendix: The IAEA Safety Standards: Activities during 2011 listed at the end of this document

Appendix

The IAEA Safety Standards: Activities during 2011

A. Summary

1. The fourth term of the Commission on Safety Standards (CSS) ended in 2011, which began in January 2008. The Chairman of the Commission, André-Claude Lacoste provided the Director General with a report highlighting the main achievements over the four-year term and the challenges and recommendations for the future.⁵⁹
2. In particular, the report highlights significant progress toward:
 - The establishment of a long term structure for the safety standards with a top-down, logical approach and the optimization of the Safety Guides;
 - The development of a document on strategies and processes for the establishment of IAEA safety standards (SPESS),⁶⁰
 - The establishment of a short term and long term vision for addressing synergies between safety and security;
 - The establishment of a plan for the review of IAEA safety standards in the light of the Fukushima accident.

A.1. Long term structure and format for the IAEA safety standards

3. In May 2008, the Commission approved the road map for the long term structure of safety standards.
4. In September 2008, the CSS approved the implementation of the road map with the long term structure of the Safety Requirements. This road map involves integrating thematic Safety Requirements into a set of General Safety Requirements, further complemented by a series of Specific Safety Requirements for facilities and activities. For General Safety Requirements and Specific Safety Requirements, a new format was also adopted with a discrete set of overarching requirements followed by requirements of associated conditions to be met.

⁵⁹ *Commission on Safety Standards — Fourth Term Report 2008–2011* (issued on 7 December 2011). The report can be downloaded at:

<http://www-ns.iaea.org/committees/files/css/204/CSS4yreport2008-2011final12December2011.doc>.

⁶⁰ *Strategies and Processes for the Establishment of IAEA Safety Standards (SPESS) — Version 1.1*, 10 March 2011. The document can be downloaded at:

<http://www-ns.iaea.org/downloads/standards/spess.pdf>.

5. The CSS also approved criteria for optimizing the Safety Guide structure for the long term, which resulted in a Safety Guide reference list; the Commission subsequently approved both in October 2009.

A.2. Strategies and processes for the establishment of IAEA safety standards

6. The first version of SPESS was issued in 2010. SPESS implements the road map for the long term structure of safety standards, providing an improved structure and format for the Safety Requirements and a reference set for the Safety Guides. It also includes all policy and strategy papers established by the Secretariat and approved by the CSS.

A.3. Synergies and interface between the IAEA safety standards and the Nuclear Security Series

7. A joint session of the Advisory Group on Nuclear Security (AdSec) and the CSS met in April 2009 to exchange views on safety and security synergies and interfaces.

8. Following recommendations made at the Joint Session, the Secretariat decided to establish a joint AdSec-CSS Task Force, to be co-chaired by the AdSec and CSS Chairmen, with equal participation by members from both groups as well as active participation from the Secretariat. The initial aim in establishing the task force was to explore the practical improvement of the processes to review and approve draft Nuclear Security Series publications, and the long term feasibility of developing an integrated series of safety and security standards.

9. The Task Force met four times between October 2009 and May 2011. At a joint session organized in November 2011, the Task Force prepared and submitted a combined report to the AdSec and the CSS. Additionally, at the joint session meeting, the participants agreed on the following four principles proposed by the Task Force:

1. Nuclear security and safety are equally important and the process for review/approval should reflect this;
2. Safety document preparation profiles (DPPs) and nuclear security DPPs should be reviewed to identify/define interfaces, if any;
3. Draft safety publications and draft nuclear security publications that have an identified interface should be developed in consultation;
4. After implementation of Principles 2 and 3, draft safety publications and draft nuclear security publications should be reviewed and approved to ensure effective coordination and agreement with the Safety Fundamentals and the Nuclear Security Fundamentals.

10. In pursuit of the short term objective of improving the process for the review and approval of draft Nuclear Security Series publications, the Joint Task Force report recommended to the Director General the establishment of a standing Nuclear Security Guidance Committee (NSGC), open to all Member States, to make recommendations on the development and review of Nuclear Security Series publications. As a long term vision of the Committee structure for the review and approval of the draft nuclear safety and nuclear security publications, the Joint Task Force report proposed that a new Safety and Security Series Commission be established; such long term vision should be revised if necessary, in light of the experience acquired with the NSGC operation.

A.4. Review of the IAEA safety standards in light of the Fukushima accident

11. The IAEA Action Plan on Nuclear Safety [1], includes the following actions:
12. The Commission on Safety Standards and the Secretariat will review and revise the relevant safety standards in a prioritized sequence, as required, using the existing process in a more efficient manner.⁶¹
13. Member States will utilize the safety standards as broadly and effectively as possible in an open, timely and transparent manner. The Secretariat will continue providing support and assistance for the application and implementation of safety standards.
14. With a view to implementing this action, a first draft of an action plan for the review of the IAEA safety standards⁶² was prepared by the Secretariat and submitted to the CSS at its meeting in November 2011. The draft plan describes the methodology for conducting the review of the safety standards in terms of scope, prioritization, approach, process, and timeline for the review, as well as possible options for subsequent revisions of those safety standards where necessary [10].
15. Taking into account the importance of the Fukushima accident, the CSS recommended that the Agency establish a central technical point for collecting, classifying and validating the information and the lessons learned from the accident.
16. The CSS members agreed to further contribute to the development of the draft action plan for the review of the IAEA safety standards and welcomed the fact that the Secretariat had started its implementation.
17. The CSS noted that the review and revision, if necessary, of the relevant safety standards in the light of the Fukushima accident is a continuous process; the collection of facts and development of lessons learned for this purpose began in November 2011.
18. The CSS further noted that the proposed plan will be a living document to be continuously updated to reflect future safety standards committees and CSS discussions, the initiatives taken by other international organizations, the results of national and regional actions following the Fukushima accident, and the conclusions of the extraordinary meeting in August 2012 of the Contracting Parties to the Convention on Nuclear Safety.

⁶¹ This review could include, inter alia, regulatory structure, emergency preparedness and response, nuclear safety and engineering (site selection and evaluation, assessment of extreme natural hazards including their combined effects, management of severe accidents, station blackout, loss of heat sink, accumulation of explosive gases, nuclear fuel behaviour and ways to ensure the safety of spent fuel storage).

⁶² See <http://www-ns.iaea.org/committees/comments/default.asp?fd=1114>.

B. The current status of IAEA Safety Standards

B.1. Safety fundamentals

SF-1 Fundamental Safety Principles (2006) Co-sponsorship: Euratom, FAO, ILO, IMO, OECD/NEA, PAHO, UNEP, WHO

B.2. General safety standards (applicable to all facilities and activities)

GSR Part 1	Governmental, Legal and Regulatory Framework for Safety (2010)
GS-R-3	The Management System for Facilities and Activities (2006)
GSR Part 3	Radiation Protection and Safety of Radiation Sources – Revision of the Internal BSS, Interim Edition (2011)
GSR Part 4	Safety Assessment for Facilities and Activities (2009)
GSR Part 5	Predisposal Management of Radioactive Waste (2009)
WS-R-5	Decommissioning of Facilities Using Radioactive Material (2006)
GS-R-2	Preparedness and Response for a Nuclear or Radiological Emergency (2002) Co-sponsorship: FAO, OCHA, OECD/NEA, ILO, PAHO, WHO
GS-G-2.1	Arrangements for Preparedness for a Nuclear or Radiological Emergency (2007) Co-sponsorship: FAO, OCHA, ILO, PAHO, WHO
GS-G-3.1	Application of the Management System for Facilities and Activities (2006)
GS-G-3.2	The Management System for Technical Services in Radiation Safety (2008)
GS-G-3.3	The Management System for the Processing, Handling and Storage of Radioactive Waste (2008)
GSG-1	Classification of Radioactive Waste (2010)
RS-G-1.1	Occupational Radiation Protection (1999) Co-sponsorship: ILO
RS-G-1.2	Assessment of Occupational Exposure Due to Intakes of Radionuclides (1999) Co-sponsorship: ILO
RS-G-1.3	Assessment of Occupational Exposure Due to External Sources of Radiation (1999) Co-sponsorship: ILO
RS-G-1.4	Building Competence in Radiation Protection and the Safe Use of Radiation Sources (2001) Co-sponsorship: ILO, PAHO, WHO
RS-G-1.7	Application of the Concepts of Exclusion, Exemption and Clearance (2004)
RS-G-1.8	Environmental and Source Monitoring for Purposes of Radiation Protection (2005)
RS-G-1.9	Categorization of Radioactive Sources (2005)
WS-G-2.3	Regulatory Control of Radioactive Discharges to the Environment (2000) (under revision)
WS-G-2.5	Predisposal Management of Low and Intermediate Level Radioactive Waste (2003) (under revision)
WS-G-2.6	Predisposal Management of High Level Radioactive Waste (2003) (under revision)
WS-G-3.1	Remediation Process for Areas Affected by Past Activities and Accidents (2007)
WS-G-5.1	Release of Sites from Regulatory Control on Termination of Practices (2006)
WS-G-5.2	Safety Assessment for the decommissioning of Facilities Using Radioactive Material (2008)
WS-G-6.1	Storage of Radioactive Waste (2006)
GSG-2	Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency (2011)

B.3. Specific Safety Standards (applicable to specified facilities and activities)

B.3.1. Nuclear Power Plants

NS-R-1	Safety of Nuclear Power Plants: Design (2000) (under revision)
SSR-2/2	Safety of Nuclear Power Plants: Commissioning and Operation (2011)
NS-R-3	Site Evaluation for Nuclear Installations (2003)
GS-G-1.1	Organization and Staffing of the Regulatory Body for Nuclear Facilities (2002)
GS-G-1.2	Review and Assessment of Nuclear Facilities by the Regulatory Body (2002)
GS-G-1.3	Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body (2002)
GS-G-1.4	Documentation for Use in Regulating Nuclear Facilities (2002)
GS-G-3.5	The Management System for Nuclear Installations (2009)
SSG-12	Licensing Process for Nuclear Installations (2010)
GS-G-4.1	Format and Content of the Safety Analysis report for Nuclear Power Plants (2004)
NS-G-1.1	Software for Computer Based Systems Important to Safety in Nuclear Power Plants (2000) (under revision)
NS-G-1.3	Instrumentation and Control Systems Important to Safety in Nuclear Power Plants (2002) (under revision)
NS-G-1.4	Design of Fuel Handling and Storage Systems for Nuclear Power Plants (2003)
NS-G-1.5	External Events Excluding Earthquakes in the Design of Nuclear Power Plants (2004)
NS-G-1.6	Seismic Design and Qualification for Nuclear Power Plants (2003)
NS-G-1.7	Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants (2004)
NS-G-1.8	Design of Emergency Power Systems for Nuclear Power Plants (2004) (under revision)
NS-G-1.9	Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants (2004)
NS-G-1.10	Design of Reactor Containment Systems for Nuclear Power Plants (2004)
NS-G-1.11	Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants (2004)
NS-G-1.12	Design of the Reactor Core for Nuclear Power Plants (2005)
NS-G-1.13	Radiation Protection Aspects of Design for Nuclear Power Plants (2005)
NS-G-2.1	Fire Safety in the Operation of Nuclear Power Plants (2000)
NS-G-2.2	Operational limits and Conditions and Operating Procedures for Nuclear Power Plants (2000)
NS-G-2.3	Modifications to Nuclear Power Plants (2001)
NS-G-2.4	The Operating Organization for Nuclear Power Plants (2002)
NS-G-2.5	Core Management and Fuel Handling for Nuclear Power Plants (2002)
NS-G-2.6	Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants (2002)
NS-G-2.7	Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants (2002)
NS-G-2.8	Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (2003)
NS-G-2.9	Commissioning for Nuclear Power Plants (2003) (under revision)
NS-G-2.10	Periodic Safety Review of Nuclear Power Plants (2003) (under revision)

NS-G-2.11	A System for the Feedback of Experience from Events in Nuclear Installations (2006)
NS-G-2.12	Ageing Management for Nuclear Power Plants (2009)
NS-G-2.13	Evaluation of Seismic Safety for Existing Nuclear Installations (2009)
NS-G-2.14	Conduct of Operations at Nuclear Power Plants (2008)
NS-G-2.15	Severe Accident Management Programmes for Nuclear Power Plants (2009)
SSG-13	Chemistry Programme for Water Cooled Nuclear Power Plants (2011)
NS-G-3.1	External Human Induced Events in Site Evaluation for Nuclear Power Plants (2002)
NS-G-3.2	Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants (2002) (under revision)
SSG-9	Seismic Hazards in Site Evaluation for Nuclear Installations (2010)
SSG-18	Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (2011)
NS-G-3.4	Meteorological Events in Site Evaluation for Nuclear Power Plants (2003) (under revision)
NS-G-3.5	Flood hazard for Nuclear Power Plants on Coastal and River Sites (2004) (under revision)
NS-G-3.6	Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants (2005)
SSG-2	Deterministic Safety Analysis for Nuclear Power Plants (2009)
SSG-3	Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants (2010)
SSG-4	Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants (2010)
WS-G-2.1	Decommissioning of Nuclear Power Plants and Research Reactors (1999) (under revision)
79	Design of Radioactive Waste Management Systems at Nuclear Power Plants (1986) (under revision)

B.3.2. Research Reactors

NS-R-3	Site Evaluation for Nuclear Installations (2003)
NS-R-4	Safety of Research Reactors (2005)
SSG-9	Seismic Hazards in Site Evaluation for Nuclear Installations (2010)
SSG-18	Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (2011)
GS-G-1.1	Organization and Staffing of the Regulatory Body for Nuclear Facilities (2002)
GS-G-1.2	Review and Assessment of Nuclear Facilities by the Regulatory Body (2002)
GS-G-1.3	Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body (2002)
GS-G-1.4	Documentation for Use in Regulating Nuclear Facilities (2002)
GS-G-3.5	The Management System for Nuclear Installations (2009)
SSG-12	Licensing Process for Nuclear Installations (2010)
NS-G-2.11	A System for the Feedback of Experience from Events in Nuclear Installations (2006)
NS-G-2.13	Evaluation of Seismic Safety for Existing Nuclear Installations (2009)
NS-G-4.1	Commissioning of Research Reactors (2006)
NS-G-4.2	Maintenance, Periodic Testing and Inspection of Research Reactors (2006)

NS-G-4.3	Core Management and Fuel Handling for Research Reactors (2008)
NS-G-4.4	Operational Limits and Conditions and Operating Procedures for Research Reactors (2008)
NS-G-4.5	The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors (2008)
NS-G-4.6	Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors (2008)
WS-G-2.1	Decommissioning of Nuclear Power Plants and Research Reactors (1999) (under revision)
SSG-10	Ageing Management for Research Reactors (2010)
35-G1	Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report (1994) (under revision)
35-G2	Safety in the Utilization and Modification of Research Reactors (1994) (under revision)

B.3.3. Fuel Cycle Facilities

NS-R-3	Site Evaluation for Nuclear Installations (2003)
NS-R-5	Safety of Nuclear Fuel Cycle Facilities (2008) (under revision)
SSG-9	Seismic Hazards in Site Evaluation for Nuclear Installations (2010)
SSG-18	Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (2011)
GS-G-1.1	Organization and Staffing of the Regulatory Body for Nuclear Facilities (2002)
GS-G-1.2	Review and Assessment of Nuclear Facilities by the Regulatory Body (2002)
GS-G-1.3	Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body (2002)
GS-G-1.4	Documentation for Use in Regulating Nuclear Facilities (2002)
GS-G-3.5	The Management System for Nuclear Installations (2009)
SSG-12	Licensing Process for Nuclear Installations (2010)
NS-G-2.11	A System for the Feedback of Experience from Events in Nuclear Installations (2006)
NS-G-2.13	Evaluation of Seismic Safety for Existing Nuclear Installations (2009)
SSG-5	Safety of Conversion Facilities and Uranium Enrichment Facilities (2010)
SSG-6	Safety of Uranium Fuel Fabrication Facilities (2010)
SSG-7	Safety of Uranium and Plutonium Mixed Oxide Fuel Fabrication Facilities (2010)
WS-G-2.4	Decommissioning of Nuclear Fuel Cycle Facilities (2001) (under revision)
116	Design of Spent Fuel Storage Facilities (1995) (under revision)
117	Operation of Spent Fuel Storage Facilities (1995) (under revision)

B.3.4. Radioactive Waste Disposal Facilities

SSR-5	Disposal of Radioactive Waste (2011)
GS-G-1.1	Organization and Staffing of the Regulatory Body for Nuclear Facilities (2002)
GS-G-1.2	Review and Assessment of Nuclear Facilities by the Regulatory Body (2002)
GS-G-1.3	Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body (2002)
GS-G-1.4	Documentation for Use in Regulating Nuclear Facilities (2002)
GS-G-3.4	The Management System for the Disposal of Radioactive Waste (2008)
SSG-1	Borehole Disposal Facilities for Radioactive Waste (2009)

WS-G-1.1	Safety Assessment for Near Surface Disposal of Radioactive Waste (1999) (under revision)
111-G-3.1	Siting of Near Surface Disposal Facilities (1994) (under revision)
SSG-14	Geological Disposal Facilities for Radioactive Waste (2011)

B.3.5. Mining and Milling

RS-G-1.6	Occupational Radiation Protection in the Mining and Processing of Raw Materials (2004)
WS-G-1.2	Management of Radioactive Waste from the Mining and Milling of Ores (2002) (under revision)

B.3.6. Applications of Radiation Sources

GSR Part 3	Radiation Protection and Safety of Radiation Sources – Revision of the Internal BSS, Interim Edition (2011)
GS-G-1.5	Regulatory Control of Radiation Sources (2004) Co-sponsorship: FAO, ILO, PAHO, WHO
RS-G-1.4	Building Competence in Radiation Protection and the Safe Use of Radiation Sources (2001) Co-sponsorship: ILO, PAHO, WHO
RS-G-1.5	Radiological Protection for Medical Exposure to Ionizing Radiation (2002) Co-sponsorship: PAHO, WHO (under revision)
RS-G-1.9	Categorization of Radioactive Sources (2005)
RS-G-1.10	Safety of Radiation Generators and Sealed Radioactive Sources (2006) Co-sponsorship: ILO, PAHO, WHO
WS-G-2.2	Decommissioning of Medical, Industrial and Research Facilities (1999) (under revision)
WS-G-2.7	Management of Waste from the Use of Radioactive Materials in Medicine, Industry, Agriculture, Research and Education (2005)
SSG-8	Radiation Safety of Gamma, Electron and X Ray Irradiation Facilities (2010)
SSG-11	Radiation Safety in Industrial Radiography (2011)
SSG-19	National Strategy for Regaining Control over Orphan Sources and Improving Control over Vulnerable Sources (2011)

B.3.7. Transport of Radioactive Material

TS-R-1	Regulations for the Safe Transport of Radioactive Material 2009 Edition (2009) (under revision)
TS-G-1.1 Rev1	Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2008) (under revision)
TS-G-1.2	Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material (2002)
TS-G-1.3	Radiation Protection Programmes for the Transport of Radioactive Material (2007)
TS-G-1.4	The Management System for the Safety Transport of Radioactive Material (2008)
TS-G-1.5	Compliance Assurance for the Safe Transport of Radioactive Material (2009)
TS-G-1.6	Schedules of Provisions of the IAEA Regulations for the Safe Transport of Radioactive Material (2005 Edition) (2010)