Nuclear Power

Objective

To enhance the capability of interested Member States considering launching nuclear power programmes to plan and build the necessary infrastructure. To enhance the capability of interested Member States with existing nuclear power programmes to improve nuclear power plant operating performance, life cycle management including decommissioning, human performance, quality assurance and technical infrastructure, through good practices and innovative approaches consistent with global objectives on non-proliferation, nuclear safety and security. To enhance the capacity of Member States to develop evolutionary and innovative nuclear technology for electricity generation, for actinide utilization and transmutation and for non-electric applications, consistent with sustainability goals.

Launching Nuclear Power Programmes

In 2013, several countries made significant progress on their first nuclear power plants. In May, the United Arab Emirates (UAE) poured the first concrete for the second unit at the Barakah site. In November, Belarus began construction of the first unit at the Ostrovets site (Fig. 1), becoming the second country in the past three decades to begin construction of its first nuclear power plant. A number of other countries that have decided to introduce nuclear power into their energy mix are in the advanced stages of infrastructure preparation: Bangladesh began site preparation work for its two-unit Rooppur nuclear power plant. Jordan selected Atomstroyexport as a preferred vendor for its first plant. Turkey signed two cooperation agreements with Japan for the Sinop plant. And Viet Nam prepared feasibility studies of two sites for nuclear power plants in Ninh Thuan Province. Table 1 shows the number of Member States at different stages of decision making and planning for nuclear power in 2011–2013.

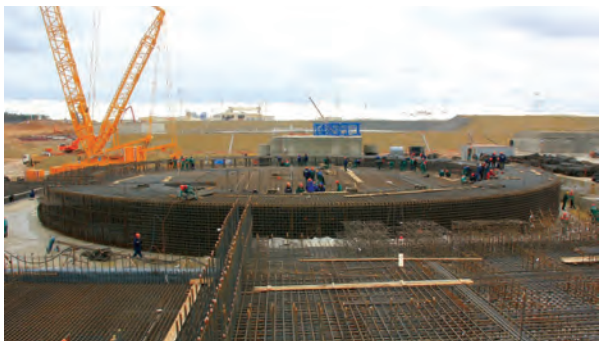

FIG. 1. Belarus began construction of its first nuclear power plant, at the Ostrovets site, on 6 November 2013. (Photograph courtesy of the Directorate for Nuclear Power Plant Construction, Belarus.)

TABLE 1. Number of Member States at different stages of decision making and planning for nuclear power in 2011, 2012 and 2013, according to their official statements.

	2011	2012	2013
First nuclear power plant started construction	0	1	2
First nuclear power plant ordered	3	2	1
Decided and started preparing infrastructure	6	6	6
Active preparation with no final decision	6	6	5
Considering a nuclear power programme	14	13	19

In 2013, the Agency continued to assist Member States that have decided to establish a nuclear power programme. In September, it launched a catalogue of services to help these 'newcomer' countries to identify and request appropriate Agency assistance for national organizations at different stages of the development or expansion of a nuclear power programme.

"In June, the International Ministerial Conference on Nuclear Power in the 21st Century attracted over 500 delegates from 87 countries and 7 international organizations, including over 50 ministerial level participants."

National and regional technical cooperation projects provided extensive support to assist interested countries in establishing the appropriate legal and regulatory framework, developing the necessary nuclear power infrastructure and building related national human resource capacity. Member States such as Bangladesh, Indonesia, Jordan, Malaysia, the UAE and Viet Nam received significant Agency assistance for the review of nuclear laws, the development and review of regulations, the assessment of sites, and the development of regulatory guidance for on-site evaluation.

In June, the International Ministerial Conference on Nuclear Power in the 21st Century attracted over 500 delegates from 87 countries and 7 international organizations, including over 50 ministerial level participants. The conference was held in cooperation with

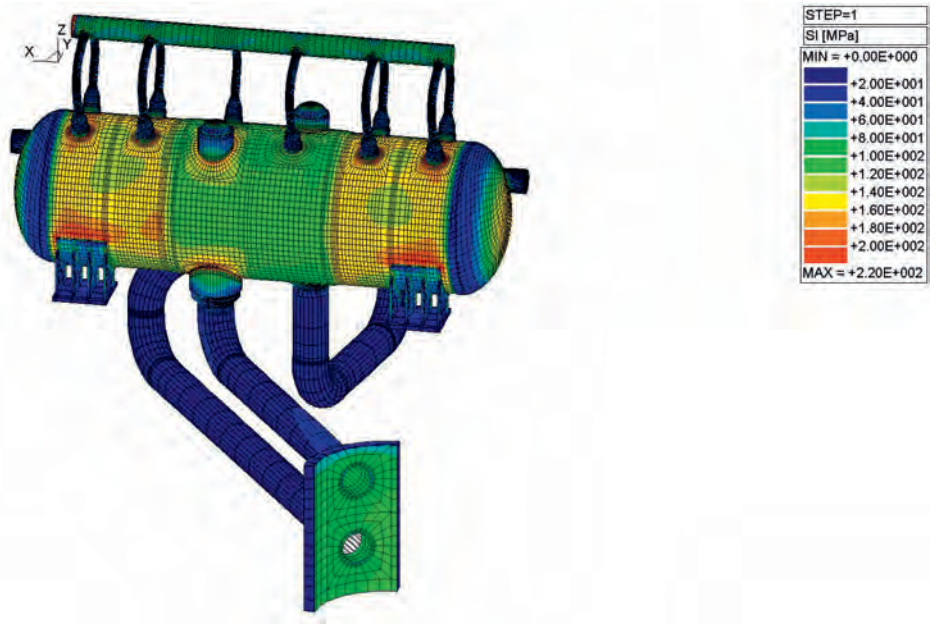

FIG. 2. Illustration of a preliminary strength analysis demonstrating the high stress areas of a steam generator. (Figure courtesy of the Centre for Material Science and Lifetime Management.)

the OECD/NEA and hosted by the Russian Federation in Saint Petersburg. As was noted in the Conference President's concluding statement, the conference "recognized that nuclear power remains an important option for many countries to improve energy security, reduce the impact of volatile fossil fuel prices and mitigate the effects of climate change", and "concluded that for many countries nuclear power is a proven, clean, safe, and economical technology that will play an increasingly important role in achieving energy security and sustainable development goals in the 21st century".

"Many countries have given high priority to licensing their nuclear power plants to operate for terms beyond the 30–40 years originally anticipated."

The Agency is committed to assisting countries that are interested in developing existing or establishing new nuclear power programmes to do so in a safe, secure and responsible manner. One of the services available to Member States provides assistance in building national capacities in energy analysis and planning, enabling them to consider the potential contribution of nuclear power to their national energy mix. Another service, Integrated Nuclear Infrastructure Review (INIR) missions, helps countries to assess the status of their national nuclear infrastructure development and to benefit from recommendations by international experts on how best to move forward. The Agency also assists countries in carrying out national Nuclear Energy System Assessments (NESAs) for developing long term strategies for nuclear energy deployment using the methodology developed through the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). These three services — energy planning, INIR and NESA — are used in an integrated way to support Member States at different stages of the development of a nuclear power programme.

In 2013, INIR missions were conducted to Poland, South Africa and Turkey. The mission to South Africa was the first in Africa; it was also the first INIR mission to a country that already generates nuclear power and is preparing new build projects. An Agency mission to Nigeria was aimed at assisting the country in preparing a nuclear infrastructure self-evaluation report.

Engineering Support for Operation, Maintenance and Plant Life Management

At the end of 2013, more than 80% of the currently operating nuclear power plants worldwide had been in service for 20 years or longer. Many countries have given high priority to licensing their nuclear power plants to operate for terms beyond the 30–40 years originally anticipated. The demanding environment in which a nuclear reactor operates may affect the ability of a broad range of materials to perform their intended function over extended service periods. Therefore, identifying materials and components that are degrading is an important aspect of the safe and secure operation of nuclear power plants (Fig. 2). Current issues and future challenges of material degradation were discussed at a Technical Meeting held in Vienna in November. The meeting, organized jointly with the European Commission's Joint Research Centre (JRC), was attended by over 80 participants from 29 countries. The meeting concluded that the relationships between operating conditions and fracture toughness of material should be defined to improve structural integrity assurance, and that

FIG. 3. Installation of the containment cap for a unit at the Sanmen nuclear power plant, one of the many nuclear power plants under construction in China, a country with an expanding nuclear power programme. (Photograph courtesy of CNNC.)

the existing surveillance specimen programme of a reactor pressure vessel should be modified for long term operation and the neutron flux effect should be taken into consideration to find new positions of surveillance specimens.

Bringing together 125 participants from 32 countries, the 12th IAEA–FORATOM Management Systems Workshop — Journey to Excellence in a Changing Environment, held in Vienna, focused on three key issues: practical solutions for integrating elements into a management system and evaluating its performance, ways to improve a management system to adapt to a changing environment, and lessons learned from an emergency situation. Participants discussed how to adapt their systems to ensure safe management of nuclear facilities in a changing environment. The objectives of the meeting were to raise awareness, increase understanding and promote the application of the IAEA safety standards for nuclear installations and activities (IAEA Safety Standards Series Nos GS-R-3, GS-G-3.1 and GS-G-3.5).

In September, the Agency published *Advanced Surveillance, Diagnostic and Prognostic Techniques in Monitoring Structures, Systems and Components in Nuclear Power Plants* (IAEA Nuclear Energy Series No. NP-T-3.14). The publication describes conventional surveillance, diagnostic and prognostic technologies as well as the latest tools, algorithms and techniques enabling earlier identification of problems and enhanced solutions.

The Agency continued to support countries with expanding nuclear power programmes (Fig. 3). A Technical Meeting on Strategic Supply Chains and National Industrial Involvement for Nuclear Power was held in November in Dijon, France. The 56 meeting participants from 30 countries also visited relevant French manufacturing and training facilities.

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Human Resource Development

The development of human resources and the impact of human behaviour on nuclear power programmes continue to be important areas of focus for the Agency. In May, an International Experts Meeting on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant was held in Vienna and attended by 160 participants from 41 countries and 5 international organizations. The participants expressed their strong support for the promotion of further activities which would both support a systemic approach to nuclear safety and emphasize the relationship between individuals, technology and organization.

The first seven modules of a new e-learning project to support newcomers were launched in 2013. The modules introduce the Agency's 'Milestones' approach[1] to non-experts through free, on-line training[2].

[1] See: *Milestones in the Development of a National Infrastructure for Nuclear Power*, IAEA Nuclear Energy Series No. NG-G-3.1, IAEA, Vienna (2007).

[2] Available at: *http://www.iaea.org/NuclearPower/Infrastructure/elearning/index.html.*

Nuclear Reactor Technology Development

In July, *Nuclear Reactor Technology Assessment for Near Term Deployment* (IAEA Nuclear Energy Series No. NP-T-1.10) was published. The publication served as the basis for workshops held in Austria, Saudi Arabia, Uruguay and Viet Nam, where over 100 participants received related training. In addition, the Agency's publicly accessible Advanced Reactors Information System (ARIS) database was revised and updated.[3]

At the International Conference on Fast Reactors and Related Fuel Cycles: Safe Technologies and Sustainable Scenarios (FR13), held in March in Paris, some 700 experts from 27 countries and 4 international organizations submitted 370 technical and scientific contributions in various fields of fast reactor and fuel cycle technology. The conference reaffirmed the consensus that nuclear fission will continue to play an important role in meeting future energy needs, complying with the expectation for energy production with minimal impact on the climate, the environment and health. In this context, the development of innovative fast neutron systems and closed fuel cycles is regarded as a necessary step to ensure a long term sustainable energy supply.

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A new CRP on Sodium Properties and the Design and Safe Operation of Experimental Facilities in Support of the Development and Deployment of Sodium Cooled Fast Reactors was launched in November. In addition, various related publications, including *Design Features and Operating Experience of Experimental Fast Reactors* (IAEA Nuclear Energy Series No. NP-T-1.9), as well as a booklet entitled *Status of Innovative Fast Reactor Designs and Concepts*, were issued in 2013.

A publication on evaluation of performance and benchmarks for high temperature gas cooled reactors (HTGRs) was issued in April as IAEA-TECDOC-1694. A CRP on modular HTGR safety design was approved in December. The goal of this CRP is to make proposals on safety design criteria, taking the unique inherent safety characteristics of HTGRs into consideration. It will also take into account the effects of the accident at the Fukushima Daiichi nuclear power plant, clarifying the safety requirements and safety evaluation criteria for design extension conditions, especially those events that can affect multiple reactor modules or are dependent on the application for which the reactors are being used, such as process heat or hydrogen production.

[3] Available at: *https://aris.iaea.org/*.

Cogeneration can effectively double thermal efficiency if waste heat is recovered and utilized. Responding to a General Conference resolution requesting the development of a report defining technical and economic aspects for a feasibility study on cogeneration, consultants meetings were organized to help prepare two draft documents, expected to be published in 2014. The Agency also conducted capacity building workshops on energy and water planning in Tunisia and on non-electrical applications in Austria and Malaysia.

Technical Meetings, workshops and seminars continued to address common technologies and issues with regard to small and medium sized reactors (SMRs). *Approaches for Assessing the Economic Competitiveness of Small and Medium Sized Reactors* (IAEA Nuclear Energy Series No. NP-T-3.7) was published in December.

Enhancing Global Nuclear Energy Sustainability through Innovation

INPRO was established in 2000 to help ensure that nuclear energy is available to contribute to meeting the energy needs of the 21st century in a sustainable manner. In 2013, INPRO welcomed Kenya as a new member, bringing the total number of members to 39[4]. In September, the results of the NESA for Belarus, performed by Belarusian experts using the INPRO methodology, were published with the Agency's assistance as IAEA-TECDOC-1716. The publication provides a model for performing a NESA for other countries. NESAs in Indonesia, Romania and Ukraine were also under way, to support strategic, long range nuclear energy planning.

The final report on the Global Architecture of Innovative Nuclear Energy Systems Based on Thermal and Fast Reactors Including a Closed Fuel Cycle (GAINS) collaborative project, entitled *Framework for Assessing Dynamic Nuclear Energy Systems for Sustainability* (IAEA Nuclear Energy Series No. NP-T-1.14), was published in November, and its findings were presented at FR13.

A number of additional reports were also published in 2013, including a report by INPRO on *Performance Assessment of Passive Gaseous Provisions (PGAP)* (IAEA-TECDOC-1698), *Passive Safety Systems in Advanced Water Cooled Reactors (AWCRs): Case Studies* (IAEA-TECDOC-1705), *Challenges Related to the Use of Liquid Metal and Molten Salt Coolants in Advanced Reactors* (IAEA-TECDOC-1696) and *Legal and Institutional Issues of Transportable Nuclear*

[4] The members of INPRO at the end of 2013 were Algeria, Argentina, Armenia, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Egypt, France, Germany, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Republic of Korea, Malaysia, Morocco, Netherlands, Pakistan, Poland, Romania, Russian Federation, Slovakia, South Africa, Spain, Switzerland, Turkey, Ukraine, United States of America, Viet Nam and the European Commission.

Power Plants: A Preliminary Study (IAEA Nuclear Energy Series No. NG-T-3.5).

A training course on the evaluation of collaborative scenarios of transition to sustainable nuclear energy systems using the Agency's energy supply model MESSAGE, held in October in Yogyakarta, Indonesia, focused on modelling scenarios based on once through and closed nuclear fuel cycles viewed from the global perspective. Thirty-three participants from 12 Member States attended the course.

The sixth INPRO Dialogue Forum, held in Vienna from 29 July to 2 August and attended by 105 participants from 37 Member States, addressed licensing and safety issues for SMRs. The Forum identified key issues for SMR development and deployment, as well as additional safety requirements for consideration in the revision of Agency safety standards for SMR development and deployment. At the seventh INPRO Dialogue Forum, held in November and attended by 63 participants from 33 Member States, the results of an assessment of the sustainability of seven evolutionary reactor designs related to safety were discussed with designers from the vendor organizations performing the assessment.