

# Nuclear Power

## Objective

*To assist Member States embarking on new nuclear power programmes in planning and building their national nuclear infrastructures. To provide integrated support to Member States with existing nuclear power plants and to those planning new nuclear build in order to help improve operating performance and help ensure safe, secure, efficient and reliable long-term operation through the implementation of good practices and innovative approaches, and lessons learned from the Fukushima Daiichi accident. To provide collaborative frameworks for operators of water-cooled reactors to benefit from advances in technology, and for Member States to facilitate effective development of fast reactors and gas-cooled reactors and to expand the safe use of non-electric applications.*

## Launching Nuclear Power Programmes

The Agency's programme to assist countries interested in launching nuclear power programmes marked its tenth year in 2017. Throughout the year, the Agency continued to support 28 Member States considering or embarking on a nuclear power programme (Table 1). Agency technical cooperation projects addressed areas such as leadership and management systems, workforce planning and human resource development, managing financial risks associated with nuclear power projects, and resource requirements for nuclear power infrastructure development. Through interregional, regional and national workshops, training courses and fellowships, the Agency provided practical training in various infrastructure issues to more than 300 people, including members of nuclear power development projects, regulatory bodies and technical support organizations.

**TABLE 1. Number of Member States considering or embarking on a nuclear power programme, according to their official statements (as of 31 December 2017)**

First nuclear power plant started construction/under construction	3
First nuclear power plant ordered	2
Decided to introduce nuclear power and started preparing the appropriate infrastructure	4
Active preparation for a possible nuclear power programme with no final decision	7
Considering nuclear power programme	12

The Agency also supported Member States through its Integrated Nuclear Infrastructure Review (INIR) service. During the year, the number of INIR missions deployed since the service's launch in 2009 reached 22, involving 16 Member States (Table 2). In 2017, the Agency conducted an INIR Phase 1 mission to Ghana, and undertook support missions to

review and provide guidance on the self-evaluation reports developed by the Niger and the Sudan in their preparations for INIR missions. To improve the quality and consistency of INIR missions, the Agency published *Guidelines for Preparing and Conducting an Integrated Nuclear Infrastructure Review (INIR)* (IAEA Services Series No. 34). In October, it conducted a workshop with representatives of Belarus aimed at enhancing understanding of the INIR Phase 3 methodology and preparation of the self-evaluation report, and at clarifying the conditions of the national infrastructure evaluation in Phase 3.

**TABLE 2. INIR missions conducted to Member States as of 31 December 2017**

Region	Embarking	Expanding
Africa	Ghana, Kenya, Morocco, Nigeria	South Africa
Asia and the Pacific	Bangladesh, Indonesia, Jordan, Malaysia, Thailand, United Arab Emirates, Viet Nam	
Europe	Belarus, Kazakhstan, Poland, Turkey	

Agency activities in 2017 focused on increasing Member State awareness and understanding of the Milestones approach and key infrastructure issues such as funding and financing, management, human resource development, and stakeholder involvement. In July, the Agency published *Managing the Financial Risk Associated with the Financing of New Nuclear Power Plant Projects* (IAEA Nuclear Energy Series No. NG-T-4.6), providing Member States with a framework for considering issues of risk allocation and project structure, financing and economics. In August, it held a Technical Meeting in Vienna to present and elaborate on the publication. The meeting, attended by 31 participants from 18 Member States, enabled experts and participants from newcomer countries to share knowledge on financial risk allocation and mitigation. At a Technical Meeting on Resource Requirements for Nuclear Power Infrastructure Development, held in December in Vienna, 32 experts from 19 Member States and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) compiled information on the resources needed to develop the infrastructure for a nuclear power programme.

The International Ministerial Conference on Nuclear Power in the 21st Century, organized in cooperation with the OECD/NEA, was held in Abu Dhabi, United Arab Emirates, in October–November. The conference drew around 700 participants from 64 Member States and 6 organizations, and included national statements and panel discussions on: nuclear power as the key to solving the 3Es (energy–economy–environment) trilemma; challenges in developing nuclear power infrastructure; safety and reliability aspects of nuclear energy; and innovations and advances in nuclear technologies. Participants confirmed that nuclear power remains an important option for climate change mitigation and for reaching the targets set out in the Paris Agreement and the Sustainable Development Goals. On the margins of the conference, the Khalifa University of Science and Technology was designated as an Agency Collaborating Centre, to promote capacity building and the sharing of experience in nuclear power infrastructure development over the next four years.

In 2017, the Agency launched a new project on management systems for embarking countries, funded through the Peaceful Uses Initiative. In September, 17 experts from governments, owner/operators and regulatory bodies in 7 Member States took part in a consultants meeting on Enhancing Leadership and Management Systems in Countries Introducing Nuclear Power Programmes, held in Vienna. Participants discussed the challenges that organizations face in developing their management systems, and identified key activities and possible means of support to embarking Member States in the area of integrated management systems. During the year, the Agency held workshops for seven Member States on modelling human resource requirements using the Agency’s Nuclear

Power Human Resources (NPHR) workforce modelling tool and on workforce planning for new nuclear power programmes.

Stakeholder involvement continued to be an important area of focus for countries at all stages of nuclear infrastructure development. In June, 66 participants from 36 Member States attended a Technical Meeting on Stakeholder Involvement and Public Information that featured a role-playing simulation of a town hall meeting on a new nuclear power plant project.

The Agency added a new ‘Procurement’ module to its on-line e-learning course based on the Milestones approach for nuclear newcomers. A total of 17 Milestone modules are now available on the Agency’s web site.

The Agency continued to enhance its Country Nuclear Infrastructure Profiles (CNIPs) mechanism, used to monitor the status of nuclear power infrastructure in Member States, and its Integrated Work Plan (IWP) mechanism, a tool for integrating Agency support for nuclear power programme development. In 2017, it created a shared platform where Member States and Agency staff can collaborate on CNIPs and IWPs, and used the improved mechanisms to plan activities in embarking Member States with active nuclear infrastructure development programmes. The Agency held meetings with nine embarking countries to develop or update IWPs and CNIPs during the year.

### Operating Nuclear Power Plants and Expanding Nuclear Power Programmes

Around 60% of the nuclear power reactors in operation in 2017 had been in operation for 30 years or longer (Fig. 1). While a nuclear reactor is typically licensed for 30–40 years, their operating lifespans can be extended significantly, following special safety reviews and assessments of their essential structures, systems and components. Over 400 nuclear energy experts from 38 Member States and 4 international organizations discussed methods for safely operating nuclear power plants beyond their design lifetime in a cost effective way at the Fourth International Conference on Nuclear Power Plant Life Management, organized by the Agency in Lyon, France, in October.

To provide further support to its Member States in this field, the Agency published the *Handbook on Ageing Management for Nuclear Power Plants* (IAEA Nuclear Energy Series No. NP-T-3.24), providing information on ageing mechanisms; the effects of ageing on structures, systems and components; the regulatory framework; and innovative techniques

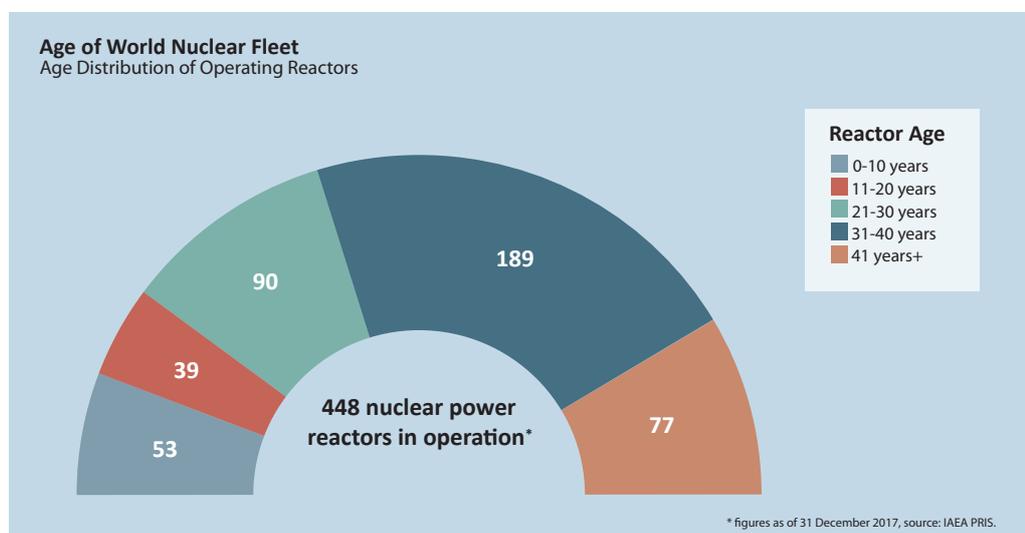


FIG. 1. Age distribution of operating nuclear power reactors as of 31 December 2017.

and research and development in the field. It also published *Benchmark Analysis for Condition Monitoring Test Techniques of Aged Low Voltage Cables in Nuclear Power Plants* (IAEA-TECDOC-1825), describing the fundamentals of cable performance and identifying condition monitoring techniques that show potential for further development and eventual implementation in cable ageing management programmes.

At a meeting of the Technical Working Group on Life Management of Nuclear Power Plants in February, 31 working group members and observers from 19 Member States and an international organization exchanged information regarding plant life management for long term operation. In May, 36 members of the Technical Working Group on Nuclear Power Plant Instrumentation and Control and observers from 20 Member States and an international organization met to plan the Agency's instrumentation and control (I&C) programme for 2018–2021.

In March, the Agency organized a Technical Meeting on Operational Experience with Implementation of Post-Fukushima Actions in Nuclear Power Plants, where 38 owner/operator and technical support organization experts from 19 Member States and 4 international organizations emphasized the importance of maintaining safety and increasing the efficiency and effectiveness of investments in safety enhancements at nuclear power plants.

To respond to growing Member State demand for assistance in the field of digital system reliability and computer security, the Agency organized a Technical Meeting on Engineering and Design Aspects of Computer Security in Instrumentation and Control Systems for Nuclear Power Plants, held in May in Gloucester, United Kingdom. At the meeting, 85 experts from 24 Member States emphasized the need for computer security controls to be considered in the design of I&C systems and the importance of strengthening Member States' understanding of the engineering and design aspects of computer security.

At a Technical Meeting on the IAEA's Power Reactor Information System (PRIS) organized by the Agency in May, 33 experts from 23 Member States and international organizations called for the development of a construction module and a decommissioning module to supplement the existing modules in PRIS.

The Agency, together with the World Nuclear Association and the World Association of Nuclear Operators, organized a Technical Meeting on Roles, Responsibilities and Interfaces between Design Authority, Responsible Designers and Technical Support Organizations, held in December in London, United Kingdom. The 40 participating experts from 16 Member States and 3 international organizations shared experience, knowledge and good practices in defining and establishing a 'design authority' and technical support organizations, and explored effective processes and interfaces between the owner/operator organizations and the designers.

## Integrated Management Systems

The Agency continued to disseminate good practices in the management of nuclear projects. At a Technical Meeting on Management and Leadership of Nuclear Power Projects from New Build to Decommissioning, held in Vienna in August, 40 participants from 26 Member States and an international organization emphasized the importance of strengthening the role of leadership and earlier planning in the management of nuclear power projects.

Participants in a Technical Meeting held in Vienna in November discussed the related topic of international quality and management standards. More than 50 experts from 26 Member States and 2 international organizations underlined the importance of good planning in ensuring the sustainability of nuclear installations from cradle to grave.

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## Capacity Building and Management Support

At the Nuclear Operators Forum, held as a side event on the margins of the 61st regular session of the Agency's General Conference, more than 100 representatives of the nuclear industry and academia discussed the key challenges in developing human resources to support nuclear power programmes in the future. Participants concluded that building and maintaining workforce competency across the full spectrum of operations is crucial for the sustainability and economic competitiveness of nuclear power.

A Technical Meeting on New Ways of Learning and the 'Capacity Building Initiative' Digital Portal explored and provided practical guidance on good practices in new learning approaches and techniques driven and enabled by digital technologies. At the meeting, held in July, 40 experts from regulatory bodies, owner/operator organizations and academia in 21 Member States developed concepts and a framework for new ways of learning.

In August, the Agency organized a Technical Meeting on Human Performance Reliability and Resilience in Nuclear Power Plant Operations in Oak Ridge, Tennessee, United States of America, with the participation of 56 psychometric experts and engineers from regulatory bodies, owner/operator organizations and academia from 18 Member States. Participants focused on behavioural assessments and evaluations across national nuclear workforces, and established a community of practice for the human performance sub-portal on the Agency's Human Resource Development digital hub.

At a Technical Meeting on Nuclear Training Accreditation Models and Activities, held at the Agency's Headquarters in October, 28 education and training experts from 19 Member States discussed the key features of a systematic approach to training based on current nuclear training programmes, including the role and implementation of consultation forums. Participants also reviewed Agency guidance related to such training programmes.

## Nuclear Technology Development

### *Advanced water cooled reactors*

The Agency held a Workshop on Advances in Understanding the Progression of Severe Accidents in Boiling Water Reactors in July, with 33 participants from 13 Member States and the OECD/NEA, including representatives of utilities, reactor vendors, regulatory bodies, universities and research organizations. In response to a recommendation from experts at the International Experts Meeting on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, the Agency initiated a new project on severe accident modelling and simulation, and the verification and validation of simulation codes. The first Technical Meeting on the Status and Evaluation of Severe Accident Simulation Codes for Water Cooled Reactors, held in October with 37 participants from 19 Member States and 8 international organizations, provided code developers and end users an opportunity to review the current status of and innovations in simulation codes, and to identify limitations and gaps in the field.

In March, the Agency held a Technical Meeting on New Concepts in Innovative Water Cooled Reactor Technology, with 19 participants from 16 Member States. The meeting participants discussed the need to increase the competitiveness of nuclear power technology, while continuing to meet rigorous safety requirements, to ensure its use worldwide in the future. The coordinated research project (CRP) entitled 'Prediction of Axial and Radial Creep in Pressure Tubes' was completed during the year, addressing an important ageing issue for heavy water reactors. The CRP led to the creation of a test version of a pressure tube creep database and a set of tools that may help nuclear power plant operators to predict the service life of reactor pressure tubes.

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The Agency conducted two training workshops on reactor technology assessment to assist newcomer countries in adopting this assessment methodology and in learning about the scope and volume of the data required for successful technology selection against country specific development goals, site requirements and energy needs. During the year, the Agency conducted training courses on the physics and technology of advanced reactors, including small and medium sized or modular reactors (SMRs). The courses, held in five Member States, made use of PC based basic principle simulators to provide valuable hands-on learning to more than 120 participants.

### *Small and medium sized or modular reactors*

Responding to increased interest from Member States, the Agency established a new Technical Working Group on Small and Medium Sized or Modular Reactors to discuss recent advances in SMR technology, identify topics of common interest for future collaboration through information exchange and cooperative research, and provide guidance on programmatic activities in this area.

Thirty-six experts from 14 Member States, including 7 embarking countries in the Middle East and North Africa region, took part in the Technical Meeting on Technology Assessment of Small Modular Reactors for Near Term Deployment, held in Tunis, Tunisia, in October. Focusing on the latest status of SMR designs and technologies, and on issues and challenges for near term deployment, the event enhanced the capacity of participating Member States to make knowledgeable technical decisions in adopting a nuclear reactor technology.

The Agency held the first Research Coordination Meeting of a CRP entitled ‘Design and Performance Assessment of Passive Engineered Safety Features in Advanced Small Modular Reactors’, at its Headquarters in August. The participants identified and assessed the design approaches adopted for passive safety systems in water cooled SMRs, and developed a project work plan.

In July, the Agency published *Instrumentation and Control Systems for Advanced Small Modular Reactors* (IAEA Nuclear Energy Series No. NP-T-3.19), addressing the specific issues and challenges related to the design, qualification and implementation of I&C systems for SMRs.

### *Fast reactors*

In June, the Agency conducted the International Conference on Fast Reactors and Related Fuel Cycles: Next Generation Nuclear Systems for Sustainable Development (FR17) in Yekaterinburg, Russian Federation. Over 550 nuclear engineers, scientists and decision makers from 27 countries and 6 international organizations discussed a broad range of topics, including advanced fast reactor design concepts, safety and licensing, operations and decommissioning, fuels and fuel cycle options, coolants, tests and simulations, and reactor economics and performance. Participants also discussed proliferation resistance and physical protection, capacity building, and professional development. The conference featured events and contests for young scientists and engineers on innovative solutions for a low carbon future.

In August, the Agency published *Benchmark Analysis of EBR-II Shutdown Heat Removal Tests* (IAEA-TECDOC-1819), presenting the results and main achievements of a CRP to validate modelling and simulation tools for the safety analysis of the sodium cooled fast reactors.

## High temperature reactors

An Agency side event entitled ‘Nuclear High Temperature Heat for Industrial Processes’, held on the margins of the 61st regular session of the Agency’s General Conference, attracted significant interest from Member States. The side event demonstrated that industry can utilize high temperature heat supplied by advanced nuclear reactors to cut carbon dioxide emissions, and that the technology is deployable today and could be incorporated into strategic plans as part of a more sustainable future.

The Technical Working Group on Gas Cooled Reactors met in October and evaluated the status of and activities in gas cooled reactor technology, including technology readiness evaluations, safety requirement studies, high fidelity methodology development and knowledge preservation, as well as irradiation graphite data and software tools.

## Non-electric Applications of Nuclear Power

The Agency issued two publications on non-electric applications of nuclear power in 2017. *Opportunities for Cogeneration with Nuclear Energy* (IAEA Nuclear Energy Series No. NP-T-4.1) provides an overview of the application of cogeneration with nuclear energy, which may offer advantages such as increased efficiency, better cost effectiveness and reduced environmental impact. *Industrial Applications of Nuclear Energy* (IAEA Nuclear Energy Series No. NP-T-4.3) gives an overview of the potential use of nuclear energy for industrial systems and processes, which have a strong demand for process heat/steam and power, and identifies the types of nuclear power reactor that can be used for various industrial applications.

The Agency hosted the sixth meeting of the Technical Working Group on Nuclear Desalination, in November, with eight participants from seven Member States. Three other Technical Meetings held in 2017 focused on: the techno-economics of and opportunities for non-electric applications of SMRs; the role of nuclear hydrogen production in the context of the hydrogen economy; and the responsibilities of users and vendors in nuclear desalination projects. The Agency also updated its Water Management Program (WAMP) tool for efficient water management in water cooled reactors, and conducted a training workshop with 14 participants from 14 Member States.

## Enhancing Global Nuclear Energy Sustainability through Innovation

The 14th INPRO Dialogue Forum on the Potential of Nuclear Energy to Support the Sustainable Development Goals, Including Climate Change Mitigation was held in Vienna in June. Thirty-five participants from 23 Member States presented national policy perspectives on nuclear power’s potential contribution to combatting climate change and achieving sustainable development goals.

In October, the Agency held a European Regional Training Course on Nuclear Energy System Modelling and Assessment Using the INPRO Methodology, in Warsaw, Poland, attended by 12 experts from 5 Member States. A Technical Meeting on the INPRO Study on Cooperative Approaches to the Back End of the Nuclear Fuel Cycle: Drivers and Institutional, Economic and Legal Impediments was held in January at the Agency’s Headquarters, with 19 participants from 15 Member States and the OECD/NEA. At the Technical Meeting to Review the Updating of the INPRO Manual Volumes on Proliferation Resistance and on Overview of the INPRO Methodology, held in October, 22 participants from 18 Member States and the European Commission recommended that the INPRO Steering Committee consider a full revision of the INPRO Manual volume on proliferation resistance.