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Strengthening the Agency's Activities related to Nuclear Science, Technology and Applications

Report by the Director General

Summary

- In response to General Conference resolutions GC(57)/RES/12 and GC(58)/RES/13, this document contains progress reports on the Agency's provision of support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (Annex 1); the use of isotope hydrology for water resources management (Annex 2); the renovation of the Agency's nuclear applications laboratories at Seibersdorf (Annex 3); nuclear energy activities (Annex 4); Agency activities in the development of innovative nuclear technology (Annex 5); the development and deployment of small and medium sized reactors, including small modular reactors (Annex 6); and approaches to supporting nuclear power infrastructure development (Annex 7).
- Further information on the Agency's activities related to nuclear science, technology and applications can be found in the *Nuclear Technology Review 2015* (document GC(59)/INF/2), the *IAEA Annual Report 2014* (GC(59)/7), in particular the section on nuclear technology, and the *Technical Cooperation Report for 2014* (GC(59)/INF/3).

Recommended Action

- It is recommended that the Board take note of Annexes 1–7 of this report and authorize the Director General to submit the report to the General Conference at its 59th regular session.

Support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC)

A. Background

1. In resolution GC(58)/RES/13/A.3, the General Conference recognized that the tsetse and trypanosomosis (T&T) problem constitutes one of the greatest constraints on the African continent's socio-economic development. It recognized the importance of livestock development in rural communities affected by T&T, in which the disease has a direct impact on food security and thereby increases poverty levels. It further recognized that trypanosomosis continues to claim thousands of human lives and millions of livestock every year, while threatening over 70 million people in 37 African countries, the majority of which are Agency Member States.

2. The General Conference welcomed the continuing close collaboration of the Secretariat with AU-PATTEC, whose main objective is to eradicate tsetse flies and trypanosomosis by creating sustainable tsetse and trypanosomosis free areas by suppression and various eradication techniques, while ensuring that the reclaimed land areas are sustainably and economically exploited.

3. The General Conference also recognized that that tsetse fly and trypanosomosis suppression and eradication are unique, complex and logistically demanding exercises that require flexible, innovative and adaptable approaches in the provision of technical support. The General Conference welcomed the Agency's work under the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, and with the support of the Agency's Technical Cooperation Fund, in developing the SIT for use against tsetse flies and providing assistance to Member States in applying the SIT as part of area-wide integrated pest management (AW-IPM) approaches. The General Conference appreciated the contributions made by various Member States and United Nations specialized agencies toward T&T control efforts in West Africa, especially the continuous efforts made by the United States of America through the Peaceful Uses Initiative (PUI) for the control of T&T in Burkina Faso and Senegal.

4. The General Conference urged the Secretariat to continue to assign high priority to agricultural development in Member States, including efforts to build capacity and further develop techniques for integrating the SIT with other techniques in creating tsetse-free zones in Africa. It called upon Member States to strengthen the provision of technical, financial and material support to African Member States in their efforts to create tsetse-free zones, while stressing the importance of a needs-driven approach to applied research and methods development and validation for serving field projects.

5. The General Conference requested the Agency and other partners to strengthen capacity building in Member States for informed decision-making regarding the choice of T&T strategies and the cost-effective integration of SIT operations in AW-IPM campaigns. It requested the Secretariat, through harmonized, synergistic cooperation with Member States and other partners, to maintain funding through the Regular Budget and the Technical Cooperation Fund for operational SIT field projects, stressing the importance of baseline data collection and data management, and to strengthen support for technology transfer and demand-driven applied research and development in African Member States to complement their efforts in creating and expanding the tsetse-free zones. The

General Conference urged the Secretariat and other partners to support the establishment and operation of regional centres for providing large numbers of sterile male tsetse flies and for coordinating SIT operations as an important component of AW-IPM campaigns against the T&T problem.

B. Progress since the 58th Regular Session of the General Conference

B.1. Strengthening Collaboration with AU-PATTEC and Other Partners

6. The Agency participated in the thirteenth meeting of the PATTEC national coordinators from 24 to 27 November 2014, which was organized by the African Union Commission (AUC) in Harare, Zimbabwe, and hosted by the Ministry of Agriculture, Mechanization and Irrigation Development. The meeting brought together approximately 60 national PATTEC coordinators and focal points from 27 tsetse and trypanosomiasis (T&T) affected African countries, representatives from international organizations, research institutions, non-governmental organizations (NGOs) and the private sector. At the end of the meeting, participants had the opportunity to visit the tsetse control programme in the Zambezi river escarpments that is currently being implemented. The IAEA also participated in the third meeting of the PATTEC Steering Committee, which was organized by the AUC in Harare on 28 November 2014, with the participation of international organizations, NGOs, donors, and the private sector. The progress in the implementation of the PATTEC initiative during 2014 was reviewed and the work plan and budget for 2015 were presented. Among the planned activities, it was agreed that an independent evaluation of the African Development Bank (ADB) supported multinational projects that aim at creating tsetse free areas in East and West Africa will be conducted in 2015.

7. A practical agreement was signed between the French International Cooperation Centre of Agricultural Research for Development (CIRAD) and the Agency with the aim to extend the successful collaboration achieved in Senegal to other projects in the areas. As a result, a renowned CIRAD scientist with extensive experience in tsetse control was seconded to the PATTEC Headquarters in Addis Ababa in August to provide scientific and technical support to the tsetse eradication project in Ethiopia and other tsetse eradication programs under the PATTEC umbrella.

B.2. Capacity Building through Applied Research and Technical Cooperation

8. In response to the demand for further capacity building on the use of geographic information systems (GIS) and data management from AU-PATTEC and several national PATTEC coordinators, the French edition of the regional training course on the use of free open source software for GIS and data management for tsetse and trypanosomosis control programmes was held in Vienna, Austria, from 19 to 30 January 2015. The course was organized jointly by FAO, AU-PATTEC and the Agency and was attended by a total of 15 participants from 10 Member States. The training course included a visit to the Insect Pest Control Laboratories in Seibersdorf where participants had the chance to learn about the latest technology and equipment developments for rearing tsetse flies, fruit flies and mosquitoes. A regional training course on the use of population genetics and GIS to identify isolated tsetse populations that can be targeted for eradication is scheduled for the 4th quarter of 2015.

9. Capacity building is one of the main components of the technical cooperation projects in this field, both at the regional level (RAF/5/059 and RAF/5/070) and national level in Angola, Ethiopia, Senegal, Uganda and Zimbabwe (ANG/5/033, ETH/5/018, SEN/5/033, UGA/5/033, UGA/5/036 and ZIM/5/019). Since September 2014, the Agency provided training in the form of fellowships and scientific visits to 17 staff from eight T&T affected countries with an overall duration of 125 weeks.

10. Fifteen countries continued to participate in research on inhibition of trypanosome transmission through symbiotic microbes under the coordinated research project (CRP) entitled "Enhancing Vector Refractoriness to Trypanosome Infection". The second research coordination meeting (RCM) of this CRP was held in December 2014 in Addis Ababa, Ethiopia.

11. During the past year, demand-driven research activities in the Insect Pest Control Laboratory have focused on the development and validation of technologies that can significantly contribute to the cost reduction and simplification of the application of the SIT. First positive results have been obtained using infrared scanners for the sex separation of tsetse pupae and the protocols are currently being optimized. Conditions for long distance shipments of chilled sterile male pupae have been optimized by adjusting the relative humidity inside the transport box. Both achievements will significantly contribute to the concept of regional mass rearing facilities that provide sterile pupae to field projects in different geographical areas. An unmanned aerial vehicle (UAV) has been equipped with a chilled tsetse release machine prototype and tested under controlled conditions, showing acceptable endurance and payload capacity to be used in operational programmes.

B.3. Support for the Planning and Implementation of SIT Activities

12. The Agency continued to provide technical assistance to the Southern Rift Tsetse Eradication Project (STEP) through the national and regional technical cooperation projects ETH/5/018 and RAF/5/070. The Ethiopian Government allocated in support of the national project a budget of 48.3 million Birr (approximately $2.36 million) for the financial year 2014–2015. Ground suppression of the tsetse population was applied in the target area that was extended from its original 25 000 km^2 to 60 000 km^2 in 2014. The reported successes of suppressing the fly populations to low levels in areas outside of the National Parks using different control tactics has led to the expansion of the project to the national level and the STEP has been upgraded to the National Institute for Control and Eradication of Tsetse & Trypanosomosis (NICETT).

13. The project has also increased its efforts in the Deme basin. Monitoring activities have been improved due following the provision of two four-wheel drive vehicles to the project. Aerial releases of sterile males were resumed after several interruptions due to breakdown of both the aircraft and the Gamma Cell irradiator. Recent entomological surveys showed very low tsetse population densities and good sterile to wild male ratios.

14. The fourth meeting of the international management and advisory committee was held in Addis Ababa on 11-13 February 2015, with the participation of the Minister of Science and Technology and the State Ministry of Livestock of the Ethiopian Government and the Agency's Deputy Director General, Head of the Department of Technical Cooperation. During the meeting, senior project management, Agency staff and an international expert reviewed the current status of the project. It was agreed that the Agency will reinforce its technical assistance to Kality through the deployment of a long term expert in the insectary to provide on hand technical assistance and training to the staff.

15. In Senegal, the project that aims to eradicate *Glossina palpalis gambiensis* from the Niayes area near Dakar continued to show excellent progress. The entire project area was divided into three operational blocks in which the activities are carried out sequentially. In Block 1, sterile male releases continued until the end of 2014. No wild fly has been detected in the monitoring traps of Block 1 since

April 2012, and it is therefore assumed that the tsetse population in this area is eradicated. In Block 2, aerial releases of sterile males were initiated in February 2014 and are scheduled to continue until late 2015. The removal of the tsetse fly from Block 1 and the drastic reduction in the fly populations in Block 2 also reflected the prevalence of the disease: serological tests on cattle have shown a reduction in the prevalence of trypanosomosis from 40-50 % in 2009-2010 to less than 10% in 2013. Data from the 2014 survey are currently being analysed. Releases are routinely carried out 4 times a week using a gyrocopter equipped with a newly developed chilled adult release machine. Suppression activities in Block 3 (Dakar and Thies) are scheduled to be initiated in early 2015.

16. Entomological and socio-economic surveys conducted on Unguja Island, Zanzibar (United Republic of Tanzania) have shown that the island has remained free of the tsetse fly *Glossina austeni*, 17 years after the eradication of tsetse was declared, resulting in an increase in improved breeds for dairy cattle (37%), goats and sheep (108%) as well as poultry (86%) (since the last survey conducted in 2003).

17. In Zimbabwe, the Agency continues to support the feasibility study for the eradication of the tsetse fly in the Matusadona National Park under technical cooperation project ZIM/5/019. Training on tsetse mass rearing and male handling and irradiation procedures was provided through three fellowships of three months at the Slovak Academy of Sciences, Bratislava, Slovakia and at the Insect Pest Control Laboratory in Seibersdorf, Austria. After the successful training on GIS and data management provided last year, a second and more advanced GIS workshop is scheduled in Harare in collaboration with FAO. Various equipment and consumables for a molecular biology laboratory were provided and basic training on molecular biology was delivered in Seibersdorf.

18. In Angola, the Agency is supporting a feasibility study for using the SIT as part of area-wide integrated pest management to eradicate *G. morsitans centralis* in an area with an estimated size of more than 32 000 km^2 in the provinces of Malanje, Kuanza-Norte and Kuanza-Sul. A mobile monitoring device installed on a four wheel drive vehicle has been designed and is currently being tested and refined to conduct the entomological monitoring for the baseline data collection in the vast and remote target. This device would make the entomological surveys more cost effective in terms of human and material resources. Further training on sterile male handling and release has been provided through fellowships to the tsetse eradication project in Senegal.

C. Conclusion

19. Tsetse flies and trypanosomosis remain major obstacles to rural development in large areas of Africa. In several areas in which intervention measures are yet to be implemented, tsetse fly species are spreading. As no new methods have emerged to eradicate the various tsetse species in an area-wide and sustainable manner, the SIT, as part of an area-wide integrated pest control approach, maintains its appeal as a unique and environmentally friendly nuclear application. Nevertheless, there remain challenges, including the lack of infrastructure and the need to establish appropriate management structures to deal effectively with such complex and logistically demanding projects. There is also the need to develop the SIT for different species and to adapt each project to unique ecological and socio-economic conditions and requirements. The scarcity of sterile male tsetse production facilities in Africa continues to be the most critical bottleneck for the expanded application of the SIT against the tsetse fly, with only five institutes holding seed or back-up tsetse fly colonies, and only one large, active tsetse mass-rearing centre located in Addis Ababa, Ethiopia.

Use of Isotope Hydrology for Water Resources Management

A. Background

1. At its fifty-seventh regular session in September 2013, the General Conference, through resolution GC(57)/RES/12, requested the Director General: to continue to further strengthen the efforts directed towards fuller utilization of isotope and nuclear techniques for water resource development and management in interested countries by helping Member States obtain easy access to isotopic analysis, including noble gases, through upgrading of selected laboratories; to expand activities related to the IAEA Water Availably Enhancement (IWAVE) project; to strengthen activities which contribute to the understanding of the climate and its impact on the water cycle; and to continue to develop human resources in isotope hydrology. It further requested the Director General to report on achievements in implementing resolution GC(57)/RES/12 to the Board of Governors and to the General Conference at its fifty-ninth regular session.

2. To build upon the successes of and lessons learned from the Millennium Development Goals (MDGs) and the International Decade of Water (2005-2015), a post-2015 Development Agenda will be launched at a United Nations' summit to be held in from 25-27 September 2015 in New York. The aim is to adopt a set of 17 goals and associated targets, including Goal 6: "Ensure availability and sustainable management of water and sanitation for all". The targets for Goal 6 emphasize the need for increased availability of freshwater and expanded capacity-building efforts, which continue to be the primary objectives of the IAEA's Water Resources Programme.

B. Work since the 57th Regular Session of the General Conference

B.1. Strengthening of Isotope Hydrology activities and the IWAVE Project

3. The IAEA Water Availability Enhancement (IWAVE) project is a pilot project funded through the Peaceful Uses Initiative (PUI) which is assisting three Member States (Philippines, Oman, and Costa Rica) with increasing the availability and sustainability of freshwater using scientifically based, comprehensive assessments of national water resources. The IWAVE project is in the final stages of implementation after having accomplished a number of its goals, which include the identification of priority gaps in knowledge, data and capacity for water resources assessment, as well the application of isotope techniques and other means to fill the gaps. Activities implemented in the three pilot countries included nine workshops and training events organized at the Agency's Headquarters and in Roorkee (India), Delft (the Netherlands), Muscat (Oman) and Manila (the Philippines) to strengthen the capacity of 102 water professionals for isotope data collection and interpretation, as well as the design of water resources monitoring networks.

4. Major outcomes from the IWAVE project so far include trained human capacity in key hydrological aspects (such as estimation of water balance, evaluation of monitoring networks,

understanding aquifer venerability), compiled and digitised hydrological data, and maps of aquifer vulnerability.

5. As an outcome of the IWAVE project, another regional technical cooperation project was formulated in Latin America for 2015-2016 involving Argentina, Brazil, Nicaragua and Ecuador. This project is based on the methodology and approach developed through the IWAVE project. The first coordination meeting was held in 2015 and a work plan was developed which focuses first on identifying gaps in existing knowledge and capacity at the national level.

6. Another PUI-funded project is being implemented in Vietnam, India, and Brazil that is complementary to the IWAVE project by aiming to widen the use of isotope by strengthening national networks of isotope and non-isotope hydrologists. In India, the project is assisting the National Institute of Hydrology to integrate the use of isotopes into aquifer mapping activities. National seminars and training workshops and field campaigns were organised in Vietnam and Brazil. The Geological Survey of Brazil (CPRM) was designated as an IAEA Collaborating Centre in 2015. This more formal collaboration with the IAEA will build professional interactions and networks between CPRM – the national agency responsible for water resources assessment – with professionals trained in isotope hydrology will help further support this project. A workplan of activities was formulated and will be implemented in 2015-2017.

7. A technical meeting entitled “Groundwater Contamination following the Fukushima Nuclear Accident” was held from 8-10 September 2014 in cooperation with UNESCO. The meeting brought together 16 experts from Japan and other countries to address issues related to extent of contaminated groundwater at the Fukushima-Daiichi Nuclear Power Plant and its vicinity following the earth quake and tsunami March 2011. The meeting reviewed the impact of environmental releases of radioactivity on surface and ground water systems and the measures adopted to manage contaminated groundwater. The meeting highlighted the importance of characterization of detailed hydrogeological settings of nuclear power plant sites worldwide as a key to better address and manage any accidental releases of radioactivity. A coordinated research project (CRP) was formulated to address this gap and will be implemented in 2016-2018.

8. Software for modelling hydrological processes for improved assessment of water resources in river basins was made available freely to all Member States through the IAEA website. Developed in collaboration with the Colorado State University, United States of America, the IAEA Water Balance Model with Isotopes (IWBMIso) uses climate and related data from publicly available data sources so that isotopes can be used to improve the assessment of river flow and lake volumes. The applicability of the model was demonstrated with improved estimates of water balance in the Upper Blue Nile and Lake Victoria watersheds in eastern Africa as part of the technical cooperation project RAF/8/042, “Adding the Groundwater Dimension in the Management of the Nile River Basin”.

B.2. Expanding Access to Isotope Techniques and Capacity Building

9. The Agency further expanded the capacity of Member States to measure and interpret stable isotope and tritium contents in water samples for improved assessment and management of water resources. Building on the successful recent efforts, a new, low cost and compact system to pre-concentrate low levels of natural tritium in water samples is being provided to Peru through the technical cooperation programme and provision for an additional three systems has been made for projects for the 2016-2017 cycle. Participants from ten Member States received a one-week training in tritium analyses with the goal of attaining improved operational competency in low-level tritium measurements using the new enrichment system. The performance of a cost effective liquid scintillation counter was also evaluated for use in isotope hydrology laboratories. Training courses on the installation and operation of the new tritium enrichment system were organized and an audio-

visual guide is being prepared. The provision of laser machines for analysing stable isotopes continued and over 55 Member States are now fully capable in this area. A software programme for data management is also provided along with the machines, which allows the Agency to remotely assist counterparts in overcoming operational difficulties and produce high quality results, and this is in addition to regular scheduled training courses.

10. To increase Member State access to the use of noble gas isotopes for groundwater age dating, a new system for extracting and purifying trace amounts of krypton gas from water samples was developed at the Agency's isotope hydrology laboratory. The lack of this purification capacity has been a major factor in limiting the wider use of kr-81 for groundwater age dating. Samples from Vietnam, Brazil, Argentina, Czech Republic and Hungary were collected for krypton gas extraction. The counting of this radioactive noble gas in extracted gas samples is conducted by atom-trap analysis (ATTA) at the Argonne National Laboratory, United States of America.

11. Water samples from twelve Member States were analysed at the IAEA's isotope hydrology laboratory for the noble gas helium. These analysis allowed Member States to use the isotope pair tritium and helium-3 to estimate groundwater recharge and discharge within the framework of a coordinated research project.

B.3. Improving Understanding of the Water Cycle and Climate Change

12. The application of isotopes for understanding the impact of climate change and anthropogenic activities on rivers was strengthened. A CRP "Environmental Isotope and Age Dating Methods to Assess Water Quality in Rivers Affected by Shallow Groundwater "is being implemented with 14 Member States. The study sites range from large basin-scales to small mountain streams affected by agricultural practices. In the CRP "Isotope methods for improving water balance estimated and understand nutrient dynamics in large rivers" more than 30 research groups from 17 Member States have embarked on detailed monitoring of isotopes and chemical tracers in 40 important river basins across five continents. The significant Member State interest in this initiative illustrates the important need for better methodologies for water balance estimates in river basins, and to address water quality issue affecting surface waters. The isotope and related hydrological data sets generated under this CRP will constitute a major contribution to the Agency's Global Network of Isotopes in Rivers (GNIR).

13. The use of environmental isotopes in assessing water resources in snow, glacier, and permafrost dominated areas under changing climatic conditions was addressed through a research project with 12 Member States. Participants used multiple isotope tracers to investigate transit times of meltwater through snow and ice layers, and of water to rivers and lakes. Several newly developed or more effective devices for field sampling were tested and the results provided insight into the causes of isotope variability of snowmelt. The project also resulted in a first and unique dataset of isotopes in ice cores from Mt. Elbrus, Russia which will be used for understanding climate changes in the past one hundred thousand years.

Renovation of the Nuclear Applications Laboratories (ReNuAL)

A. Background

1. During the 56th regular session of the General Conference in 2012, the Director General called for an initiative to modernize and renovate the eight laboratories of the Department of Nuclear Sciences and Applications (NA) in Seibersdorf to enable them to meet the growing and evolving needs of Member States. The General Conference supported the initiative of the Director General in resolution GC(56)/RES/12.A.5, and the Renovation of the Nuclear Applications Laboratories (ReNuAL) project officially began on 1 January 2014. The groundbreaking ceremony for the project was held in Seibersdorf on 30 September 2014 and was attended by over 200 participants, with approximately 50 Member States represented.

2. In resolution GC(58)/RES/13.A.6, the General Conference requested the Secretariat to develop an appropriate resource mobilization strategy for the project that would include efforts to raise funds from non-traditional donors, and to implement the project in a manner consistent with recommendations made by the Standing Advisory Group for Nuclear Applications (SAGNA). The General Conference requested the Director General to report on progress made in implementing resolution GC(58)/RES/13.A.6 at its 59th regular session.

B. Progress since the 58th General Conference

B.1. Project Management

3. In January 2015, as agreed with the Department of Safeguards, five staff members of the Project Management Group (PMG) of the Enhancing the Capabilities of the Safeguards Analytical Laboratories (ECAS) project began supporting ReNuAL to capitalize on lessons learned from ECAS and provide necessary project support functions. These staff members are now supporting project management and administration, finance and accounting, procurement and engineering. As the ECAS project nears its conclusion, these staff members will dedicate an increasing share of the time to ReNuAL.

B.2. Implementation Progress

B.2.1. Design Development

4. In July 2014, an architectural and engineering firm was contracted to develop conceptual designs for the new buildings to be constructed under ReNuAL: a new Insect Pest Control Laboratory (IPCL); a Flexible Modular Laboratory (FML) to house an additional three of the eight NA laboratories in Seibersdorf, and a new bunker for the Dosimetry Laboratory to house a medical linear accelerator. The conceptual designs provide the basic layout and structure of the new buildings, with

the specific details of each building, such as the type and quantity of each material to be used, identified in a subsequent design phase.

5. In consultation with the other departments on site in Seibersdorf, a site development plan for ReNuAL was also developed to identify where the new buildings could be located. The site development plan was completed in October 2014, with a decision made to build the Insect Pest Control Laboratory and Flexible Modular Laboratory, as well as new site infrastructure, in the greenfields on the southwest of the Seibersdorf site. This decision was based on a cost-benefit analysis conducted by external consultants. The conceptual designs were completed in November 2014 and provided preliminary cost estimates for the new buildings with a range of +/- 25%. In December 2014, the Secretariat conducted a technical briefing for Member States to provide an update regarding these and other developments and to present the next steps in the project.

6. In February 2015, the Secretariat convened a consultants' meeting with Member State experts in the design, construction and management of laboratories. The group included members of Standing Advisory Group for Nuclear Applications SAGNA and they were asked to review and advise on the effectiveness and efficiency of the conceptual designs. The experts validated the designs and expressed their confidence that the designs would deliver fit-for-purpose facilities. They also found that the designs and the decision to locate the buildings in the greenfields on the southwest of the site, as well as to construct new site infrastructure to support these buildings, were consistent with recommendations made by SAGNA and by a panel of external experts that met in early 2014 to review and advise on the development of the strategy for ReNuAL.

7. Another purpose of this review was to obtain expert opinion on the conceptual designs before beginning the next stage of design development — the detailed design phase — to ensure that any changes suggested by the external experts could be incorporated at an appropriate and beneficial time in the development of the designs. Following a competitive bidding process, a second architectural and engineering firm was subsequently contracted to develop the detailed designs, with work beginning in March 2015 and planned for completion at the end of August 2015. When completed, these designs will provide final cost estimates for the new buildings within a range of +/- 10%.

B.2.2. Biosafety Level 3 Capabilities

8. Biosafety level 3 (BSL3) capabilities are required by the Animal Production and Health Laboratory to support Member States' efforts to control transboundary animal and zoonotic diseases. These capabilities are an element of ReNuAL Plus (ReNuAL+), which was established by GOV/INF/2014/11/Add.1 to provide for additional elements needed by the NA laboratories in Seibersdorf upon completion of ReNuAL. The addendum states that implementation of this particular element could begin, provided the necessary extrabudgetary funding is available, in parallel with the €31 million required to fund the ReNuAL project, and subject to a mutually satisfactory agreement with Austria.

9. Accordingly, the Agency has consulted extensively with Austrian authorities, including the Austrian Agency for Health and Food Safety (AGES) to review options for the provision of BSL3 capabilities at an AGES facility in Mödling. As a result of the consultations, during the March 2015 meeting of the Board of Governors the Austrian government announced an offer to provide the Agency full access to a new BSL3 facility in Mödling constructed by AGES. AGES will retain ownership of the BSL3 facility and provide necessary safety and technical support.

10. The facility became operational in August 2015, with Agency staff now working at the facility full-time to implement all relevant programmatic activities, including training. This facility provides

the Agency with BSL3 capabilities needed to provide enhanced and increased assistance to Member States in controlling transboundary animal and zoonotic diseases.

11. Also during the March 2015 meeting of the Board of Governors, the Austrian government announced the offer of a package of land, infrastructure and technical services that it values at €2 million. Consultations on this offer involving the Agency, Austrian authorities and AGES are ongoing.

B.3. Resource Mobilization and Financial Status

B.3.1. Resource Mobilization

12. In February 2015, a Resource Mobilization Officer joined the project as a cost-free expert, and a framework was established to guide resource mobilization activities for the project. The framework focuses on identifying and engaging potential donors, including non-traditional donors such as foundations and private companies, preparing relevant project and public information materials, and creating structures for reporting to stakeholders. A key objective of this framework is to use ReNuAL as an opportunity to develop capacities and expertise that can support future fundraising activities beyond the project.

13. With regard to Member States, the Secretariat has held multiple bilateral meetings with interested Member States in Africa, Asia and the Pacific, Europe, Latin America and North America, to seek contributions to ReNuAL. Of these, 14 Member States have made or pledged cash or in-kind contributions to the project and stands to date: Australia, Austria, China, Germany, Indonesia, Israel, Japan, Kazakhstan, the Republic of Korea, Norway, the Russian Federation, Switzerland, the United Kingdom and the United States of America. Some of these contributions have been made through the Peaceful Uses Initiative, and the Secretariat is continuously seeking to attract contributions from additional Member States. The Friends of ReNuAL, an informal Member State grouping co-chaired by Germany and South Africa, have supported the Secretariat's fundraising efforts by actively engaging with Member States to promote ReNuAL and encourage contributions.

14. In recent months, increased human resources have been directed toward fundraising from foundations and the private sector, with a specific focus on equipment manufacturers. Regarding foundations, efforts have focused on mapping the identified priorities and grant issuing policies of individual foundations to identify those that may be willing to contribute to ReNuAL, and specifically to construction costs. Each foundation has distinct thematic priorities and funding regulations that may or may not allow support for construction projects, which creates challenges. The Secretariat recently started to engage with specific foundations, for example, the Bill and Melinda Gates Foundation, with which several meetings and discussions have been held.

15. Regarding the private sector and equipment manufacturers, the Secretariat has begun to seek partnerships that could result in donations or other low-cost arrangements. Simultaneously, the Secretariat is working quickly and effectively to define legal and procurement modalities that can make such arrangements possible and consistent with the Agency's existing legal and financial regulations, as well as with its Partnership and Resource Mobilization Policy. Discussions with equipment manufacturers to pursue mutually beneficial arrangements are expected to continue throughout the life of the project.

16. In an effort to strengthen resource mobilization efforts for ReNuAL, the Secretariat is also seeking the assistance of UN partner organizations. For example, Agency staff are maintaining ongoing contact with resource mobilization staff of the Food and Agriculture Organization of the

United Nations (FAO). Relevant staff from both organizations are in regular contact, with an FAO resource mobilization officer most recently visiting Vienna in May 2015.

17. The Secretariat has prepared various public information and resource mobilization products to maintain and increase awareness of the project and its progress, and to promote fundraising. This includes preparation of a comprehensive and thematically organized donor package to allow potential donors to match their interests with the needs of the project. The Secretariat also regularly prepares customized resource mobilization products for interested donors that detail how the NA laboratories in Seibersdorf benefit the specific donor, and the additional benefits that ReNuAL will enable the laboratories to provide. Efforts to enhance and add to products such as these will continue throughout the life of the project.

B.3.2. Financial status

18. To date, approximately €8.3 million in extrabudgetary funds have been raised from 12 Member States. This leaves a gap of roughly €12.3 million to reach the €20.6 million portion of the project's €31 million target budget that is to be funded by extrabudgetary resources. Close to €1.6 million of the funds raised are committed for the procurement of equipment, and a further €0.5 million have been provided to support cost-free experts and junior professional officers. An additional €1.1 million have been expended, almost entirely on design costs. Given these commitments and expenditures of $3.2 million, and deducting programme support costs from the remaining available funds of €5.1 million, approximately €4.7 million in extrabudgetary funds are currently available to support construction.

19. Regarding regular budget resources, during the 2014-15 biennium a total of €5.4 million from the Major Capital Investment Fund (MCIF) was allocated to ReNuAL. This leaves a gap of €5.0 million to reach the €10.4 million portion of the project's €31 million budget that is to be funded through the regular budget. To fill this gap, €2.5 million in additional resources from the MCIF have been proposed for both 2016 and 2017 in the upcoming Programme and Budget. Of the regular budget funds allocated to ReNuAL to date, approximately €1 000 000 have been spent, primarily on design costs. This leaves approximately €4.9 million currently available to support construction.

20. The total, therefore, of extrabudgetary and regular budget funding currently available for construction stands at approximately €9.1 million.

21. The target date for raising all extrabudgetary funds to make full implementation of the project possible by the scheduled December 2017 deadline was 30 June 2015. As this target was not met, it is unlikely that the project can be completed in full by December 2017, as was initially planned. It should also be noted that any extension of the project beyond 2017 will have cost implications. However, given the currently available funds, and provided the 2016-17 Programme and Budget is approved with the additional proposed regular budget funds for ReNuAL, there will potentially be sufficient resources available in September to begin the construction of the required site infrastructure and either the IPCL or FML in 2015. This would allow for their selected completion by December 2017.

C. Next Steps

22. As there are sufficient funds available at present to pay for the construction of the new site infrastructure, procurement for construction of the infrastructure began in June 2015, with work on site

to begin in September 2015 and to be completed by December 2017. Once the final costs estimates for the buildings are received in late August, and depending on the funding available as well as other relevant considerations, a decision will be made to construct either the IPCL or FML.

23. If sufficient funds or pledges are available in September to cover the cost of the selected building, procurement for construction will begin immediately, with the construction contract to start by the end of 2015. This would allow for completion of the building by December 2017. If the needed funds or pledges are unavailable in September, procurement for construction cannot begin, which in turn will delay the start of construction. In this case, completion of the buildings by December 2017 would be uncertain.

24. Resource mobilization to raise funds for the remaining elements of the project will continue as construction moves forward and throughout the life of the project. The construction contract for the first building will be structured in a way that will enable construction of the remaining building elements to begin as funds become available, provided that these funds are received in a timely manner. This "build-to-budget" approach was successfully employed with ECAS.

25. With regard to equipment, approximately €1.6 million in extrabudgetary funds have been contributed to date by Germany and Switzerland to fund the procurement of specific items that are urgently needed and for which the NA laboratories currently have space available. The Secretariat initiated procurement processes for these items in early 2015, and aims to complete the procurement of all items by the end of 2015.

Nuclear Energy Activities

1. This Annex highlights a number of nuclear energy activities undertaken by the Agency and not reported on in Annexes 5 to 7.

2. The Agency annually updates its low and high projections for global growth in nuclear power in its publication *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050* (Reference Data Series No. 1). The updated low projection of 2014 shows growth in nuclear power capacity of 8% by 2030, while the high projection shows 88% growth by 2030. The Agency also annually publishes its report *Nuclear Power Reactors in the World* (Reference Data Series No. 2), which presents the most recent data on nuclear power reactors across the world. The 2014 edition contains summary information as at the end of 2013 on power reactors operating, under construction and shut down, as well as performance data on reactors operating in the Agency's Member States.

3. For the 20th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP20), held in Lima, Peru, from 1 to 12 December 2014, the Agency published its report *Climate Change and Nuclear Power 2014*. The report has been substantially revised, updated and extended since the previous edition of 2013. It summarizes the role of nuclear power in mitigating global climate change and how nuclear power contributes to other development and environmental challenges. It also examines broader themes relevant to the climate and nuclear energy such as cost, safety, waste management and non-proliferation. In addition, the 2014 edition included a section on prospects for nuclear power, highlighting new developments in resource supply and innovative nuclear technologies, including small and medium sized reactors. At COP20, the Agency maintained an information centre to explain the links between nuclear power and climate change mitigation, the role of nuclear power in sustainable energy development and other related issues. In addition, the Agency co-organized (with the United Nations Industrial Development Organization) a United Nations system side event on climate change mitigation in the energy sector and delivered a presentation on this topic at the side event.

4. Some 280 experts from over 35 countries were trained in uranium geology, exploration, mining and processing in various interregional and regional courses and workshops held in Burkina Faso, Cameroon, China, Indonesia, the Niger, Mozambique, South Africa and Uganda,. The Agency supported three conferences related to the uranium production cycle: Uranium Mining and Hydrogeology 7, an international conference held in Freiberg, Germany, on 24–25 September 2014; the ALTA 2015 conference and exhibition, held in Perth, Australia, from 23 to 30 May 2015; and the International Mining Symposium WISSYM_2015, with the title 'Reclaimed Mining Sites between Post-Remedial Care and Reuse', held in Bad Schlema, Germany, from 31 August to 3 September 2015.

5. The technical cooperation project 'Supporting Sustainable Development of Uranium Resources' continued to support 30 countries through activities designed to tackle common priority needs in Africa related to uranium exploration, mining, processing and regulation using available infrastructure and expertise, thereby enhancing regional cooperation. The project focused on developing teamwork and leadership skills, such as planning and communication, so that planned uranium mining projects will not underperform due to project management inadequacy. More than 100 experts from the region along with international experts participated in three workshops held during the year.

6. The Agency also provided focused assistance to francophone African Member States, through the PUI project entitled 'Supporting Sustainable Uranium Mining in Less Prepared Areas'. In workshops held in Burkina Faso, Cameroon and the Niger, more than 125 experts from 10 countries

discussed the pressing need to strengthen their countries' current capabilities in order to optimize production, implement good practices and ensure effective management of their region's uranium endowment to match the predicted future growth in uranium activities.

7. The third Research Coordination Meeting (RCM) of the coordinated research project (CRP) entitled 'Near Term and Promising Long Term Options for Deployment of Thorium Based Nuclear Energy' was held in Cambridge, United Kingdom, from 1 to 4 September 2015. Participating Member States included China, the Czech Republic, Germany, India, Italy, Switzerland, the United Kingdom and the United States of America. The main purpose of the meeting was to assess, review and discuss the progress of work related to the processing of thorium-based fuels and their use in different reactor systems, namely water cooled reactors, high temperature gas cooled reactors, fast reactors and molten salt reactors. As a part of this project, an IAEA Technical Document entitled *Performance Analysis Review of Thorium TRISO Coated Particles during Manufacture, Irradiation and Accident Condition Heating Tests* was published in March 2015 (IAEA-TECDOC-1761).

8. Partitioning and transmutation (P&T) is a multidisciplinary approach to the management of spent fuel, which aims to improve the chances of successful implementation through closer collaboration and better integration of the different disciplines involved. A total of 110 experts from 19 countries and two international organizations participated in the 13th Information Exchange Meeting on Actinides and Fission Product Partitioning and Transmutation, organized in collaboration with the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), in Seoul, Republic of Korea, from 23 to 26 September 2014. Thirty-nine oral presentations were given and 64 posters presented in 5 technical sessions covering: fuel cycle strategies and transition scenarios, transmutation systems and infrastructures, fuels and targets, advanced nuclear recycling, and waste management. The main conclusion of this meeting was that similar motivation exists in different countries to develop P&T research and development programmes to reduce the nuclear waste burden for future generations.

9. The CRP entitled 'Spent Fuel Performance Assessment and Research' (SPAR-III), which was launched in 2009 with the objective of developing a technical knowledge base on dry and wet long term storage of power reactor spent fuels through the evaluation of operating experience and research by participating institutes, was completed in September 2014.

10. The second RCM of the CRP entitled 'Demonstrating Performance of Spent Fuel and Related Storage System Components during Very Long Term Storage' was held in Tokyo, Japan, from 10 to 14 November 2014, at the same time as the 11th International Subcommittee Meeting of the Electric Power Research Institute's Extended Storage Collaboration Program. The meetings were attended by 43 experts (from 11 Member States and 3 international organizations representing 26 institutions) some of whom visited the Demonstration Test Program for Long-term Dry Storage of Pressurized Water Reactor Spent Fuel, implemented at the Nuclear Development Corporation's facilities in Tokai, Japan.

11. The Agency organized the International Conference on the Management of Spent Fuel from Nuclear Power Reactors: An Integrated Approach to the Back End of the Fuel Cycle, from 15 to 19 June 2015, in Vienna, Austria. The purpose of this major event on spent fuel management convened by the Agency was to highlight the importance of an integrated long term approach to the management of spent fuel from nuclear power reactors. There were over 200 participants from Member States and international organizations. The conference, which comprised 4 keynote addresses, lectures by 7 invited speakers, 77 oral presentations and 27 posters in 7 technical sessions covering the current status, challenges, safety, technical and strategic issues related to the back end of the fuel cycle, reflected developments worldwide since the last conference, held in 2010 (the proceedings of which were published in May 2015).

12. At the 13th IAEA–FORATOM Management System Workshop — Leadership and Management for Safety in a Challenging Environment, held from 23 to 25 June 2015 at the EdF Energy offices in Barnwood, United Kingdom, discussions focused on how to adapt systems to ensure the safe management of nuclear facilities in an environment of financial challenges to nuclear power, new international management system standards, and countries decommissioning and starting up new nuclear power plants (NPPs).

13. The Department of Nuclear Energy develops and maintains some 50 separate computerized tools and information resources aimed at supporting Member States in decision-making, training, and understanding the scope and impacts of nuclear energy programmes. The tools comprise simulation models, databases, and knowledge management systems covering all areas of power generation, research reactor operations, and the fuel cycle, including facility decommissioning, radioactive waste management, and spent nuclear fuel management. Examples include: the Power Reactor Information System, which contains performance and technical design data on nuclear power reactors in operation, under construction, or in the process of being decommissioned; the Advanced Reactors Information System, which contains up-to-date design descriptions of innovative and evolutionary advanced nuclear reactors; the Net Enabled Waste Management Database, which contains information on national radioactive waste management programmes, radioactive waste inventories, radioactive waste disposal, relevant laws and regulations, waste management policies, and relevant plans and activities; the Research Reactor Database, which provides extensive information on research reactors all over the world; and the Research Reactor Ageing Database, which is intended to assist Member States in sharing information and experiences specific to the management of technical issues related to research reactor ageing, as well as in the development and implementation of comprehensive ageing management programmes. Other computer-based databases and resources were updated, namely the Integrated Nuclear Fuel Cycle Information System, the two online databases World Distribution of Uranium Deposits and World Thorium Deposits and Resources, the Nuclear Fuel Cycle Information System, the Post Irradiation Examination Facilities Database, the Minor Actinide Property Database, and the Nuclear Fuel Cycle Simulation System.

14. In 2014, the Agency launched a CRP entitled ‘Assessing the National and Regional Economic and Social Effects of Nuclear Programmes’ (planned to run until 2017). Within this project, participants from 11 Member States will review, test and apply quantitative models to analyse the economic and social impacts of nuclear programmes at the national and regional levels. It is expected that this CRP will assist policymakers, in particular from Member States with limited experience in macroeconomic analysis (‘newcomers’), in understanding the key implications of nuclear projects. In 2015, the Agency provided training on conducting macroeconomic impact assessments in Ankara, Turkey, from 4 to 6 May and in Riyadh, Saudi Arabia, from 8 to 10 June.

15. In November 2014, a Technical Meeting on Financial Planning and Risk Management attracted participants from 15 Member States who received practical ‘hands-on’ experience in using a large, stochastic financial model. In the first half of 2015, expert missions were conducted in Poland (on financial risk management in the European new build context) and Egypt (on financial risk mitigation in NPP projects). A Workshop on Regional and Trans-Boundary Energy Issues and Cooperation in Nuclear Power Programmes: Stakeholder Involvement was held in Bucharest, Romania, in September 2014, with participants from 13 Member States.

16. The Department of Nuclear Energy is working to expand current e-learning resources based on the Agency’s Milestones approach. They target a variety of stakeholders in Member States interested in, embarking on, or expanding a nuclear power programme. Additional modules, including on management of spent fuel and radioactive waste, siting, legal framework and pre-feasibility studies, are currently under development, which will bring the total number of available modules to 15. All

existing modules have now been made available in a downloadable format to make them more accessible for Member States and to facilitate feedback and thus improvements to the modules. A Technical Meeting on Education and Training using E-Learning Tools, held in Vienna, Austria, from 24 to 26 March 2015, was attended by 42 participants from 28 countries and sought to solicit feedback on these and other IAEA e-learning initiatives.

17. The second RCM under the CRP entitled 'Qualification, Condition Monitoring and Management of Ageing of Low Voltage Cables in Nuclear Power Plants' was held in Shanghai, China, from 14 to 17 October 2014, to discuss the benchmark baseline test results and prepare an extended draft report on condition monitoring techniques for cable ageing management for long term operation of NPPs. A total of 56 participants from 13 countries participated in this RCM and shared the results of their research on monitoring and ageing management of low voltage cables.

18. A Training Workshop on the Assessment of Degradation Mechanisms of Primary Components in Water Cooled Nuclear Reactors: Current Issues and Future Challenges, organized by the Agency and hosted by the Research Centre for Energy, Environment and Technology, was held in Madrid, Spain, from 29 September to 2 October 2014. This activity was intended to follow up on an Agency Technical Meeting on the same topic held in Vienna, Austria, in November 2013, and was designed primarily for young professionals, early stage researchers and engineers who work in fields such as NPP operation, safety, regulation, structural integrity and surveillance, or carry out applied research on material science, specifically degradation mechanisms, and other related fields.

19. The Department of Nuclear Energy, in partnership with the Department of Nuclear Safety and Security, organized an International Experts' Meeting (IEM) on Strengthening Research and Development Effectiveness in the Light of the Accident at Fukushima Daiichi Nuclear Power Plant. More than 150 experts representing 35 Member States and 5 international organizations gathered at the Agency's Headquarters in Vienna, Austria, from 16 to 20 February 2015 to discuss the topic. The IEMs are organized within the framework of implementation of the IAEA Action Plan on Nuclear Safety. Such meetings have been held since 2012 on topics such as radiation protection, decommissioning and remediation, and severe accident management. This IEM, the eighth in the series, was convened to discuss new areas and directions of research and development (R&D) work in safety, technology, and engineering following the Fukushima Daiichi accident. It was organized in cooperation with the OECD/NEA.

20. The Agency organized a third international peer review of Japan's Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1–4, in February 2015, with follow-up visits by two experts in April 2015 who received additional information about the management of contaminated water and the Tokyo Electric Power Company's (TEPCO's) efforts to improve public communication and outreach. The mission report prepared by the 15-member team acknowledges that "Japan has achieved good progress in improving its strategy and the associated plans, as well as in allocating the necessary resources towards the safe decommissioning" of the Fukushima Daiichi NPP. The report contains further advisory points on topics such as long term radioactive waste management, measures to be taken against contaminated water, and issues related to the removal of spent nuclear fuel and fuel debris.

21. Several cross-cutting missions were carried out to familiarize Member States considering building their first or a new research reactor with the guidance and approaches contained in *Specific Considerations and Milestones for a Research Reactor Project* (IAEA Nuclear Energy Series No. NP-T-5.1, Vienna, 2012). Such activities were conducted in Saudi Arabia (27-30 January 2014), Kuwait (18-22 May 2014), the United Republic of Tanzania (26-30 May 2014), South Africa (3-7 November 2014), the Sudan (25-29 January 2015) and the Plurinational State of Bolivia (10-12 March 2015). In addition, a Training Workshop on Specific Considerations and Milestones for

a Research Reactor Project was organized in Vienna, Austria, from 12 to 16 May 2014 to provide Member States with practical information relating to the above-mentioned IAEA Nuclear Energy Series publication, as well as to other documents referenced in that publication, and was attended by 50 participants representing 30 Member States. A Training Workshop on Assessment of the National Nuclear Infrastructure to Support a New Research Reactor Project was held in Vienna, Austria, from 4 to 8 May 2015. The workshop was attended by 27 participants representing 22 Member States, and contributions were provided by Agency staff from the three technical Departments (Nuclear Energy, Nuclear Sciences and Applications, and Nuclear Safety and Security), the Department of Safeguards and the Office of Legal Affairs. A consultancy meeting to initiate the preparation of a new Agency publication provisionally entitled *Feasibility Study for a New Research Reactor Project* was held in Vienna, Austria, from 2 to 6 February 2015.

22. Under the Russian Research Reactor Fuel Return (RRRFR) programme, launched in 2002 by the Agency, the Russian Federation, and the United States of America, a total of 2159.8 kg of Russian-supplied high enriched uranium (HEU) spent and fresh research reactor fuel has been transferred back to the Russian Federation from 14 countries in 60 separate shipment operations. The Agency upon request supports the RRRFR programme through a broad range of technical advice and organizational support, and by providing training in the conversion of research reactors from high to low enriched uranium fuel. Recent shipments include 53 kg HEU spent fuel from the Maria research reactor (Poland) and 47.5 kg HEU fresh and spent fuel from Alatau (Kazakhstan). A Technical Meeting considering the lessons learned from the RRRFR programme was held in Samarkand, Uzbekistan, from 3 to 5 June 2015.

23. In order to reflect the current status of and trends in research reactor utilization and management, a group of international experts reviewed 31 strategic plan documents submitted by research reactor managers from all over the world. Several publications providing guidance on research reactor utilization were published in 2014, including *Applications of Research Reactors* (IAEA Nuclear Energy Series No. NP-T-5.3), *Hands-on Training Courses Using Research Reactors and Accelerators* (Training Course Series No. 57), and *Compendium of Neutron Beam Facilities for High Precision Nuclear Data Measurements* (IAEA–TECDOC–1743). A research reactor database, containing information on research reactor utilization and other technical data, is regularly updated with new information provided by Member States.

24. Activities carried out in support of research reactor operation and maintenance in 2014 included the final RCM under the CRP entitled ‘Improved Instrumentation and Control (I&C) Maintenance Techniques for Research Reactors using the Plant Computer’ and the second RCM under the CRP entitled ‘Establishment of Material Properties Database for Irradiated Core Structural Components for Continued Safe Operation and Lifetime Extension of Ageing Research Reactors’. The Research Reactor Ageing Database was also updated with new information gathered from Member States.

25. The CONNECT (Connecting the Network of Networks for Enhanced Communication and Training) project, which was co-sponsored by the European Commission, was formally completed in February 2014. The project resulted in the establishment of a fully operational web-based platform, the development of almost 30 e-learning modules covering radioactive waste disposal and safety case development, and initiation of a customized wiki-based knowledge base initially focused on practical case studies and technology descriptions in the area of decommissioning. The implementation portion of the CONNECT project is part of an interregional technical cooperation project (INT/9/174) that will be completed in December 2015. CONNECT was officially launched in October 2014 at a Technical Meeting with more than 100 participants from around 65 Member States.

26. Successful missions to Honduras and Morocco took place in late 2014 and the first half of 2015, resulting in the repatriation and/or recycling of four high activity disused sealed radioactive sources

(DSRSs). An additional four missions are scheduled for 2015, to remove sources from Cameroon, Lebanon and Tunisia. Methods to facilitate the disposal of DSRSs are being initiated to provide additional options and tools for addressing the disposal and long term storage of DSRSs, including implementation of the borehole disposal concept in Malaysia and a pilot project in Ghana now under way.

27. The International Nuclear Information System (INIS), which is operated in collaboration with 130 Member States and 24 international organizations, is the Agency's largest document database. It now comprises over 3.7 million records and 500 000 full texts not readily available through commercial channels to the public. There are over 145 000 visits to the INIS Collection each month from all over the world, with over 3.4 million page views annually. The International Nuclear Library Network increased its membership to over 50 research institutes, libraries and nuclear regulatory bodies from 31 countries. The number of electronic journals available through the IAEA Library reached 28 000. More than 14 000 people visited the IAEA Library in 2014, and more than 30 000 documents were lent.

Agency Activities in the Development of Innovative Nuclear Technology

A. Background

1. In resolution GC(58)/RES/13, adopted on 25 September 2014, the General Conference referred to the role of innovative technologies in addressing improved nuclear safety and sustainability. It also noted the progress achieved in a number of Member States in the development of technology for advanced and innovative nuclear energy systems and the high technical and economic potential of international collaboration in the development of such technology.

2. It was further noted that membership of the Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), which was launched in 2000, is continuing to grow and its membership now comprises 40 Agency Member States plus the European Commission. Resolution GC(58)/RES/13 also called upon the Secretariat and Member States in a position to do so to investigate new reactor and fuel cycle technologies with enhanced proliferation resistance, including those needed for the recycling of spent fuel and the use of such recycled fuel in advanced reactors under appropriate controls and for the long term disposition of remaining waste materials, taking into account, inter alia, economic, safety and security factors.

3. The General Conference recommended that the Secretariat consider establishing, through the consolidation of available resources and assistance from interested Member States, regular training courses and workshops on advanced and innovative nuclear technologies to exchange knowledge and experience in the area of innovative, globally sustainable nuclear energy systems. The Director General was requested to report on progress made in the implementation of this resolution to the Board of Governors and to the General Conference at its 59th regular session. This report has been issued in response to that request.

B. Activities of the Agency

4. In line with resolution GC(58)/RES/13, INPRO Task 1 ('Global Scenarios'), has progressed with the development and evaluation of various nuclear energy scenarios and roadmaps for making the transition to sustainable nuclear energy systems, based on synergistic collaboration among the countries involved.

5. A consultancy meeting under the INPRO collaborative project 'Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability' (SYNERGIES) was conducted in March 2015 to finalize documentation and reporting on the 28 case studies, carried out by participants from the 24 IAEA Member States working on the project, and exploring 'win–win' strategies of collaboration among countries interested in the back end of the fuel cycle to amplify sustainability benefits resulting from synergies between the various nuclear energy system technologies. A draft report of the SYNERGIES project has been prepared and summary chapters of results found in the compiled country reports have been drafted and are being edited.

6. During the implementation of the SYNERGIES project it was noted that there are particular legal and institutional impediments to collaboration among countries on activities related to the back end of the nuclear fuel cycle. Examining these impediments and outlining ways of overcoming them would be an important step in the near term to ensure the long term sustainability of nuclear energy systems. The launch of a cross-cutting study on legal and institutional issues pertaining to collaboration among countries on activities related to the back end of the nuclear fuel cycle is being considered, and the Secretariat's proposal was accepted by the INPRO Steering Committee at its meeting in June 2014. An initial consultancy meeting was held in October 2014 to define the terms of reference and agenda of an INPRO Dialogue Forum held in May 2015, with the theme 'Cooperative Approaches to the Back End of the Nuclear Fuel Cycle: Drivers and Legal, Institutional and Financial Impediments'.

7. A consultancy meeting was held in June 2015 to prepare for an INPRO Dialogue Forum on the INPRO collaborative project 'Roadmaps for a Transition to Globally Sustainable Nuclear Energy Systems' (ROADMAPS), to be held in October 2015. The ROADMAPS project has the objective of developing a structured approach to achieving globally sustainable nuclear energy systems, and providing models of cooperation among countries and a template for documenting actions, scopes of work, and timeframes for specific collaborative efforts by particular stakeholders. The annexes to the project report will include roadmaps developed by Member States. The results of the INPRO Dialogue Forum will be compiled and analysed at a consultancy meeting planned for November 2015.

8. The INPRO collaborative project 'Key Indicators for Innovative Nuclear Energy Systems' (KIND) was launched in July 2014 and has so far resulted in tentative suggestions for a set of key indicators and the assessment method, as well as a preliminary selection of expert judgement aggregation methods. The objective of the KIND project is to develop guidance and tools for comparative evaluation of the status, prospects, benefits and risks associated with the development of innovative nuclear technologies for a more distant future. The target is to help Member States prioritize and adjust the allotment of resources within national programmes on innovative nuclear technology development. A consultancy meeting was held in April 2015 and a Technical Meeting is scheduled for December 2015.

9. Under INPRO Task 2 ('Innovations'), several new collaborative projects are being initiated to address issues relating to innovative nuclear energy systems as well as institutional and infrastructure innovations. A collaborative project on the dissemination of good practices in enhancing collaboration in innovations to support sustainable nuclear energy systems has been initiated through a Technical Meeting convened in April 2014. The objectives of this activity are to disseminate to Member States worldwide good practices in establishing effective mechanisms for collaboration in research and development (R&D) that are particularly applicable to nuclear energy, including nuclear energy systems, and to investigate options for further support to Member States in pursuing innovations, in particular for the development and deployment of sustainable nuclear energy systems. The draft final report is targeted for completion in 2015.

10. Activities for the INPRO collaborative project 'Review of Innovative Reactor Concepts for Prevention of Severe Accidents and Mitigation of their Consequences' continued. The objective of this project is to demonstrate that the evolution of safety requirements and related technical and institutional innovations in advanced nuclear reactor designs are contributing to ongoing improvements in 'safety by design', which may ultimately make it possible to practically eliminate the risk of large release of radioactivity outside nuclear power plant (NPP) sites, thereby avoiding the need for extended evacuation or relocation of adjacent populations, even in the event of a severe accident. The second consultancy meeting was held in March 2015 and a third meeting is planned for the fourth quarter of 2015.

11. Consultancy meetings in relation to the INPRO collaborative project 'Nuclear Fuel and Fuel Cycle Analysis for Future Nuclear Energy Systems' were held in November 2014 and January 2015 and a Technical Meeting is scheduled for November 2015. The objectives of this project are to carry out feasibility analyses of advanced and innovative fuels for different reactor systems in order to better understand the impacts of such fuels on the development of future nuclear energy systems, and to analyse spent fuel management options for advanced and innovative fuel cycles, while addressing potential technology improvements. The draft report is due in 2016.

12. The INPRO collaborative project 'Waste from Innovative Types of Reactors and Fuel Cycles' (WIRAF) will identify any problematic waste arising from innovative reactor designs and corresponding nuclear fuel cycles that could influence the development and deployment of future nuclear energy systems. WIRAF will also analyse problematic waste streams that may require either further enhancement of existing waste management processes and technologies or the development of new ones, and will discuss the technologies needed for the processing of such waste streams. A consultancy meeting was held in March 2015 and another is scheduled for October 2015. A Technical Meeting is scheduled for December 2015, and the draft report is expected to be delivered in 2016.

13. Following the publication of *Legal and Institutional Issues of Transportable Nuclear Power Plants: A Preliminary Study* (IAEA Nuclear Energy Series No. NG-T-3.5) in 2013, preparations for initiating the second phase of the study have been under way. The topic selected for the second phase is the development of several case studies, conducted by Member States, concerning the deployment of factory fuelled small modular reactors of different types. The proposal was supported by an INPRO Steering Committee meeting in June 2014 and the new collaborative project 'Case Study for the Deployment of a Factory Fuelled Small Modular Nuclear Reactor' was started at a consultancy meeting held in February 2015. More information on small modular reactor technologies is included in Annex 6 of this document.

14. Under INPRO Task 3 ('Sustainability Assessment and Strategies'), the current Nuclear Energy System Assessment (NESA) of Romania is taking place in coordination with the energy planning study services offered by the Planning and Economic Studies Section.

15. Ongoing discussions with Kazakhstan regarding the provision of services have been fully coordinated among the relevant areas of the Secretariat. A preparatory mission took place in May 2015 to discuss a work plan for performance of a national NESA.

16. The NESA of Indonesia continues, following Indonesia's decision in 2015 to further refine the scope of its NESA to include consideration of nuclear fuel cycle facilities (not including enrichment or reprocessing) and a new small high temperature gas reactor programme. Indonesia has requested a further extension to its NESA project to include this new programme.

17. Experts from China, India and the Russian Federation are cooperating under INPRO Task 3 to perform bilateral limited scope NESA projects focusing on the detailed designs of liquid metal cooled fast reactors. The primary purpose of these NESA projects will be to test the applicability of the INPRO methodology for the assessment of detailed innovative reactor designs (to date, full scope assessments have only been performed for nuclear energy systems based on evolutionary water cooled reactors). In October and November 2014, INPRO teams conducted preparatory visits to China and India. In February 2015, an INPRO team conducted a preparatory visit to the Russian Federation. The scope of the three assessments has been defined and two joint consultancy meetings have been scheduled for May and September 2015, respectively, to review the work done and discuss preliminary findings.

18. Under INPRO Task 3, all nine volumes of *Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems: INPRO Manual* (IAEA-TECDOC-1575 Rev. 1), published in 2008, are in the process of being revised and issued as IAEA Nuclear Energy Series publications. This effort is being performed as an INPRO consultancy task with the participation of Member State experts, all relevant Sections of the Agency, and expert consultants. Currently, two manuals, on economics and infrastructure, have been revised and published in the IAEA Nuclear Energy Series (NG-T-4.4 and NG-T-3.12). In addition, the revised manuals on resource depletion and environmental stressors have been accepted for publication. Additional draft documents are undergoing an internal coordinated review involving all relevant Sections of the Department of Nuclear Safety and Security and the Department of Nuclear Sciences and Applications.

19. The Agency provided the Scientific Secretaries for the annual coordination meeting between the Generation IV International Forum (GIF) and the Agency. The Ninth GIF–INPRO Interface Meeting was held in Vienna, Austria, in March 2015. In addition, INPRO Task 3 includes projects conducted in coordination with GIF on proliferation resistance and, more recently, on economics. In the area of economics, the Agency is cooperating with the GIF Economic Methodology Working Group (EMWG) to perform benchmark comparisons between the INPRO methodology-based macroeconomics estimator code, the Nuclear Economics Support Tool, and the comparable EMWG modelling tool (G4Econs). In the area of reactor safety, the Nuclear Power Technology Development and INPRO Sections provide the Scientific Secretaries for a series of joint GIF–Agency workshops on the safety of sodium cooled fast reactors, which in particular address the development of safety design criteria and guidelines for these innovative nuclear systems.

20. Under INPRO Task 4 (‘Policy and Dialogue’), the practice of conducting INPRO Dialogue Forums twice a year continues. The objectives of these INPRO Dialogue Forums are to bring together nuclear technology users, technology holders and newcomers from among all interested Agency Member States to discuss topics of mutual interest related to nuclear energy sustainability. The Eighth INPRO Dialogue Forum was convened in August 2014 and addressed nuclear energy system sustainability in the areas of economics, resource availability and institutional arrangements. The event was attended by representatives from 40 Member States.

21. The Ninth INPRO Dialogue Forum was convened in November 2014 and addressed international collaboration on innovations to support globally sustainable nuclear energy systems. The event was attended by representatives from 33 Member States and 3 international organizations with coordinated nuclear R&D portfolios.

22. In May 2015, the Tenth INPRO Dialogue Forum addressed cooperative approaches to the back end of the nuclear fuel cycle, including drivers and legal, institutional and financial impediments.

23. Within the framework of INPRO, the Agency is taking steps to provide regular education and training services to Member States to help build long term nuclear energy system planning capacity. Two regional training workshops were organized to provide training on energy planning, nuclear energy system modelling and application of the INPRO methodology for sustainability assessments. The first workshop was held in Santiago, Chile (for the Latin America region) in November 2014 and the second workshop was held in Kuala Lumpur, Malaysia (for the Asia and the Pacific region) in March 2015. Distance learning training on application of the INPRO methodology is also provided as a regular service to interested university programmes.

24. INPRO activities elicit strong interest from Member States, as evidenced by continuing growth in INPRO membership. The latest country to join INPRO was Thailand, in 2015, bringing the total number of INPRO Members to 41.

25. More than 150 experts representing 35 Member States and 5 international organizations met at the Agency's Headquarters in Vienna, Austria, from 16 to 20 February 2015 to take part in the International Experts' Meeting on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant. This eighth in the series of international experts' meetings (IEMs) was organized by the Agency, through its Departments of Nuclear Energy and Nuclear Safety and Security, in cooperation with the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA). The IEMs are organized within the framework of implementation of the IAEA Action Plan on Nuclear Safety and have been held since 2012 on topics such as radiation protection, decommissioning and remediation, and severe accident management. This IEM was convened to discuss new areas and directions of innovation, and R&D work, in safety, technology, and engineering following the Fukushima Daiichi accident.

26. In April 2015, the Agency released the beta version of the SAMG-D toolkit. The toolkit aims to help the user understand the basic elements required for the development of severe accident management guidelines (SAMGs) for NPPs and to guide transitions from emergency procedures to severe accident management procedures, and it can also be used for education and training purposes. SAMG-D is designed to be user-friendly software and is characterized by significant modularity and flexibility. A training workshop on the development of SAMGs based on this toolkit is planned for October 2015.

27. In the area of water cooled reactors, which represent over 95% of both operating civil power reactors and those under construction, three coordinated research projects (CRPs) are progressing according to schedule. Research Coordination Meetings (RCMs) under each of these projects — which are entitled 'Understanding and Prediction of Thermal Hydraulics Phenomena Relevant to Supercritical Water Cooled Reactors', 'Application of Computational Fluid Dynamics (CFD) Codes for Nuclear Power Plant Design', and 'Prediction of Axial and Radial Creep in Pressure Tubes' — were held in October 2014, February 2015 and April 2015, respectively.

28. Training courses on natural circulation and passive safety systems have been conducted in India in October 2014 and in China in July 2015, and two training courses on understanding the physics and technology of advanced passively safe water cooled reactors using computer-based simulators have been held in Malaysia in December 2014 and at the International Centre for Theoretical Physics in Trieste, Italy, in February 2015.

29. In support of the efforts by newcomer countries to develop their nuclear power programmes, three expert missions on reactor technology assessment for newcomers were conducted in Algeria in October 2014, in the Republic of Korea in November 2014, and in Kazakhstan in March 2015.

30. The important role of fast reactors and related fuel cycles for the long term sustainability of nuclear power was reaffirmed at the International Conference on Fast Reactors and Related Fuel Cycles: Safe Technologies and Sustainable Scenarios, held in Paris, France, in March 2013. The proceedings from this conference have recently been published. The next conference is scheduled for 2017 in the Russian Federation. The benefits of fast reactor technology include a more efficient utilization of natural resources (uranium and thorium) and a reduction in the quantity and radiotoxicity of radioactive wastes. Fast neutron systems consequently offer significant benefits in terms of making nuclear energy production more sustainable. Fast reactors are in operation in China, India, Japan and the Russian Federation, and several innovative fast neutron system concepts to further refine the utilization of such systems are being developed, designed or constructed in the aforementioned countries as well as in Belgium, France, Italy, the Republic of Korea and the United States of America.

31. In response to resolution GC(58)/RES/13, the Secretariat has strengthened collaboration among interested Member States with the objective of accelerating the development and early deployment of fast neutron systems with enhanced safety, economic and non-proliferation characteristics. In particular, this has led to enlargement of the Technical Working Group on Fast Reactors, which now includes 24 countries and 3 international organizations. Furthermore, the Agency has been collaborating with GIF on the development of safety design criteria and guidelines for innovative sodium cooled fast reactors; the new phase of this activity, which also involves design organizations, regulatory bodies and technical support organizations, and which was initiated in June 2015, has been implemented in particular by means of the organization of a Joint IAEA–GIF Technical Meeting/Workshop on Safety of Sodium Cooled Fast Reactors, held in Vienna, Austria, on 23–24 June 2015.

32. In response to the recommendation contained in resolution GC(58)/RES/13 to continue pursuing activities in the area of innovative nuclear technologies such as fast neutron systems, a new CRP proposed by India on radioactive release from the Prototype Fast Breeder Reactor under severe accident conditions was approved in February 2015, with the first RCM planned for November 2015. Meanwhile, the ongoing CRP entitled 'Sodium Properties and Safe Operation of Experimental Facilities in Support of the Development and Deployment of Sodium Cooled Fast Reactors' (NAPRO) and the CRP on safety shutdown tests conducted at the Experimental Breeder Reactor-II (EBR-II) are progressing as planned. The third NAPRO RCM is planned for October 2015, and the third RCM under the EBR-II project was held in Italy in March 2015. Research results in the form of technical publications and papers from other CRPs have been disseminated, notably *Benchmark Analyses on the Control Rod Withdrawal Tests Performed during the PHÉNIX End-of-Life Experiments* (IAEA-TECDOC-1742), and *Benchmark Analyses of Sodium Natural Convection in the Upper Plenum of the Monju Reactor Vessel* (IAEA-TECDOC-1754), both of which were issued in June 2014.

33. The new initiatives recently launched in the area of fast neutron systems on the basis of resolution GC(58)/RES/13 include a database of experimental facilities that exist in support of liquid metal cooled fast neutron systems, a principle-based simulator of an innovative sodium cooled fast reactor for educational purposes (through an extrabudgetary contribution from Japan's Ministry of Education, Culture, Sports, Science and Technology) and a new portal for knowledge preservation, which is now ready to be populated with data and documents from interested Member States.

34. Agency activities in support of high temperature gas cooled reactor (HTGR) technology development are being implemented according to the recommendation of resolution GC(58)/RES/13 on innovative reactors. The fifth RCM under the CRP entitled 'Improved Understanding of the Irradiation Creep Behaviour of Nuclear Graphite' — the objective of which is to predict plant lifetime and ensure that the graphite used as reactor core structural material can fulfil its safety functions — was held in March 2015. The second RCM under the CRP on uncertainty analysis in reactor physics, thermal hydraulics and burnup — which seeks to ensure adequate margins in operation and safety analysis — was held in December 2014. Drawing on lessons learned from the Agency's recently issued report on the Fukushima Daiichi accident and aiming, in accordance with resolution GC(58)/RES/10, to promote consistency among safety related aspects of HTGRs, a new CRP is under way to develop harmonized safety design procedures and make proposals on safety design criteria, taking the unique inherent safety characteristics of HTGRs into account. The first RCM under this new CRP was held in June 2015. Other areas of investigation include the study of 'deep burn' HTGR concepts that can use coated particle fuel for the incineration of nuclear waste, surplus fissile materials and plutonium, as well as economic studies with the organization of a Technical Meeting on the Economic Analysis of High Temperature Gas Cooled Reactors and Small and Medium Sized Reactors, held in Vienna, Austria, in August 2015. The potential of HTGR process heat applications

for mineral processing, or phosphate fertilizer production, with the concomitant recovery of uranium and thorium impurities for a more sustainable use of resources will also be studied in a new CRP.

35. Since 1997, the Agency has maintained a project on 'basic principle' reactor and power plant simulation to assist Member States in educating nuclear and regulatory professionals in the fundamental behaviour and operation of various types of water cooled reactors. In 2014, 75 compact discs containing simulator software executables and manuals were distributed to 69 institutions located in 36 Member States. A new effort is under way to help advance the understanding among Member States of next generation reactor technology by acquiring two additional basic principle simulators to aid in the understanding of emerging 'walk away safe' small integral pressurized water reactors and an advanced sodium cooled fast reactor. In 2015, the Agency published *New Technologies for Seawater Desalination Using Nuclear Energy* (IAEA-TECDOC-1753). This publication documents the results obtained by participants of a CRP organized by the Agency and completed in 2011, which was followed by a new CRP launched in December 2014 on the application of advanced low temperature desalination systems to support NPPs and non-electric applications. Also, in December 2014, the Agency released an updated version of its Desalination Economic Evaluation Program (DEEP 5.11). In October 2014 and June 2015, two Technical Meetings on Advances in Non-Electric Applications of Nuclear Energy and on Efficiency Improvement at Nuclear Power Plants were organized by the Agency in Canada and Turkey, respectively. The purpose of the meetings was to exchange information on prospects and challenges relating to non-electric applications of nuclear power; to assess the technical and economic aspects of cogeneration of electricity and useful heat at NPPs; and to explore approaches and strategies for improving efficiency at existing NPPs.

36. As requested by the General Conference at its 57th and 58th regular sessions in resolutions GC(57)/RES/12 and GC(58)/RES/13 respectively, the Agency is developing three IAEA Technical Documents, on opportunities for cogeneration using nuclear energy, industrial applications of nuclear energy, and generic guidance on cogeneration options assessing the economics associated with such options. Drafts of the first two reports have been submitted for publication while the third is still being compiled. In December 2014, the third RCM under the CRP on examining the techno-economic aspects of nuclear hydrogen production and on benchmark analysis of the Agency's Hydrogen Economic Evaluation Program (HEEP) software was held. During this meeting, the Agency released an updated version of the HEEP software as well as the beta version of the toolkit on nuclear hydrogen production. Users are able to access technical publications on nuclear hydrogen production through the links contained in the toolkit, learn about Agency activities, and easily make rough estimates of the cost and environmental impact of nuclear hydrogen production based on various methodologies.

37. Further work is being carried out in support of the IAEA Action Plan on Nuclear Safety through the CRP entitled 'Fuel Modelling in Accident Conditions' (FUMAC), for which the first RCM was held from 10 to 14 November 2014 in Karlsruhe, Germany, with the participation of some 30 organizations from 20 Member States. This project is being implemented in collaboration with the joint OECD/NEA–IAEA International Fuel Performance Experiments Database, which was created within the framework of the earlier 'Fuel Modelling at Extended Burnup' (FUMEX) projects that focused mainly on the modelling of fuel behaviour during normal (non-accident) operation. Concurrent with the FUMAC project, a new CRP entitled 'Analysis of Options and Experimental Examination of Fuels for Water Cooled Reactors with Increased Accident Tolerance' is open for proposals, and its first RCM will be held from 14 to 18 September 2015.

38. An Agency guide entitled *Quality and Reliability Aspects in Nuclear Power Reactor Fuel Engineering* (IAEA Nuclear Energy Series No. NF-G-2.1) was published in 2015 following six years of work, including three consultants' meetings and one Technical Meeting. The guide covers major technical, safety and organizational aspects of fuel quality and reliability assurance for both light and

heavy water cooled power reactors that are operated in 30 States and amount to more than 90% of their reactor fleet.

39. A report entitled *Accelerator Simulation and Theoretical Modelling of Radiation Effects*, which is in the process of being finalized for publication as part of the IAEA Nuclear Energy Series, summarizes the results of the CRP with the same title, which was implemented from 2008 to 2012. It was amended by a substantial expert review of experimental and theoretical studies of very high dose radiation damage with the use of ion accelerators. Such studies are particularly important for the development of advanced radiation resistant fuel claddings, needed for optimizing the fuel cycle — in particular, the utilization of fuel material resources — and reducing the highly radioactive waste of innovative fast reactor systems. The proceedings of two Technical Meetings that considered advances in the fabrication and operation of fuels for pressurized heavy water reactors, held in 2012 in Bucharest, Romania, and in 2013 in Mumbai, India, were published as *Pressurized Heavy Water Reactor Fuel: Integrity, Performance and Advanced Concepts* (IAEA-TECDOC-CD-1751), while intermediate results of the CRP entitled 'Near Term and Promising Long Term Options for Deployment of Thorium Based Nuclear Energy', which began in 2012, are presented in *Performance Analysis Review of Thorium TRISO Coated Particles during Manufacture, Irradiation and Accident Condition Heating Tests* (IAEA-TECDOC-1761, Vienna, 2015).

Development and Deployment of Small and Medium Sized Reactors, Including Small Modular Reactors

A. Background

1. In resolution GC(57)/RES/12/B.2, the General Conference encouraged the Secretariat to continue to assist Member States in the development of safe, secure, economically viable and proliferation-resistant small and medium sized reactors, including for nuclear desalination and hydrogen production. The General Conference requested the Director General to report to the Board of Governors and to the 59th regular session of the General Conference on: (a) the status of the programme initiated to assist developing countries interested in such reactors; (b) progress made in research and development (R&D) work on small and medium sized reactors and in the demonstration and deployment of such reactors in interested Member States; and (c) progress made in the implementation of the above-mentioned resolution. This report has been prepared in response to that request.

2. The Agency has a number of cross-cutting initiatives to support the development and deployment of small and medium sized reactors, recognizing their potential for enhancing energy supply security both in countries that are expanding existing nuclear power programmes and in embarking countries. These initiatives are focused within the Department of Nuclear Energy.

3. The trend in development has been towards design certification of small modular reactors, which are defined as advanced reactors that produce electric power up to 300 MW(e), designed to be built in factories and shipped to utilities for installation as demand arises. Reactors of this kind are also a viable option for producing heat for cogeneration and non-electric applications. Some Member States developing such reactors have recommended that the Agency use the abbreviation SMR to refer solely to ‘small modular reactor’ and avoid using SMRs to stand for ‘small and medium sized reactors’. However, other Member States are also developing advanced small and medium reactors without emphasizing modularity or multiple-module aspects, e.g. small or medium reactors for single-unit plants. In order to take into account and accommodate both trends in its Member States, the Agency seeks to use the appropriate terminology depending on the context. It does not appear possible to eliminate either term entirely — because both represent ongoing R&D work in different Member States. Current Agency activities focus on addressing issues related to SMRs whilst acknowledging that there are also ongoing activities related to non-modular small and medium sized reactors in its Member States.

4. Small modular reactor (SMRs) designs include water cooled reactors (e.g. integral pressurized water reactors (PWRs)) and high temperature gas cooled reactors (HTGRs), as well as liquid metal cooled reactors with fast neutron spectra. Some SMRs are designed for deployment as multiple-module power plants. Several countries are also pioneering the development and application of factory-fuelled transportable nuclear power plants (NPPs), including floating and seabed-based SMRs. The projected timelines of readiness for deployment of SMRs generally range from the present to 2025–2030.

B. Activities of the Agency

5. Within the framework of supporting the main action from the IAEA Action Plan on Nuclear Safety that calls for the effective utilization of R&D, and in particular R&D activities related to SMRs, the Agency has started incorporating lessons learned from the Fukushima Daiichi accident to enhance application of the defence in depth concept in the design of engineered safety features for water cooled SMRs so as to enable such reactors to cope with extreme external hazards. A combination of extrabudgetary contributions, including funds from the Peaceful Uses Initiative (PUI), is being used to support the development of a toolkit for SMR technology assessment, with a focus on assessing the reliability of engineered safety features. It is envisaged that this toolkit will help Member States to identify commercially available SMR designs for near term deployment and to make use of the process of technology assessment in support of informed decision-making. In connection with this activity, the draft text of a new IAEA Technical Document provisionally entitled *Considerations to Enhance the Defence-in-Depth of Engineered Safety Features in Small Modular Reactors in Coping with Fukushima-Type Accidents* has been completed for publication.

6. With respect to the regulatory infrastructure needed in preparation for the deployment of SMRs, the Agency has completed, in collaboration with nuclear regulatory bodies in leading nuclear countries, a draft report on environmental impact assessments (EIAs) for SMR deployment, intended for publication in the IAEA Nuclear Energy Series. In support of this, a Technical Meeting on Environmental Impact Assessment for the Deployment of Small and Medium Sized Reactors was convened in Vienna, Austria, from 28 to 31 October 2013, with the objective of assisting Member States that are considering deploying SMRs in preparing for the EIA process by exchanging information on Member States' current regulatory practices in the conduct of EIAs for new builds and their views on the EIA approach for SMRs. The Member States participating in that meeting also discussed specificity, new design features, operational characteristics, and unique deployment schemes of SMRs that may affect environmental impacts and review thereof.

7. The coordinated research project (CRP) entitled 'Development of Methodologies for the Assessment of Passive Safety System Performance in Advanced Reactors' was completed in July 2012. The main objective of the CRP was to determine a common method to analyse and test the reliability of passive safety systems. During the four years of the CRP, natural circulation tests were performed in Italy, and the test data used to benchmark the capability of several thermal-hydraulic codes to simulate the flow behaviour in the test apparatus. The requirements for a method of reliability assessment of passive safety systems for future advanced NPPs were identified. Four Research Coordination Meetings were held under the project and these were attended by the representatives of seven research institutions and organizations from five Member States (Argentina, France, India, Italy, and the Russian Federation). The report describing the work carried out under this CRP was issued in 2014 as *Progress in Methodologies for the Assessment of Passive Safety System Reliability in Advanced Reactors* (IAEA-TECDOC-1752).

8. A publication entitled *Options to Enhance Proliferation Resistance of Innovative Small and Medium Sized Reactors* (IAEA Nuclear Energy Series No. NP-T-1.11) appeared in 2014. The objective of this report is to harmonize the methodologies developed by the International Project on Innovative Nuclear Reactors and Fuel Cycles and the Generation IV International Forum for the assessment of proliferation resistance and physical protection.

9. As a supplement to its Advanced Reactors Information System, the Agency published a booklet entitled *Advances in Small Modular Reactor Technology Developments* in September 2014.

10. A draft report on instrumentation and control (I&C) systems for advanced SMRs, intended for publication in the IAEA Nuclear Energy Series, has been prepared following a Technical Meeting on the subject held in Vienna, Austria, from 21 to 24 May 2013. That meeting was organized to enable Member States to share knowledge and information on practices, design and architecture, implementation, and operating experience related to I&C systems for advanced SMRs, as well as to discuss the challenges and issues that need to be resolved before the deployment of such reactors.

11. A Technical Meeting on Small and Medium Sized Reactors Technology Development for Near Term Deployment was hosted by the Nuclear Power Institute of China in Chengdu, China, from 2 to 4 September 2013. Its primary aim was to enable newcomer countries to identify SMR technologies that are commercially available for near term deployment. The participating Member States also discussed specific areas of concern in SMR technology assessment associated with deployment, such as the design certification timeline, target deployment dates, and infrastructure development needs common to various SMR product lines.

12. In December 2013, *Approaches for Assessing the Economic Competitiveness of Small and Medium Sized Reactors* (IAEA Nuclear Energy Series No. NP-T-3.7) was published to assist embarking countries, in particular, in becoming familiar with the methods and approaches used to conduct economic competitiveness assessments of various SMR designs through comparison with commercially available alternatives.

13. A Technical Meeting on Operating Fundamentals of Pressurized Water Reactor-type Small and Medium Sized Reactors was hosted by the Pakistan Atomic Energy Commission in Islamabad, Pakistan, from 12 to 16 May 2014. Its key purpose was to enable embarking countries launching their first nuclear power project to become aware of the operating fundamentals of water-cooled small and medium sized reactors, through understanding the general design and technology of the 300 MW(e) NPP on the Chashma site. The meeting also provided small and medium sized reactor technology users with an opportunity to communicate with newcomer countries and to inform them of the design features, system and component descriptions, and operational and safety characteristics of reactors of this type that they have developed.

14. Recently, the Agency has also initiated an activity to develop computer-based simulators for integral PWR-type SMRs for educational purposes as part of a technical cooperation interregional project.

15. An important activity, funded through the PUI, is in progress to develop the Agency's technology roadmap for SMR deployment. The goal of this roadmap, which will be issued as a publication in the IAEA Nuclear Energy Series, is to provide Member States with an overview of how several SMRs that are currently under construction have progressed along their respective roadmaps and to present a model roadmap for pursuing SMR deployment in the future. In addition, this publication will provide a methodology for developing a technology roadmap for SMR designs with longer development horizons and discuss emerging opportunities and challenges for this relatively new technology.

C. Activities in Member States

16. Global activities supporting SMR design and technology development for near term deployment have emerged as an important new paradigm. Small modular reactors are under development for all principal reactor lines, i.e. water cooled reactors, liquid metal cooled reactors and gas cooled reactors.

As of 2014, three reactors in the SMR category are under construction in Argentina (CAREM-25, an industrial prototype), China (the High Temperature Reactor–Pebble-Bed Module (HTR–PM), an industrial demonstration plant), and the Russian Federation (KLT-40S, a barge mounted floating power unit). The distinct concepts of operations, licensing processes, and legal and regulatory frameworks for the various reactor designs are the main areas of activity on which Member States are concentrating in connection with SMR deployment.

17. Research is being carried out on approximately 45 SMR concepts for electricity generation, process heat production, desalination, hydrogen generation and other applications in 11 Member States (Argentina, Canada, China, France, India, Italy, Japan, the Republic of Korea, the Russian Federation, South Africa, and the United States of America). The following paragraphs summarize the activities undertaken by some of these Member States in the development of SMRs:

a) Argentina has developed the CAREM reactor, a small, integral type pressurized light water reactor design, with all primary components located inside the reactor vessel and an electrical output of 150–300 MW(e). Site excavation work for a 27 MW(e) CAREM-25 prototype was completed at the end of August 2012, construction has begun and contracts with various Argentinian stakeholders for manufacturing of the components have already been signed.

b) The construction of the HTR-PM industrial demonstration power plant in China will make HTGR technology available for near term deployment. The HTR–PM is a unique twin nuclear steam supply system feeding a single 200 MW(e) superheated steam turbine generator. Construction started in December 2012 and the plant is expected to begin operation by the end of 2017. Furthermore, the China National Nuclear Corporation is developing the ACP100 design and has submitted its preliminary safety analysis report to the National Nuclear Safety Administration in 2014, with construction expected to commence in 2016.

c) In France, the Flexblue design is a conceptual small seabed-moored NPP with a power output of 160 MW(e) which is scheduled for deployment by 2025. This marine-based SMR has been developed using France's experience of designing and operating nuclear powered submarines. It is designed to supply electricity to coastal grids.

d) In Japan, at least two water-cooled SMR designs are under development. The DMS (Double MS: 'Modular Simplified and Medium Small Reactor') design is a small-sized boiling water reactor with an electrical output of 300 MW(e). The integrated modular water reactor (IMR) is a medium sized power reactor capable of producing 350 MW(e) of electricity. Validation testing, R&D on components and design methods, and basic design development are required before licensing of the IMR.

e) Italy has been carrying out R&D work on SMR designs and technologies in an academic domain at the Polytechnic University of Milan, continuing the development of the International Reactor Innovative and Secure (IRIS) concept, previously led by the Westinghouse consortium. IRIS is an integral PWR design with an electrical capacity of 335 MW(e). The Polytechnic University of Milan also promotes international R&D activities on thermal hydraulics and safety engineering for SMR design development using the SPES-3 integral-effect test facility at the laboratories of the Company for Information on Thermal-hydraulic Experimentation (SIET) in Piacenza.

f) In July 2012, the Republic of Korea's Nuclear Safety and Security Commission issued the standard design approval for the 100 MW(e) system-integrated modular advanced

reactor (SMART) — the first integrated PWR design to receive certification. The design aims at achieving improved economics through system simplification, component modularization, reduction of construction time and high plant availability.

g) The Russian Federation is building two 35 MW(e) units of the KLT-40S series, to be mounted on a barge and used for cogeneration of process heat and electricity. The construction will be completed by October 2016 with expected electricity production in 2017. The ABV-6M, with an electrical output of 8.6 MW(e), is a nuclear steam generating plant using natural circulation for its integral reactor coolant system. Its development is at the final design stage. The RITM-200, an integral reactor with forced circulation for 'universal' nuclear powered icebreakers (i.e. multipurpose icebreakers that can be used both in the open sea and on rivers), is designed to generate 50 MW(e). Two RITM-200 reactor plants are being manufactured for the first such universal icebreaker, with complete delivery of the plant equipment scheduled for 2016.

h) In the USA, four integral pressurized water SMR designs are under development: the NuScale Power Module, the B&W mPower reactor of Babcock & Wilcox (B&W), the Westinghouse SMR, and Holtec's SMR-160. NuScale Power envisages an NPP made up of 12 modules producing 50 MW(e) per module and expects that the first such plant, which is to be built in Idaho, could begin commercial operation by 2023. The design certification application for the NuScale Power Module is expected to be submitted to the Nuclear Regulatory Commission in late 2016, and a combined construction and operating license application in 2017. The B&W mPower design consists of two 180 MW(e) modules. Its design certification plan is being rescheduled. The Westinghouse SMR has an electrical output of 225 MW(e) and incorporates passive safety systems and proven components from the same company's AP1000 design. Conceptual design of the SMR-160, a 160 MW(e) modular single loop reactor with passive safety features, is to be completed in 2015.

i) As for heavy water cooled SMRs, India has been developing the AHWR300-LEU, an advanced heavy water reactor (AHWR) design with a power output of 304 MW(e). The design incorporates vertical pressure tubes, low enriched uranium (LEU) and thorium fuel, and passive safety features; it is currently in the detailed design stage. A pre-licensing safety appraisal of the AHWR300-LEU design has been completed by the Indian national regulatory body, which has approved the design in principle.

j) Liquid metal cooled fast reactors in the SMR category are being investigated in several countries. Japan has developed a reactor called the 4S ('Super-Safe, Small and Simple') reactor, which is designed to provide 10–50 MW(e) and to be located in a sealed, cylindrical vault about 30 m underground while the turbine building would be above ground. The Russian Federation plans to construct several units of the SVBR-100 design, a small fast reactor with lead–bismuth eutectic molten alloy as the coolant and a power output of 100 MW(e). Its modular and integral design makes it suitable for large scale factory production, with high quality control, in order to reduce unit costs. Both the SVBR-100 pilot project and an experimental lead cooled fast reactor called BREST-300 are currently in their first stage of development. In China, the China Experimental Fast Reactor has been in operation since July 2010. In the USA, the detailed design of the 330 MW(e) Power Reactor Innovative Small Module (PRISM) has been developed.

Approaches to Supporting Nuclear Power Infrastructure Development

A. Background

1. In resolution GC(57)/RES/12, the General Conference recognized that the development and implementation of an appropriate infrastructure to support the successful introduction of nuclear power and its safe, secure and efficient use are of great importance, especially for countries that are considering and planning for the introduction of nuclear power. The General Conference acknowledged the Agency's significant and increasing role in assisting Member States in this area, in accordance with the growing number of requests received from Member States. The General Conference further noted the joint efforts of the Integrated Nuclear Infrastructure Group — now the Nuclear Infrastructure Development Section — and the International Project on Innovative Nuclear Reactors and Fuel Cycles in developing innovative infrastructure approaches for future nuclear energy systems. The General Conference further recognized the value of the Agency's Integrated Nuclear Infrastructure Review (INIR) missions, which provide expert and peer-based evaluations to help Member States determine their nuclear infrastructure development status, and encouraged the Secretariat to continue working on the development of the methodology for Phase 3 INIR missions. Finally, the General Conference commended the work of the Technical Working Group on Nuclear Power Infrastructure and recommended that the Secretariat renew its mandate for another three years.

2. The General Conference requested the Director General to report on the progress made in the implementation of the above-mentioned resolution to the Board of Governors and to the General Conference at its 59th regular session under an appropriate agenda item. This report has been prepared in response to that request.

B. Progress since the 57th Regular Session of the General Conference

B.1. General

3. Interest in introducing nuclear power has not diminished since the Fukushima Daiichi accident. Notably, Belarus and the United Arab Emirates have continued construction of their first nuclear power plants (NPPs), while Turkey has signed contracts and is actively preparing for construction. Other countries are in the process of establishing the necessary nuclear infrastructure following a national decision to develop a nuclear power programme. This group includes Bangladesh, Egypt, Jordan, Nigeria, Poland and Viet Nam. Finally, there are countries that are currently considering the introduction of nuclear power who have not yet made a national decision.

4. Extrabudgetary contributions to the Agency in support of nuclear power infrastructure have increased. In particular, contributions since 2011 to Agency infrastructure projects from donors to the Peaceful Uses Initiative (PUI) have exceeded US $8 million. These funds have allowed the Agency to rebuild services which had not been offered for some time, notably for future owner/operator organizations that will have the prime responsibility for nuclear safety. Some activities of particular

interest that have been enabled by PUI funding include the expansion of the legislative assistance programme., the development and application of a modelling tool for workforce planning, and the preparation of guidance documents and organization of training events on several topics, including design review, feasibility studies, and technology assessment. The PUI has also supported efforts to update the delivery of Agency guidance through modern e-learning materials. Many of these extrabudgetary activities were also identified in the IAEA Action Plan on Nuclear Safety as relevant to embarking countries.

5. Extrabudgetary resources have also directly supported nuclear power infrastructure in Member States through technical cooperation footnote-a/ projects. Some specific projects have included the provision of support for human resource development in Nigeria through the purchase of a simulator, and the promotion of capacity building in Viet Nam through the conduct of workshops and expert missions on several topics.

6. At the IAEA Ministerial Conference on Nuclear Safety held in Vienna, Austria, in June 2011, the Director General announced the preparation of an action plan on nuclear safety. The draft Action Plan was adopted by the Board of Governors and later endorsed by the General Conference in September 2011. Actions 8 and 9 in the IAEA Action Plan on Nuclear Safety refer, respectively, to the development of the infrastructure necessary for Member States embarking on a nuclear power programme and to strengthening and maintaining capacity building in Member States with nuclear power programmes and those planning to embark on such a programme. Several tasks have been undertaken to support these actions.

7. The annual Technical Meetings on Topical Issues in the Development of Nuclear Power Infrastructure were held in February 2014 and February 2015, with each meeting gathering approximately 100 participants from around 40 Member States, representing government ministries, organizations responsible for nuclear power programme planning in newcomer countries, current and future owner/operator organizations, vendors, technical support organizations, universities and regulatory agencies. These two annual meetings provided opportunities for participants from operating and newcomer countries to share their experiences and lessons learned in relation to the 19 infrastructure development issues identified under the Agency's Milestones approach, and to provide updates on the status of their nuclear infrastructure.

8. A working paper entitled *Interim Report on the Implications of the Fukushima Daiichi Accident for the IAEA Document 'Milestones in the Development of a National Nuclear Infrastructure for Nuclear Power', NG-G-3.1* was prepared in consultation with Member States and reviewed by the Nuclear Power Support Group. It summarizes the immediate lessons learned from the Fukushima Daiichi accident that are relevant for embarking countries which are following the Milestones approach.

9. The *IAEA Catalogue of Services for Nuclear Infrastructure Development* — a comprehensive catalogue of Agency services available to Member States in all areas of infrastructure development — is updated and maintained by the Nuclear Infrastructure Development Section.

B.2. Technical Working Group on Nuclear Power Infrastructure

10. The Technical Working Group on Nuclear Power Infrastructure (TWG-NPI) is a group of international experts who provide advice to the Agency on the development and implementation of national nuclear power programmes. These experts represent countries with established national nuclear power programmes and countries considering starting such programmes. The TWG-NPI ensures that sound and comprehensive guidance and recommendations based on recent developments and best practices related to infrastructure development for national nuclear power programmes are

being developed, implemented and pursued by the Agency in support of interested Member States. In the last two years, the TWG-NPI has convened five times to provide guidance to the Agency on approaches, strategies, policies and actions to be implemented for the establishment of a national nuclear power programme.

B.3. Technical Cooperation

11. There are currently over 40 national, regional and interregional technical cooperation projects supporting countries considering or planning nuclear power. As several countries have moved into a more active phase of infrastructure development, the Agency's support through technical cooperation has emphasized review services and capacity building. Countries at the same level of infrastructure development have had the opportunity to share their experiences with each other through regional and interregional projects. This sharing of lessons learned among newcomer countries is especially useful given the length of time that has passed since the last newcomer prior to the United Arab Emirates started construction of an NPP.

B.4. Assessment of Nuclear Infrastructure

12. Integrated Nuclear Infrastructure Review missions continue to be a primary source of international expert/peer review for embarking countries. This service, facilitated by the Agency, has been widely recognized as an effective way to evaluate the status of a country's nuclear infrastructure, and Member States that have received an INIR mission have found it useful for supporting further development. The international experts who take part in the missions review the progress in infrastructure development achieved by the host country and make recommendations and suggestions as to how it can advance further.

13. Fourteen of these missions have been conducted since 2009. Recent missions (since September 2013) have been undertaken in Jordan, Kenya, Nigeria, Turkey and Viet Nam. Missions are planned for Bangladesh and Morocco before the end of 2015.

14. The Agency is currently developing the methodology for an INIR mission in Phase 3, which will review the readiness of the infrastructure to support operation. This was requested as part of the IAEA Action Plan on Nuclear Safety and will take into account the results of other Agency peer review services. In 2014, the Agency conducted an exercise to test the methodology, which resulted in its further refinement. The methodology and guidance for INIR Phase 3 missions are expected to be ready in early 2016, in time to be piloted in countries that have NPPs under construction and are planning for the commissioning of these.

B.5. Support for Human Resource Development

15. Human resource development continues to be a high priority for both Member States and the Agency, and there are several ongoing activities in this area.

16. In June 2015, the Agency trained new experts in the use of the Nuclear Power Human Resources (NPHR) modelling software, provided cost-free by the United States of America, and held a meeting with Kenya to adapt it for use. With new experts now available to lead the training, the Agency anticipates broader implementation of the NPHR tool.

17. Within the framework of a project financed by extrabudgetary funds from the Republic of Korea under the PUI, several e-learning modules based on existing Agency publications on nuclear infrastructure development, as well as on relevant feedback from Member States, have been developed. The first 11 modules are available on the Agency website and additional modules, which,

inter alia, cover management of spent fuel and radioactive waste, siting, legal framework and pre-feasibility studies, are currently under development.

18. Training courses on nuclear safety management and leadership, construction management, and mentoring programmes have also been held on an annual basis in China, France, the Republic of Korea, the Russian Federation and the USA.

B.6. Conferences and Workshops

19. An International Ministerial Conference on Nuclear Power in the 21st Century was held in Saint Petersburg, Russian Federation, from 27 to 29 June 2013. It was attended by more than 100 ministerial-level or high-level participants from over 50 countries. The conference provided delegates with an opportunity to discuss, at the ministerial and international expert level, the role and viability of nuclear power in sustainable development, including climate change mitigation, its role in meeting growing global requirements for electricity, and its status and prospects for the future.

B.7. Documents under Preparation

20. The updated version of *Milestones in the Development of a National Infrastructure for Nuclear Power (IAEA Nuclear Energy Series No. NG-G-3.1)* will be published in September 2015, in accordance with the IAEA Nuclear Energy Series policy of reviewing guidance documents every five years. This revision incorporates feedback received from Member States currently following the Milestones approach, lessons learned from the Fukushima Daiichi accident, and evolutions in the NPP bidding and ownership processes.

21. Two new IAEA Nuclear Energy Series publications, entitled *Managing Organizational Change in Nuclear Organizations* (IAEA Nuclear Energy Series No. NG-T-1.1) and *Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes* (IAEA Nuclear Energy Series No. NG-T-3.11), were issued in April 2014 and September 2014, respectively.

22. An IAEA Technical Document entitled *Alternative Contracting and Ownership Approaches for New Nuclear Power Plants* (IAEA-TECDOC-1750) was published in September 2014.

23. Drawing on lessons learned from the completed INIR missions, the Agency has also revised *Evaluation of the Status of National Nuclear Infrastructure Development* (IAEA Nuclear Energy Series No. NG-T-3.2). The evaluation approach contained in this publication provides a comprehensive means of determining the status of the infrastructure conditions covering all of the 19 issues identified in the Milestones approach. The updated version will be available in 2016.

24. Additional IAEA Nuclear Energy Series publications and/or IAEA Technical Documents on the development of a national position on a new nuclear power programme, on industrial involvement, and on lessons learned from five years of INIR missions will be issued by the end of 2015.