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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(55)/RES/12 and GC(56)/RES/12, this document contains progress reports on the Programme of Action for Cancer Therapy (PACT) (Annex 1); support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC) (Annex 2); use of isotope hydrology for water resources management (Annex 3); modernization of the Agency's nuclear applications laboratories at Seibersdorf (Annex 4); nuclear energy activities (Annex 5); producing potable water economically using small and medium sized nuclear reactors (Annex 6); Agency activities in the development of innovative nuclear technology (Annex 7); small and medium sized reactors (SMRs) — development and deployment (Annex 8); and approaches to supporting infrastructure development for nuclear power (Annex 9).

Further information on the Agency's activities related to nuclear science, technology and applications can be found in the *Nuclear Technology Review 2013* (document GC(57)/INF/2), the *IAEA Annual Report 2012* (GC(57)/3), in particular the Technology section, and the *Technical Cooperation Report for 2012* (GC(57)/INF/4).

## **Recommended Action**

It is recommended that the Board take note of Annexes 1–9 of this report and authorize the Director General to submit the report to the General Conference at its fifty-seventh session.



# Programme of Action for Cancer Therapy

1. At its fifty-fifth regular session in September 2011, the General Conference, in resolution GC(55)/RES/12.A.2, requested the Director General to continue advocating and building support for the Agency's work on cancer control, including by allocating and mobilizing resources for the implementation of the Programme of Action for Cancer Therapy (PACT), as one of the priorities of the Agency; and to continue formalizing, where feasible and appropriate, PACT's collaboration with partners already identified for the more effective development and implementation of country-level PACT projects.
2. The General Conference called on the PACT Programme Office (PPO) to harness the benefits that may be derived from the WHO-IAEA Joint Programme on Cancer Control, particularly in terms of accelerated programmatic delivery to Member States, strengthening public health approaches to cancer control, and increased resource mobilization potential. The General Conference further called on the Secretariat to follow up on the outcome and recommendations of the high-level meeting on the prevention and control of non-communicable diseases (NCDs), particularly cancer, including by assisting developing countries to adopt and implement a comprehensive approach to cancer control.
3. The General Conference recommended that the PPO, in consultation with the Department of Technical Cooperation, other relevant Agency departments and the World Health Organization (WHO), as appropriate, continue working to assist developing Member States in establishing integrated and comprehensive national cancer control plans, involving the full participation of other international organizations and agencies. The General Conference requested the Director General to report on the implementation of this resolution at its fifty-seventh (2013) regular session.

## **A. Agency-wide Cancer Control Activities**

4. PACT has been recognized by Member States as an Agency flagship programme. Along with its partners, the WHO, the International Agency for Research on Cancer (IARC) and the Union for International Cancer Control (UICC), among others, PACT enables Member States to introduce, expand and improve their cancer control capacity by integrating radiation medicine into a comprehensive National Cancer Control Programme (NCCP). Such programmes integrate and align activities and investments in all areas of cancer control, namely, cancer prevention, surveillance, early detection, diagnosis, treatment, and palliative care into a public health system.
5. The Agency continues to support its Member States through its technical cooperation (TC) and human health programmes. The greatest share of TC funding (26.2%) is allocated to support projects in human health. Three regional TC projects are ongoing in Africa (RAF/6/043), Europe (RER/6/027) and Asia and the Pacific (RAS/6/069) which include impACT missions to support comprehensive cancer control in the regions.
6. The PACT Working Group, composed of representatives of the PPO, the Department of Technical Cooperation, the Division of Radiation, Transport and Waste Safety and the Division of Human Health, was established in 2012. The Working Group is tasked with coordinating and planning the various Agency activities related to cancer control thus maximizing their benefits for Member States.

7. To strengthen the delivery of the PACT programme, the PPO will be relocated to the Department of Technical Cooperation as of 2014. This move responds to increasing demands from Member States for PACT services, and will maximize the existing synergies between PACT and the technical cooperation programme, which is the Agency's primary mechanism for delivering technical cooperation support to Member States. Furthermore, the 2014–15 Programme and Budget calls for the PPO to be upgraded to a Division, with additional resources to be provided in support of this upgrade.

## **B. WHO-IAEA Joint Programme on Cancer Control**

8. The Agency, WHO and IARC, which is an agency of WHO, have been holding high-level meetings throughout 2012–13 to review the current practical arrangements between the Agency and WHO with the aim of developing a more integrated and actionable framework for collaboration that would include joint project development and resource mobilization.

9. Additionally, the Agency has been closely collaborating with WHO and other UN agencies as part of the United Nations Interagency Task Force on the Prevention and Control of Non-communicable Diseases (NCDs) that was created following the 2011 Political Declaration of the High-level Meeting of the UN General Assembly on the Prevention and Control of NCDs. The declaration calls for a UN system-wide effort, with partners, to develop comprehensive, multi-sectorial strategies for the prevention and control of NCDs.

10. The Agency hosted a meeting of the Interagency Task Force on 11–12 December 2012 in Vienna, with experts from the Agency, WHO, the United Nations Development Programme (UNDP), the Joint United Nations Programme on HIV and AIDS (UNAIDS), United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA), the International Telecommunications Union (ITU) and the World Intellectual Property Organization (WIPO). These discussions resulted in the development of an initial integrated UN framework for addressing NCDs; and the next step is to refine and enhance this framework.

11. In May 2013, the Secretariat attended the Sixty-Sixth World Health Assembly (WHA) in Geneva to promote international efforts to address the growing challenge of cancer control and to participate in the discussions of the draft Global Action Plan on NCDs. The Agency's participation in the development and implementation of the plan ensures that radiation medicine will be reflected as a key element in cancer treatment, cancer control and the global NCD agenda.

## **C. Cancer Control Capacity Assessment, Evaluation and Support in Member States**

12. One of the key services provided to Member States is the impACT review, the purpose of which is to assess the Member State's readiness to develop and implement a long-term radiation medicine capacity building plan, including the relevant safety, regulatory and quality assurance requirements, within the framework of a NCCP. To date, official requests for impACT reviews have been received from 66 Member State Ministers of Health. Since September 2011, PPO has coordinated 22 impACT reviews in close collaboration with the relevant Departments of the Agency and WHO, including WHO's regional and/or country offices. All impACT missions performed during the last two years have included representatives of WHO, which has allowed for specific WHO recommendations for the

establishment of integrated and comprehensive national cancer control plans to be included in the corresponding mission reports.

13. Responding to the inadequate access to radiation therapy that persists in the developing world, the Advisory Group on Increasing Access to Radiotherapy Technology (AGaRT) was launched by the Agency in 2010. AGaRT seeks to bring together users and suppliers of diagnostic and radiotherapy technologies and other stakeholders, to encourage the production of safe, affordable and reliable equipment that meets the specific requirements of radiotherapy centres in low and middle income (LMI) countries. In 2012, AGaRT developed packages of equipment options for Member States which will be presented at the 2013 AGaRT annual meeting. The group is also developing guidelines for sale and service contracts to ensure the long-term affordability of radiotherapy equipment and maintenance for LMI countries in the future. In all cases, due consideration is given to ensuring the compliance of recipient Member States with radiation safety requirements prior to delivery, whether cancer therapy equipment - including with radioactive sources - is provided through the Agency or directly by suppliers.

## **D. PACT Model Demonstration Sites**

14. The PACT Model Demonstration Sites (PMDSs) are pilot projects in Member States aimed at demonstrating synergies between international partners, donors, cancer therapy experts and national authorities for effective cancer control planning and implementation. PMDSs are currently operational in Albania, Ghana, Mongolia, Nicaragua, Sri Lanka, the United Republic of Tanzania, Vietnam and Yemen. Cancer control experts from all eight PMDS countries met with the Agency, WHO and IARC on 21-22 November 2012 in Vienna to share their experiences in developing comprehensive national approaches to address cancer control and to discuss future PMDS activities.

15. In 2013, the project, “Strengthening Albania’s Comprehensive Cancer Control Structures and Capacities for Early Detection of Breast Cancer”, was initiated with US \$40 000 in funding through the One UN Coherence Fund. In Ghana, a project to strengthen capabilities in nuclear medicine and radiotherapy services at the Korle Bu Teaching Hospital in Accra and the Komfo Anokye Teaching Hospital in Kumasi has continued to make progress. A tripartite agreement was signed on 14 February 2012 at Agency Headquarters between the Agency, the Principality of Monaco and the Government of Mongolia under which the Principality agreed to provide €125 000 to support the implementation of a project to improve palliative care in Mongolia. The project will equip the Palliative Care Department of the National Cancer Centre of Mongolia with upgraded medical devices to provide training to health professionals and to improve the quality of palliative care in 21 provinces and nine districts.

16. An agreement was signed with the Ministry of Health in Nicaragua for a project to strengthen cervical and breast cancer diagnosis at the Bertha Calderon Hospital in Managua, with funding provided by the Government of Spain. In Sri Lanka, two expert missions were conducted to assess patient information management systems related to cancer, as well as access to and the quality of radiotherapy and palliative care. An agreement was also signed with the National Cancer Institute of Maharagama in Sri Lanka for a project to improve radiotherapy that will be funded by the Republic of Korea, which contributed US \$145 000 to support multiple PMDSs in the Asia Pacific region. A National Cancer Control Steering Committee was established in the United Republic of Tanzania with assistance from PACT to identify priorities in the various areas of cancer control and to complete a national cancer control programme (NCCP). The NCCP was formally endorsed by the Ministry of Health in February 2013. Upon request by the Government of Yemen, PACT convened a 'National Cancer Control Planning Workshop for Yemen - PACT Model Demonstration Site' from 10 to 12

February 2013. The workshop was held under the auspices of the WHO Regional Office for the Eastern Mediterranean in Cairo, Egypt. The primary outcome of the meeting was the development of a list of prioritized recommendations for cancer control in Yemen with deadlines for fulfillment. On 2 February 2012, the Agency signed an agreement with the OPEC Fund for International Development in Vienna under which OFID agreed to provide US \$450 000 to support cancer control in Vietnam, in particular to combat women's cancers.

## **E. Regional Cancer Training Networks through a Virtual University**

17. The Annual Stakeholders Project Coordination Meeting of the Virtual University for Cancer Control and Regional Training Network (VUCCnet) was held in Lusaka, Zambia in July 2012 and was attended by more than 60 representatives of Member States, WHO, IARC, the International Network for Cancer Treatment and Research (INCTR), the National Cancer Institute (NCI) in the United States of America, the African Radiation Oncology Group (AFROG) and other Agency partners. The meeting concluded that a regional approach is needed, building upon existing training materials, African training networks and African infrastructure, and embedded in existing African education and training institutions.

18. The Member States of VUCCnet<sup>1</sup> are in the process of establishing a regional governance structure which will allow them to take regional ownership of the initiative.

## **F. Funding, Resource Mobilization and Partnerships**

19. PACT's support to Member States largely relies upon external financial resources. To date, PACT has mobilized a total of US \$31.5 million in extrabudgetary funding from development banks, bilateral donors, Member States, partner organizations, the Peaceful Uses Initiative (PUI) and the private sector. In 2012–13, US \$3.5 million has been mobilized.

20. Since September 2011, investments have been made to enhance PPO's resource mobilization capabilities. Two dedicated fundraising positions have been filled and a comprehensive PACT resource mobilization strategy has been developed to provide a framework for systematic resource mobilization.

21. A high level seminar was organized by the Agency, the Islamic Development Bank (IDB) and the Organisation of Islamic Cooperation (OIC) in Jeddah, Saudi Arabia, in September 2012, with the participation of nine African Member States of the IDB and the Agency. The seminar aimed to enhance cooperation between the IDB, the OIC and the Agency, to better support the cancer control efforts of common Member States of the Agency and IDB in Africa. The seminar adopted a roadmap to facilitate and guide follow-up actions, including the submission of bankable project documents by participating Member States for funding consideration by the IDB or other donors. Technical cooperation support is also being provided directly to other Member States who have decided to

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<sup>1</sup> The Member States of the VUCCnet are Ghana, the United Republic of Tanzania, Uganda and Zambia, with Egypt and South Africa serving as mentor States.

proceed with applications for grants and/or loans, to support the development of radiotherapy services. Such documents are currently under development with Afghanistan, Albania, Malawi, Sudan and Yemen.

22. Over the long term, fundraising and resource mobilization can benefit from effective partnerships. During the reporting period, the Agency signed four new Practical Arrangements with well-recognized organizations active in cancer control, namely, the African Organization for Research and Training in Cancer (AORTIC), the French National Cancer Institute (INCa), the Sovereign Order of Malta and Cairo University.



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

## A. Background

1. In resolution GC(56)RES/12/A.3, the General Conference recognized that the tsetse and trypanosomosis (T&T) problem is spreading, and that this problem constitutes one of the greatest constraints on the African continent's socioeconomic development. It recognized the importance of livestock development in rural communities affected by T&T, in which the disease directly impacts food security and thereby increases poverty levels. It further recognized that trypanosomosis continues to claim tens of thousands of human lives and millions of livestock every year while threatening over 60 million people in 36 African countries, the majority of which are Agency Member States. The General Conference welcomed the continuing close collaboration of the Secretariat with AU-PATTEC, in consultation with other United Nations (UN) organizations mandated to address the T&T problem. The General Conference also welcomed the work of the Agency, under the Joint FAO/IAEA Programme, and with the support of the Agency's Technical Cooperation Fund, in developing the sterile insect technique (SIT) 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 UN specialized agencies toward T&T control efforts in West Africa, especially those made by the United States of America through the Peaceful Uses Initiative (PUI) for the control of T&T in Senegal. It further acknowledged the Agency's continuing close collaboration with the International Centre of Research and Development for Livestock in Subhumid Zones (CIRDES) in Bobo-Dioulasso, Burkina Faso, the first IAEA Collaborating Centre in Africa in the field of SIT using AW-IPM approaches to target tsetse fly populations.

2. The General Conference urged the Secretariat to continue assigning 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. 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, and to strengthen support for technology transfer and demand-driven applied R&D in African Member States, to complement their efforts in creating and expanding the tsetse-free zones.

## **B. Progress since the 56th Regular Session of the General Conference**

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

3. During the week of the 56<sup>th</sup> General Conference, on 18–19 September, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture organized the annual Scientific Forum with the theme, “Food for the Future: Meeting the Challenges with Nuclear Applications”. The AU-PATTEC Coordinator, Dr Hassane Mahamat, presented a keynote address, entitled “The Importance of Tsetse and Trypanosomosis Elimination for Food Security and Rural Development in Sub-Saharan Africa”. On 26–27 September 2012, the Agency hosted a meeting of the Secretariat of the Programme Against African Trypanosomosis (PAAT), in which AU-PATTEC, the Inter-African Bureau for Animal Resources (AU-IBAR), FAO, WHO and IAEA collaborate to harmonize their T&T efforts. In consultation with its partners, particularly FAO and WHO, the Agency maintained close interaction with AU-PATTEC and provided, based on the existing memorandum of understanding with the Agency, assistance to the six current national PATTEC projects in Burkina Faso, Ethiopia, Ghana, Kenya, Mali and Uganda.

4. Together with approximately 90 national PATTEC coordinators from 29 T&T-affected African countries and representatives from international organizations, institutions, NGOs and the private sector, the Agency participated in the eleventh meeting of the PATTEC national coordinators from 10 to 12 December 2012. Organized by the African Union Commission (AUC) in Hawassa, Ethiopia, and hosted by the Ethiopian Southern Rift Valley Tsetse Eradication Project (STEP), this was the largest meeting of national PATTEC coordinators to date. STEP used this opportunity to demonstrate to partners, and to many for the first time, its tsetse control and eradication field activities, which include insecticide-based tsetse suppression and aerial releases of sterile male tsetse flies. The Agency also participated in the first meeting of the new PATTEC Steering Committee, which was organized by the AUC in Hawassa, Ethiopia, on 12 December 2012, with the participation of international organizations, NGOs, donors, and the private sector. The meeting reviewed and adopted the PATTEC strategic plan and recommended that AU-PATTEC should document its achievements over the past ten years.

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

5. Following close consultations with AU-PATTEC, FAO and several national PATTEC coordinators, the IAEA hired consultants to develop a tutorial DVD on the use of geographic information systems (GISs) in support of insect pest control programmes. The DVD makes use of free open source software and contains a special chapter on GIS applications as applied to tsetse control and eradication operations. Based on this DVD, the Agency, in close cooperation with AU-PATTEC and FAO, will conduct a GIS training course for senior tsetse control personnel in Addis Ababa in late 2013.

6. The Agency continues to support the AU-PATTEC Plan of Action through two regional technical cooperation (TC) projects in Africa and five national TC projects in Chad, Ethiopia, Senegal, Uganda, the United Republic of Tanzania and Zimbabwe (CHD/5/003, ETH/5/016, SEN/5/033, UGA/5/033 and ZIM/5/017). In the past year, the Agency provided assistance through these projects in the form of training, expert services and equipment to 17 T&T-affected Member States. The focus was on baseline data collection, feasibility assessment studies, capacity building and pre-operational support for the

use of the SIT. The Agency's support for STEP continues to be delivered through the national and regional TC projects ETH/5/016 and RAF/5/064.

7. Under the Joint FAO/IAEA Programme two coordinated research projects (CRPs) relevant to tsetse and trypanosomosis were completed. The CRP entitled "Improving SIT for Tsetse Flies through Research on their Symbionts and Pathogens" contributed to the development of strategies for managing and treating a virus affecting tsetse salivary glands, which is hampering the mass-rearing of *Glossina pallidipes* (*G. pallidipes*), one of the most important tsetse species from an economic standpoint. A combination of virus management tactics, such as treatment with an anti-viral drug and a modified feeding regimen, was successfully validated at the FAO/IAEA Insect Pest Control Laboratory (IPCL) in Seibersdorf and introduced at the STEP mass rearing and irradiation centre in Kality in Ethiopia. The adoption of this virus management system in 2013 reduced the prevalence of the salivary gland virus in the *G. pallidipes* colony at Kality to nearly 7%, which is approximately one-third of the prevalence recorded in 2012. Additional achievements of this CRP include the further development of methods for modifying the genes of symbiotic microbes present in tsetse flies to achieve desirable genetic results that can improve the effectiveness of the SIT. For example, these methods may eventually allow for the inhibition of trypanosome transmission by tsetse flies. The results of this CRP will be published in the *Journal of Invertebrate Pathology*.

8. Under the CRP entitled "Applying GIS and Population Genetics for Managing Livestock Insect Pests" the latest research coordination meeting (RCM) was held in London, United Kingdom, 16–19 April 2013. The meeting reviewed twelve progress reports on population genetics and geometric morphometrics of new and old world screwworm flies, and of tsetse fly species in East and West Africa, as well as new findings to generate GIS-aided maps illustrating possible gene flow between neighbouring tsetse populations, which has implications for planning AW-IPM campaigns. The research results under the CRP are scheduled to be published in a special issue of *Acta Tropica*. The first RCM of a new CRP entitled "Enhancing Vector Refractoriness to Trypanosome Infection" was held in Vienna, Austria, 3–7 June 2013. Several papers presented at the meeting summarized the current state of knowledge on factors that influence and specifically reduce the susceptibility of the tsetse flies to trypanosome infections.

### **B.3 Support for the Planning and Implementation of SIT Activities in East Africa**

9. The Agency continued to provide technical assistance to STEP through the national and regional TC projects ETH/5/016 and RAF/5/064. In addition, the Ethiopian Government allocated a budget of 25 million Birr (~ US \$1.4 million) in nationally administered funds for 2012–13, and in a similar manner has proposed 45 million Birr for the fiscal year 2013–14 in support of STEP. The Ethiopian Government, FAO and the Agency held consultations and a high level meeting on the status of the STEP project in Vienna, Austria, and in Hawassa, Ethiopia on 25 September 2012 and 23 January 2013, respectively. Significant progress in the areas addressed below, among others, was presented and discussed at these two meetings.

10. Improvements in blood collection and processing at the Kality facility and the repair of the door to the irradiation chamber of the gamma cell, which temporarily halted irradiation activities, resulted in the accumulation of a stock of more than 2000 litres of irradiated blood by January 2013, which is enough to feed the colonies for more than two months. Procedures to manage the salivary gland virus have been expanded to the complete *G. pallidipes* colony. The appointment of a Quality Assurance Team Leader has resulted in the establishment of a quality control system for blood management and sterile fly handling and the strengthening of quality assurance procedures of the rearing process. Making use of a loan from the African Development Bank (AfDB), two additional modules of the

Kality mass rearing facility have been equipped with tsetse production units, thereby doubling the current mass production capacity. All of these advances have helped the growth of the two tsetse colonies at the Kality mass rearing facility to reach 1.24 million females for *G. f. fuscipes* and 192 000 females for *G. pallidipes* in mid-2013. Good progress has also been made in the construction of the mass rearing facility's industrial irradiator building, with construction of the structure expected to be complete by August 2013. The industrial irradiator, which is expected to be equipped and functioning in early 2014, will offer significantly greater capacity for the irradiation of blood, which will enable the more precise gamma cell to be used exclusively to sterilize male flies.

11. Sequential aerial insecticide spraying for the suppression of tsetse populations over 5000 km<sup>2</sup> of national parks and other high density areas in Ethiopia reduced the target fly populations by more than 90%. Ground tsetse suppression was expanded to cover more hot-spots in the project area, which delivered a reported reduction of fly densities from an average of 20 flies per trap per day to 0.35 flies. The aerial spraying operations were complemented by thorough environmental monitoring activities, which recorded no adverse effects. Furthermore, the campaign was accompanied by effective public outreach via local radio in seven local languages to inform the public of the purpose and nature of these suppression activities. Despite the success of these activities, the results make clear that the SIT will be required to achieve full tsetse eradication in these areas.

12. SIT aerial field operations continued in Ethiopia's Deme Basin with the release of between 30 000 and 60 000 sterile male *Glossina f. fuscipes* on a weekly basis starting in April 2012. Releases of the second species, *G. pallidipes*, were initiated in August 2012. To prevent reinvasion from the Omo Basin, approximately 250 insecticide impregnated targets were deployed in the Deme Valley. As STEP personnel have had to expand suppression activities to other areas in Ethiopia, the number of staff and vehicles available to monitor the impact of the SIT operations in the 700 km<sup>2</sup> release zone of the Deme basin has been insufficient. To compensate for this, the Agency has provided expert services to assist in carrying out the required intensified entomological monitoring. Ethiopia has submitted a proposal for IAEA technical cooperation support to STEP for 2014–15, and is seeking financial support from a variety of international organizations. Additionally, the Agency worked with counterparts in June 2013 to finish drafting a proposed long-term national strategy for the nationwide eradication of tsetse flies, with the SIT included as a component of the plan. The plan has been submitted to the Ethiopian Ministry of Science and Technology and to the Ministry of Finance and Economic Development for review.

13. To date, area-wide activities in Ethiopia in support of resolution GC(56)/RES/12.A.3 have resulted in the suppression of *Glossina pallidipes* tsetse populations over approximately 10 000 km<sup>2</sup> of the Southern Rift Valley, thereby protecting livestock from trypanosomosis infection. The resulting substantial reduction of the T&T problem has already permitted an increase of productive livestock and opened up opportunities for sustainable agricultural and rural development, benefitting thousands of farmers. To ensure that these gains are preserved, the Agency in the past year provided Ethiopia with a senior expert who assisted with the planning and implementation of field activities designed to keep the tsetse population under control.

14. Collaborators in Uganda have made progress with the standardized collection and processing of field data relevant to the T&T problem. Tsetse suppression activities are under way in parts of the *G. f. fuscipes* belt in the country. As the STEP mass-rearing facility in Ethiopia is in a position to produce substantially more sterile male flies of this species than are required for the SIT operations in the STEP project area, the Agency facilitated a workshop involving the national PATTEC coordinators of Ethiopia and Uganda in Kampala, Uganda, 17–21 May 2013, to plan an SIT feasibility demonstration project for a small pilot area on the Kalangala Islands in Lake Victoria in Uganda. These

developments demonstrate the feasibility of having regional sterile male production facilities that are cooperatively shared and supported by Member States.

15. Counterparts in Chad shared with various partners a strategic document on the programme for the eradication of trypanosomiasis and tsetse flies in Southern and South-Eastern Chad, to which the Agency provided technical feedback. This document is expected to provide a basis for future cooperation between Chad and the Agency in addressing the T&T problem.

#### **B.4 Support for the Planning and Implementation of SIT Activities in Western and Southern Africa**

16. The Agency continues to make use of funding provided by the USA through the Peaceful Uses Initiative (PUI) in support of a project entitled “Contributing to Agricultural Development in West Africa through the Control of Tsetse Flies and the Trypanosomiasis Problem”. The funding is being used to validate field methods developed by the IPCL in the framework of the Agency’s coordinated research projects (CRPs) in support of a tsetse SIT project in Senegal and Burkina Faso. Activities include the refinement of tsetse mass rearing techniques, the long distance transport of tsetse pupae, ground and aerial release systems for sterile male tsetse flies and the provision of other support to tsetse SIT operations in West Africa. A commercial gyrocopter was adapted to carry out the project’s first test releases in Senegal, which showed positive results in terms of sterile male survival and dispersal. The project is expected to benefit several AU-PATTEC tsetse control and eradication programmes in Africa in contributing to agricultural development and food security.

17. The above complement funding under the national and regional TC projects SEN/5/033 and RAF/5/064, which aim at eradicating a tsetse population (*Glossina palpalis gambiensis*) from the Niayes region in Senegal. In the past year, the project progressed towards implementing operational suppression and eradication activities in most parts of the project area, including completed trial ground releases in four different ecological zones, and the results have been encouraging. A quantitative assessment of the socio-economic impact of these activities indicated that farmers located outside the tsetse area produced 38% more milk and sold 2.8 times more animals than farmers that are located in the tsetse area. This translates into an annual economic benefit of 900 million CFA francs (€1.37 million).

18. Making use of data generated from detailed entomological monitoring, an efficient strategy for aerial releases of sterile male flies is being developed. Suppression of the tsetse population in the area of Kayar in Senegal using insecticide impregnated screens was completed and followed by operational ground releases of sterile males. Weekly shipments of sterile male pupae from Burkina Faso to Senegal were continued throughout 2012. Efforts were made to improve the handling and transport conditions of the pupal shipments, which resulted in improved quality of the male flies. Standard quality control protocols for the shipment of pupae have been put in place. Remote sensing and land cover maps were used in the Pout/Sebikotane area in Senegal to deploy more than 1200 insecticide impregnated traps for the suppression of the tsetse population. This was complemented with insecticide pour-on treatment of more than 2900 resident cattle as an additional method to suppress the fly population. A new aerial release machine for chilled adult releases was developed, tested and delivered to the project in Senegal, and is now being considered for use in Ethiopia as well. An introgressed strain (crosses using Burkina Faso females and Senegal male flies) was developed and transferred from the IPCL to the Slovak Academy of Sciences for colony expansion. These flies will be used to complement sterile male flies supplied by the Burkina Faso facility.

19. Following its phased and conditional planning and implementation approach, the Agency continued to support South Africa and Mozambique in developing a strategy for eradicating *Glossina austeni* and *G. brevipalpis* from the KwaZulu-Natal province in South Africa and the Matutuini

Province of southern Mozambique. Work at the Onderstepoort Veterinary Institute in South Africa focused on the radiation biology of *G. austeni* and *G. brevipalpis*, and the effect of various handling methods on the mating behaviour and the competitiveness of the male flies were studied. During the past year, field surveys were conducted in areas of KwaZulu-Natal where there was a lack of sufficient entomological data. Additional entomological and veterinary baseline data were also collected in Matutuini. Agency expert missions were carried out to assist counterparts with the management of collected data and with the development of land cover maps of the target area that indicate probable habitats for certain tsetse fly species.

## C. Conclusion

20. 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 sterile insect technique (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 establishment of appropriate management structures to deal effectively with such complex and logistically demanding programmes, the development of the SIT for different species with a different biology, and the adaptation of 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 tsetse, 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. A new facility in Bobo-Dioulasso, Burkina Faso is expected to begin operations this year, but the procurement of needed equipment has been slowed by delays in the release of some of the allotted funds.

# Use of Isotope Hydrology for Water Resources Management

## A. Background

1. At its 55th session in September 2011, the General Conference, through resolution GC(55)/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 through appropriate programmes, by increased collaboration with national and other international organizations dealing with water resources management; to continue to help Member States obtain easy access to isotopic analysis by upgrading selected laboratories; to expand work on the IAEA Water Availability Enhancement project (IWAVE)<sup>2</sup>; 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(55)/RES/12 to the Board of Governors and to the General Conference at its 57th session.

2. Water issues continue to feature prominently in the Post-2015 Development Agenda that will succeed the decade dedicated to the Millennium Development Goals (MDGs). The currently proposed target in the Post-2015 Agenda is called the “Sustainable Development Goal for Water”, which highlights all relevant dimensions of water including rural and urban supply, food and agriculture, energy and ecosystems, among others. As was the case with the MDGs, the emerging new agenda strongly emphasizes the importance of improved understanding and quantification of water resources, which continue to be the primary objectives of the Agency’s water resources programme.

## B. Progress since the 55th Regular Session of the General Conference

### B.1. Cooperation with Partners and the IWAVE Project

3. A number of activities were implemented to raise awareness of the Agency’s role in promoting the use of isotopes for water resource management. Under the umbrella of UN-Water, which continues to foster collaboration and coordinate the activities of different UN agencies working on water issues, including the IAEA, the Agency participated in the 6<sup>th</sup> World Water Forum in Marseille, France, in March 2012. For the first time at this event, all Agency colleagues with activities related to water participated to present work being done in a broader range of areas, including water resource assessment, soil and water management, marine ecosystem monitoring and assessment, and energy. Along with the International Association of Hydrological Sciences and UNESCO, the IAEA co-sponsored the HydroPredict2012 Conference held in Vienna in September 2012, which was

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<sup>2</sup> The three Member States currently participating in IWAVE are Costa Rica, Oman and the Philippines.

organized by the University of Natural Resources and Life Sciences (BOKU). The conference focused on scientific and technical tools for assessing and mitigating the impacts of climate change on water resources, and on policy responses to reduce vulnerability and increase water resource resilience. The Agency also sponsored the 21st International Radiocarbon Conference, held in Paris in July 2012, which focused on emerging uses of carbon-14 as a powerful tracer of flow and transport processes in hydrology and other fields. The Agency developed a new series of isotope hydrology outreach materials to promote better understanding of how isotope methods can help Member States address their water resources problems. To raise awareness among the technical community, information booths were established at the 6<sup>th</sup> World Water Forum in Marseille and the annual European Geosciences Union (EGU) 2012 meeting in Vienna.

4. The IWAVE project, supported by Peaceful Uses Initiative (PUI) funds contributed by the Government of the United States of America, assists Member States in increasing the availability and sustainability of freshwater using scientifically based, comprehensive assessments of national water resources. Specifically, the project strengthens national capacities for collecting, managing and interpreting water resources data using advanced techniques. This work includes continuing cooperation with the UNESCO-IHE Institute for Water Education, which provides training for complementary conventional techniques as part of IWAVE. The Agency held a side event describing the project's progress during its 56th regular session of the General Conference in September 2012. Ministerial representatives from Costa Rica, Oman and the Philippines highlighted achievements in their countries and shared their experiences.

5. In Costa Rica, a new initiative by the Ministry of Environment, Energy and Telecommunications to establish comprehensive water resource management policies and capacities at the national level, known as the "Agenda for Water", was initiated with the involvement of IWAVE and major national stakeholders. Currently, this effort is focused on creating the institutional and legal framework necessary to support national water assessment and management. In Oman, work focused on completing the third assessment of national monitoring networks used to measure the usage and quality of groundwater resources. This involved substantial field work, as well as upgrading of the monitoring networks and national hydrological databases. The methods and tools applied in Oman can also be applied in other arid and semi-arid regions, which tend to be heavily dependent on groundwater resources. Also through the IWAVE project, the Agency assisted the Philippines in identifying the main gaps in the data and scientific capacity required to provide a sound assessment of surface and groundwater systems, as well as the specific investments needed to fill those gaps. The results of this work were summarized in a publication that will serve as a strategic document guiding future IWAVE activities in the country.

6. Field studies to collect hydrological and isotope data are in progress in selected areas in the three IWAVE Member States. Regarding the project's potential expansion, steps are being taken to expand IWAVE to other Member States by including its methodology in new regional technical cooperation (TC) projects in the upcoming TC project cycle. Additionally, preliminary activities begun this year in India, and scheduled to begin in Mexico in October, may result in these Member States following the approaches adopted in the IWAVE initiative.

7. The Agency cooperated with the Japan International Cooperation Agency (JICA) and the Ethiopian Water Technology Centre in jointly organizing a three-week, PUI-funded training workshop on isotope hydrology. The workshop emphasized hands-on training in practical hydrological issues, thereby facilitating the integration and expansion of the use of isotope hydrology tools in many on-going studies on water resources assessment in African Member States. The Agency is currently planning to participate in a similar workshop to be organized by JICA in Myanmar in

2014. Additionally, the Agency is working with the University of Vienna to prepare e-learning hydrology modules in which the Agency will provide input regarding isotope hydrology, and the university will address complementary non-nuclear techniques.

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

8. More than 25 scientific articles and technical publications on different aspects of isotope hydrology were published by Agency staff members describing new methods for isotope data collection and interpretation. These include a new interpretation of the factors controlling isotope contents in precipitation at global and regional scales, thereby overcoming the inconsistencies and limitations of previous approaches. Other work dealt with the development of a simplified graphical interpretation of carbon-14 data in groundwater, which will provide Agency counterparts with more precise data to better assess groundwater flow and transport. Another publication dealing with the environmental impact of accidental releases of radioactivity resulted from the Agency's evaluation of the tritium content of precipitation in Japan following the accident at the Fukushima Daiichi nuclear power plant.

9. In 2012, assessments of groundwater resources were carried out using noble gas dating tools in Argentina, Brazil, Costa Rica, Thailand and Vietnam. In the case of shallow groundwater systems, the studies demonstrated how tritium/helium-3 dating and other noble gas dating techniques can be used as powerful tools to assess groundwater dynamics, recharge processes and vulnerability to pollution. In the case of large sedimentary basins, the dynamics of very old groundwater were assessed following the development of new tools based on long-lived radionuclides, such as krypton-81 and chlorine-36, and other isotopes of noble gases, such as helium-4. In collaboration with Argonne National Laboratory in the United States of America, the first measurements of krypton-81 in very old groundwater were conducted in 2012 in the Guarani transboundary aquifer, where ages above 500 000 years were found in the deepest groundwater. This new technique is the first to enable accurate dating of groundwater of this age, and the Agency is already working to facilitate access by Member States to this technique. The information gathered in this study has important implications for understanding and modelling water flow and transport in such systems, which include large aquifers in arid and semi-arid regions, and for water management in similar systems.

10. The Agency has substantially built upon the progress previously made in facilitating access to isotope analyses for isotope hydrology studies in Member States. The use of laser-based stable isotope analysers in Member States has greatly increased since the Agency became involved in helping to develop and transfer this technology in 2008. In the last two years, these instruments have achieved mainstream status as the preferred analytical tool for measuring oxygen-18 and deuterium in water samples. There are now 45 Member State laboratories using these instruments as a result of Agency assistance, as compared to 23 Member State laboratories in 2011, and the delivery of additional units is planned for the upcoming 2014–2015 TC project cycle. In the last two years, the Agency organized four one-week training courses on the installation and operation of such instruments, involving approximately 25 participants. The Agency provides additional assistance through intercomparison and proficiency testing, and the organization of laser analyser users' meetings that offer exchanges of experience and best practices as well as assistance in improving the overall performance of these analytical facilities. Moreover, the Agency, in collaboration with the US Geological Survey, recently launched the new Laboratory Information Management System (LIMS), a cost-free isotope hydrology software tool that helps users of laser-based analysers to process their stable isotope data more accurately and efficiently.

11. A new, low cost and compact system to pre-concentrate low levels of natural tritium in water samples was developed and built at the Agency's Isotope Hydrology Laboratory, and is being tested for potential transfer to interested Member States through the TC programme. In addressing this need for the measurement of tritium, which is required for the accurate dating of younger water sources, the enrichment system has the added advantages of reducing installation and operational costs as well as space requirements. This system will greatly expand Member States' access to the fundamental set of isotopes used in hydrology and will help increase the efficiency of their technical cooperation projects.

12. The fourth proficiency test for laboratories engaged in the routine analysis of the hydrogen and oxygen stable isotope composition of water samples was completed at the end of 2011. More than 135 laboratories from 53 Member States submitted their isotope datasets to the Agency and had their performance assessed. The results of the exercise helped these laboratories to identify analytical problems and evaluate their overall performance. A similar proficiency test involving isotope hydrology laboratories that measure low-level tritium contents in natural waters is in progress and expected to be completed by the end of 2013.

13. Several coordinated research projects (CRPs) were completed or active during the last two years. One CRP entitled "Quantification of Hydrological Fluxes in Irrigated Lands Using Isotopes for Improved Water Use Efficiency", which was completed in 2011, focused on the development of isotope methods that can be applied to measure water use efficiency in irrigated lands, as well as the large effect irrigation practices have on water use efficiency and the potential transport of contaminants to groundwater. Another CRP entitled "Isotopic Techniques for the Assessment of Hydrological Processes in Wetlands", which was also completed in 2011, evaluated integrated isotopic and conventional hydrological tools that can be used to assess the role of groundwater in maintaining the supply of water, dissolved salts and nutrients to wetlands. As part of future capacity building activities, these CRPs will contribute to improved irrigation practices and groundwater quality in Member States, and more sustainable management of wetland areas and resources. Through an ongoing CRP on tritium/helium-3 dating, the Agency is continuing its efforts to provide Member States with access to noble gas age dating tools for groundwater. The tools being evaluated in the CRP are showing excellent progress in estimating groundwater age in a variety of hydrogeological settings, and the Agency is now preparing guidelines for the transfer of these tools via TC projects.

14. In Africa, collaboration through an Agency TC project with the joint programme managed by the United Nations Development Programme (UNDP) and the Global Environmental Facility (GEF) saw isotope hydrology play a pivotal role in filling gaps in scientific data needed for the preparation of the Strategic Action Programme (SAP) for the Nubian Sandstone Aquifer. This project benefits Chad, Egypt, Libya and Sudan. A database and three-dimensional model of the aquifer were developed that will be available to the Joint Authority for the Study and Development of the Nubian Sandstone Aquifer System, the transboundary management and coordinating body established by the four Nubian Member States. The four Member States have agreed to sign the SAP in 2013, and a new TC project to implement the programme is being planned with UNDP-GEF.

15. In 2012, the Agency launched a new TC project entitled, "Integrated and Sustainable Management of Shared Aquifer Systems and Basins of the Sahel Region", which covers five aquifer systems and 15 African countries (Algeria, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Gambia, Ghana, Guinea Bissau, Mali, Islamic Republic of Mauritania, Niger, Nigeria, Senegal and Togo). The project aims to strengthen human capacities and analytical infrastructure for the application of conventional and isotope hydrology techniques in the participating countries to promote the development of integrated management strategies that will support the

sustainable and joint management of shared groundwater resources in the Sahel region. The project has progressed well, with several key activities being implemented, such as the procurement of field equipment and sampling items to support project activities; the training of national experts in the operation of laser isotope equipment and sampling techniques; advisory missions to support aquifer-wide coordinated activities and to guide national activities, including the development and updating of field work plans and sampling plans; and the analyses of water samples. The next step in the project will be for the participating Member States to develop a strategic action programme based on the hydrogeological characterisation of these major transboundary aquifers.

16. In Latin America, a regional TC project has provided Argentina, Costa Rica, Ecuador, Peru and Uruguay with equipment and services to upgrade and enhance capacities for applying isotopic tools for the integrated management of coastal aquifers. Training was provided through fellowships, scientific visits, workshops and symposia focused on isotope hydrology, hydrogeology, hydrochemistry and other topics. Hydrogeological databases and vulnerability charts were also developed for the management of the project. Another regional project is helping 16 Member States use isotopes to assess intensively exploited aquifers, thereby supporting the development of sustainable resource management strategies. Collaboration among Member States has included the exchange of technical and human resources capabilities, and training activities are strengthening participants' capabilities in the use of isotopic techniques for the evaluation of groundwater dynamics.

17. In the Asia and the Pacific region, an TC project under the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA) is helping 12 Member States to build their capacities to apply isotope techniques to investigate groundwater dynamics and recharge rates in support of sustainable groundwater resource management. This has led to the establishment of an expanded database of isotopes and chemical constituents that will support the understanding and application of isotopic techniques by different end users.

18. In addition to these regional projects, support was provided through national TC projects to upgrade laboratory facilities and strengthen capacities in the application of isotope hydrology techniques in Algeria, Cambodia, the Dominican Republic, Ecuador, Eritrea, Georgia, Iraq, Madagascar, Nigeria, Pakistan and Tunisia. In addition, national TC projects supported hydrological assessments of groundwater resources that will contribute to improved national groundwater resource management strategies in Georgia, Kuwait, Paraguay and Qatar.

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

19. Old groundwater, i.e. water stored in geological formations for periods ranging from approximately a thousand to a million years, is an excellent archive of the water cycle in past climate regimes. In early 2013, the Agency published the monograph *Isotope Methods for Dating Old Groundwater*, which provides theoretical and practical information for using a variety of isotope tracers in different hydrogeological environments specifically for dating old groundwater. The methods, findings and conclusions presented in this publication will provide practising groundwater scientists with new tools and techniques to carry out more advanced and detailed assessments of older groundwater that are beyond the reach of current tools and techniques. This will contribute to greater confidence in groundwater assessments and the development of management strategies in changing climate regimes, as well as to better assessments of the impact of climate change on aquifer systems.

20. The expansion of the Agency's Global Network of Isotopes in Precipitation (GNIP) to new monitoring sites continues, with some of the stations reaching 50 years of continuous operation. Responding to a growing user demand for raw global data and maps for visualizing isotope data, the Agency significantly expanded operations for GNIP and its similar network for rivers, the Global

Network for Isotopes in Rivers (GNIR), through the establishment of new monitoring stations and collaboration with equivalent national networks, research institutes and isotope hydrology laboratories. The Agency remains the principal repository of isotope data generated by these networks, the importance of which continues to grow due to the increasing demand for globally distributed isotope data to support hydrological, ecological and other environmental studies, including those for understanding the impacts of climate change on land use and water resources. As isotopes provide a link between hydrology and climatology, the climate modelling community is the second-largest group of users of the Agency's isotope hydrology databases. This group includes both palaeoclimatologists and climatologists who study atmospheric circulation to increase the predictability and understanding of climate variations, which in turn helps them to model future climatic changes and inform policy responses to these changes. The Agency has worked to facilitate greater Member State access to raw and processed data on isotopes in precipitation, surface and groundwaters to support studies incorporating isotope data into assessments of the impact of climate change on water resource availability. These efforts include the development of a new internal database activated in January of 2013, and a new online platform linked to this database that will be active by the end of the year.

21. Isotope mapping continued to be a strong focus during the period under review. As data on isotopes in precipitation are available only in the form of point measurements, there are substantial gaps, both temporal and spatial, that require the estimation of the isotope contents of meteoric waters (precipitation, rivers, lakes and shallow groundwater) at a global scale. To address this need for processed isotope data, the Agency has developed a new method for the interpolation of data on isotopes in precipitation. This method, based on the use of regionally defined climate models, has resulted in the production of isotope maps that are more accurate than those that were previously available. In addition, the Agency's new method enables the production of isotope maps at variable time and space intervals (for example, monthly, growth season, or yearly at regional or local scales). A variety of these new isotope maps are accessible online to scientists and users of environmental isotopes in other disciplines.

# Modernization of the Agency's Nuclear Applications Laboratories in Seibersdorf

## A. Background

1. The General Conference at its 56<sup>th</sup> regular session responded positively to the Director General's call for the modernization of the laboratories of the Agency's Department of Nuclear Sciences and Applications (NA laboratories) in Seibersdorf with resolution GC(56)/RES/12.5. The General Conference noted the indispensable nature of the NA laboratories in Seibersdorf in responding to three pillars of Member States' needs with regard to technical assistance: research and development (R&D), capacity building and technical services. Member States fully supported the continuation of the mandate and the role of the NA laboratories in Seibersdorf in this regard within the strategic direction of the Department of Nuclear Sciences and Applications, and recognized the laboratories' urgent need for modernization given the evolving range and complexity of Member States' growing demands for increasing technological development. The General Conference requested the Secretariat to develop a detailed strategic plan for the modernization of the laboratories based on a vision of the role of the eight NA laboratories in Seibersdorf in meeting the current and future needs of Member States. The General Conference requested the Director General to report on progress made in implementing resolution GC(56)/RES/12.5 to the Board of Governors and to the General Conference at its 57th session.

## B. Progress since the 56th Regular Session of the General Conference

2. During the last year, steady progress has been made in preparing for the modernization of the NA laboratories in Seibersdorf. In November 2012, a ceremony was held with Member State representatives to commemorate the 50th anniversary of the Seibersdorf laboratories, which provided the opportunity to highlight the history and current activities of the laboratories, and the need for their modernization.

3. A new €2.6 million per year capital investment project to support the modernization initiative was included in the Regular Budget capital investment plan in the draft 2014–2015 Programme and Budget. According to preliminary cost estimates, additional needs of €5.4 million remain unfunded in each of these two years. The project is currently planned to be completed in 2017 with funding requirements of approximately €7.5 million in each of the years 2016 and 2017. More detailed planning for the modernization initiative is being conducted during 2013, including the development of specific technical assessments that will be the basis for comprehensive cost estimates.

4. As part of the Financial and Administrative Workshops held in April and May 2013, a briefing was provided to Member States to present initial elements of this new capital investment project.

5. Extensive consultations have been held with staff members of the Enhancing Capabilities of the Safeguards Analytical Services (ECAS) project to learn from their experience in initiating, planning and implementing this capital investment project on the adjacent part of the Agency's Seibersdorf site.

6. In April 2013, an NA Laboratory Coordinator position was created that will have the initial task of facilitating the preparation and coordination of the modernization project. The establishment of a project office with its support team has been initiated in Seibersdorf. Additional positions are planned for which extrabudgetary contributions are being sought.

7. A draft modernization concept was developed and presented to the Director General's Standing Advisory Group on Nuclear Sciences and Applications (SAGNA) in June 2013. SAGNA made the initial recommendation for the modernization of the NA laboratories in Seibersdorf in June 2012, and at its meeting this year provided advice that is being considered in developing a more strategic and detailed draft concept. The document presents a detailed approach for positioning the laboratories appropriately for the future, where they have comparative advantages, with the necessary infrastructure and equipment, while additionally outlining the next steps in implementing the project.

8. Steps have been taken to raise awareness of the services provided by the NA laboratories in Seibersdorf and the needs for modernization. A growing number of visitors from Member States have taken tours of the laboratories and initial discussions have been held with some Member States concerning potential extrabudgetary support. Partnership opportunities are also being assessed, including with non-traditional partners, such as, non-governmental organizations (NGOs), foundations, the private sector and other institutions.

## **C. Actions in Progress**

9. Technical assessments have been initiated with external architectural and planning specialists to study the options for enhancing the infrastructure of the NA laboratories in Seibersdorf based on existing conditions, regulatory norms, existing needs and future requirements. These assessments, which should be complete in the fourth quarter of 2013, include the evaluation of options for the refurbishment of existing space as well as the addition of needed space in line with the overall development of the Seibersdorf site.

10. Budget planning is being conducted based on the new Regular Budget modernization project that will have capital investment funds available as of 1 January 2014.

11. A resource mobilization strategy is being developed that includes plans to recruit a resource mobilization officer by the fourth quarter of 2013. This strategy will be supported by dedicated communication activities for specific audiences and purposes.

## **D. Future Actions**

12. A detailed strategic plan for the modernization project, including updated cost estimates, timelines, options and design concepts, will be presented for Member States' review by early 2014.

13. Targeted stakeholder engagement activities will be undertaken to promote and gain support for the modernization initiative. For example, efforts to mobilize resources for specific project elements, such as individual buildings and pieces of equipment, will be carried out.

14. Briefings to Member States will be provided on a regular basis to inform them of the Secretariat's progress as well as to receive guidance on future actions.

# Nuclear Energy Activities

1. This Annex summarizes highlights of Agency activities not covered in Annexes 6 to 9.
2. The Agency annually updates its low and high projections for the global growth in nuclear power. The 2012 low projection update shows growth in nuclear power capacity of 23% by 2030 and the high projection shows 100% growth by 2030. The growth rates are slower than what was previously projected in the assessment undertaken in 2011, particularly for the low projection. Most new nuclear power reactors planned or under construction are in Asia, particularly in China and India. Additionally, the Republic of Korea and the Russian Federation plan significant expansion. The 2013 projections are due to be released in the very near future and are not expected to be significantly different from those published in 2012.
3. For the 18th Conference of the Parties (COP18) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Doha, Qatar, between 26 November and 7 December 2012, the Agency published *Climate Change and Nuclear Power 2012*, which emphasizes the importance of nuclear power, in conjunction with hydropower and other renewables, in reducing CO<sub>2</sub> emissions in the electricity sector. The main conclusion is that it will be difficult for the world to achieve the twin goals of ensuring sustainable energy supplies and curbing greenhouse gases without the use of nuclear power to generate electricity.
4. The International Ministerial Conference on Nuclear Power in the 21st Century took place from 27 to 29 June 2013 in St Petersburg, Russian Federation. The conference provided a forum for policy-makers and experts to discuss and take stock of the role and viability of nuclear power in sustainable development, including climate change mitigation, and in meeting the growing global requirements for electricity. The status and prospects of nuclear power for the future, including the importance of nuclear safety and security as necessary prerequisites for nuclear power, were also a focus, as was consideration of various technical aspects involved in the development of nuclear power.
5. In March 2013, the Agency organized an International Conference on Fast Reactors and Related Fuel Cycles in Paris, France. The conference focused on strategic and technical options to deploy fast reactors operating with a closed fuel cycle in a safe, proliferation resistant and economic manner.
6. At the second meeting of the Nuclear Operating Organization Cooperation Forum held in September 2012, more than 70 delegates and other participants from Member States met to share operating experience and management strategies to help strengthen the effectiveness of operating organizations. The important role of operating organizations and other stakeholders in the development of safe and sustainable nuclear power plants (NPPs) was recognized and recommendations to increase the Agency's interactions and strengthen its cooperation with NPP operators and other stakeholders in the nuclear industry were made.
7. In 2013 the Department of Nuclear Energy was involved in the organization of the International Experts' Meeting on Decommissioning and Remediation after a Nuclear Accident (28 January–1 February 2013 in Vienna) and the International Experts' Meetings on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant (21–24 May 2013 in Vienna).
8. The Agency continued to maintain and update a number of databases that serve the nuclear community and other stakeholders. Several databases are managed by the Department of Nuclear Energy, including: the Power Reactor Information System (PRIS), containing performance and technical design data on nuclear power reactors in operation, under construction or those being

decommissioned; the Net Enabled Waste Management Database (NEWMDB), that contains information on national radioactive waste management programmes, radioactive waste inventories, radioactive waste disposal, relevant laws and regulations, waste management policies, and plans and activities; and the Research Reactor Ageing Database (RRADB) that 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 the development and implementation of comprehensive ageing management programmes.

9. An Independent Engineering Review of Instrumentation and Control (I&C) Systems (IERICS) mission was conducted at the All-Russian Scientific Research Institute for Nuclear Power Plant Operation (VNIIAES), Russian Federation, in December 2012 to review the computerized process control system of the AES-2006 NPP. The mission concluded that extensive engineering work of high quality had been performed to develop the advanced I&C system, and that, in general, the reviewed areas met the requirements of the relevant sections of *Instrumentation and Control Systems Important to Safety in Nuclear Power Plants* (IAEA Safety Standards Series No. NS-G-1.3).

10. The Agency supports Member States in enhancing the operational safety of existing NPPs. In October and December 2012, Agency experts participated in an international engineering review of reactor pressure vessel material at the Doel-3 and Tihange-2 plants in Belgium. Recommendations included that the licence holder, Electrabel, carry out a confirmatory test programme before the next refuelling outage as well as an ultrasonic testing (UT) inspection during the next refuelling outage, enabling the validation of the overall safety case performance.

11. Since it was established in 2010, the Integrated Nuclear Infrastructure Group (INIG) has continued to strengthen Agency support for Member States considering, or committed to, the introduction of nuclear power. The work of INIG integrates resources and competencies from across all of the Agency's programmes and covers a wide range of technical topics, including workforce planning, human resource development and supporting the development of competent regulatory systems. The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) has, since its creation in 2000, provided a robust methodology for the comprehensive assessment of proposed and planned nuclear energy systems and it continues to improve understanding in Member States of technical innovations and institutional features that support a transition to sustainable nuclear energy systems. Work being carried out by INPRO and INIG is closely coordinated in order to maximize the benefit for newcomer Member States and further information concerning recent activities is reported in Annexes 7 and 9 respectively.

12. Since September 2012, almost 200 experts from 30 countries were trained in interregional and regional courses on uranium geology and exploration. These were held in China, Madagascar, Nepal, the United Republic of Tanzania and Venezuela. Additionally, at a meeting in Vienna on the origin of sandstone uranium deposits, experts from 35 Member States discussed recent advances in understanding the origin of sandstone uranium deposits to assist efforts in exploration, production optimization, and in the safe management of mine wastes and remediation.

13. Advances in the evaluation of thorium and uranium deposits were discussed in October 2012 at an interregional workshop, held in Lisbon, Portugal, on the evaluation of uranium and thorium resources. The Workshop was organized jointly by the Agency, the Ibero-American Programme of Science and Technology for Development and the United Nations Economic Commission for Europe. Experts from 30 countries and two international organizations discussed initial experience in using the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (2009) for uranium resource reporting and for mapping the full life cycle of uranium mining, from exploration to end of mine life remediation.

14. An IAEA expert team was invited by Japan to review efforts to plan and implement the decommissioning of TEPCO's Fukushima Daiichi nuclear power plant. The 13-person team began work in April 2013 when they visited the nuclear accident site to collect first-hand information on Japan's plans to decommission the facility. Earlier, the team held two days of meetings in Tokyo with officials from the Ministry of Economy, Trade and Industry (METI) and the Tokyo Electric Power Company (TEPCO). The team also met with officials of the Nuclear Regulation Authority.

15. The Agency conducts training courses on nuclear knowledge management to reach broader audiences and supports networks that disseminate information in this field. During the first part of 2013, it held Nuclear Energy Management (NEM) Schools in March in Texas, USA; in May in Tokyo, Japan, and in July in Trieste, Italy, in cooperation with the International Centre for Theoretical Physics (ICTP). To support sustainable and high quality nuclear education, the Agency continued to facilitate three important regional educational networks, the Asian Network for Education in Nuclear Technology (ANENT), the AFRA Network for Education in Nuclear Science and Technology (AFRA-NEST), and the Latin American Network for Education in Nuclear Technology (LANENT).

16. The Agency continues to provide technical assistance to support the establishment of non-high enriched uranium (HEU)-based molybdenum-99 production capabilities in interested Member States. This has included assistance to Egypt to prepare for the production and marketing of molybdenum-99 from low enriched uranium (LEU). In addition, fact finding missions were undertaken to Romania in June 2013 and to Peru in July 2013 to support the development of molybdenum-99-9 production infrastructure. A report of the small-scale non-HEU molybdenum-99 production CRP is due to be published.

17. A training course to assist Member States interested in initiating new research reactor projects or improving the utilization of existing research reactors was held in 2012. The six week course, organized by the Eastern European Research Reactor Initiative and supported by the Agency, was conducted at research reactors in Austria, the Czech Republic and Slovenia. Since this course was established in 2009, 44 students from Africa, Asia, Europe and Latin America have been trained.

18. To provide a peer review service on research reactor operational performance, and complementing Integrated Safety Assessment of Research Reactors (INSARR) missions, the Agency established the Operation and Maintenance Assessments for Research Reactors (OMARR) service in 2012. The first OMARR review mission was concluded in December to the National Institute of Standards and Testing in Maryland, USA. A second OMARR review mission was undertaken in March 2013 to the TRIGA research reactor at the University of Pavia, Italy.

19. Reports on two CRPs were published as *Modelling of Transport of Radioactive Substances in the Primary Circuit of Water-Cooled Reactors* (IAEA-TECDOC-1672) and *Fuel Modelling at Extended Burnup (FUMEX-II)* (IAEA-TECDOC-1687). These addressed the analysis of in-core radioactivity transport and prediction of fuel behaviour by computer simulation, focused on the improvement and verification of computer codes developed in different Member States. Both CRPs are part of a series of Agency projects on fuel modelling, with a focus on safety-sensitive issues of behaviour of in-core fuel and structural materials in accident conditions

20. The Agency developed further the Irradiated Fuel Management Advisory Programme (IFMAP), and the first IFMAP mission was conducted in March 2013 to the Spent Fuel Dry Storage Project of the Atucha I NPP in Lima, Argentina. An international team of experts reviewed the project's technical and planning documentation, suggesting improvements to the conceptual engineering, and issued a report covering technical and organizational aspects, including recommendations for interaction with the regulator or technical improvements like an enhanced drying procedure. Backup

options in case of delays, including the temporary use of the spent fuel pools at the adjacent Atucha II NPP, expected to start operation in 2013, were also discussed.

21. In May 2013, 17 participants from 10 States and the European Commission attended the second Research Coordination Meeting of a CRP on spent fuel performance assessment and research (SPAR-III), held in Charlotte, USA. In addition to exchanging information and experience on a range of activities in support of spent fuel storage, the participants focused on the effect of long term storage and handling of fuel during spent fuel retrieval. The effects of the reorientation of hydrides on the properties of zircaloy cladding were discussed in detail and the final RCM has been scheduled for November 2013 in Korea.

22. A compilation of updated information on experience with the manufacturing technology of nuclear fuels for power reactors and research reactors was published as *Experiences and Trends of Manufacturing Technology of Advanced Nuclear Fuels* (IAEA-TECDOC-1686) in 2012.

23. The Agency continued to assist Member States in training and capacity building in radioactive waste management, including through the activities of the three networks which are directly concerned with these issues: the Underground Research Facilities Network (URF Network), dealing with geological disposal of high level waste and long-lived intermediate level waste; the International Low Level Waste Disposal Network (DISPONET), dealing with low level waste disposal; and the International Network of Laboratories for Nuclear Waste Characterization (LABONET), dealing with waste characterization. Workshops and Technical Meetings were organized on a range of topics, which included: policies and strategies for waste management (Vienna); advanced technologies for waste treatment and conditioning (Buenos Aires); predisposal waste management (Moscow); waste characterization (Brussels) and on waste acceptance procedures (France). In addition, training events were organized on stakeholder dialogue for radioactive waste disposal (Poland) and on the identification and management of uncertainty in post-closure safety assessments for repositories (Portugal).

24. Two new projects were launched by the International Decommissioning Network (IDN): the International Project on Decommissioning Risk Management (DRiMa) and Data Analysis and Collection for Costing of Research Reactor Decommissioning (DACCORD) project. The latter will utilize a software tool (CERREX) that has recently been developed by the Agency to facilitate cost estimation of decommissioning of research reactors. A global survey was undertaken jointly with the Network on Environmental Management and Remediation (ENVIRONET) (the CIDER survey) on the status of sites containing radioactive material and on factors that were constraining progress with implementation of decommissioning and remediation programmes. The publication *Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities* (IAEA Nuclear Energy Series No. NW-G-2.1) was issued.

25. The Agency's International Nuclear Information System (INIS) is operated with the collaboration of 128 States and 24 international organizations. It comprises almost 3.5 million bibliographic records and more than 314 000 full-text non-conventional publications, making it the Agency's largest document database. It is fully indexed and searchable on the Internet using the INIS Collection Search (ICS), a Google based web application developed originally by the Agency in 2011. A new version of ICS that integrates the various INIS databases was implemented in 2012. Over 90 000 bibliographic records from the IAEA Library catalogue were incorporated into the INIS Collection in 2012, making the ICS a single access point for both the IAEA Library and INIS Collection.

# Producing Potable Water Economically using Small and Medium-sized Nuclear Reactors

## A. Background

1. In resolution GC(55)/RES/12.A.4, the General Conference noted: that seawater desalination using nuclear energy is technically feasible and generally cost-effective; that a great portion of the world's population will, over the next few years, face the ever-growing problems of potable water shortages; that a number of Member States have expressed interest in activities relating to seawater desalination using nuclear energy; that several projects in some States have successfully been demonstrated; and that the activities on nuclear desalination carried out by the Agency are appreciated.

2. The General Conference requested the Director General to continue consultations and interactions with interested Member States, the competent organizations of the United Nations system, regional development bodies and with other relevant intergovernmental and non-governmental organizations on activities relating to seawater desalination using nuclear energy. The General Conference also requested the Director General, subject to the availability of resources, to (a) develop a report that defines all the aspects for a technical and economic feasibility study on seawater desalination including cogeneration options (e.g. electricity generation, seawater desalination, hydrogen production), and (b) hold a workshop to discuss issues concerning nuclear desalination and water management in NPPs. The General Conference requested that the Director General note the high priority given by interested Member States to the nuclear desalination of seawater in the process of preparing the Agency's Programme and Budget, and to report on progress to the Board of Governors and to the General Conference at its 57th session. This report responds to that request.

## B. Activities of the Agency

3. The Agency's activities on seawater desalination using nuclear energy are conducted largely within the framework of the Technical Working Group on Nuclear Desalination (TWG-ND) and the Agency responds to the recommendations of that group. The TWG-ND met for the third time in January 2013. Recommendations addressed, inter alia, enhancing the scope of the TWG-ND to better respond to the challenges of integrated water resources management in nuclear facilities and issues of public perception of nuclear desalination efforts. It was noted that effective responses could be achieved through the promotion and increased use of Agency tools such as the recently released versions of the Desalination Economic Evaluation Program (DEEP), Desalination Thermodynamic Optimization Program (DE-TOP) and the Agency's toolkit on nuclear desalination. The TWG-ND also recommended updating the Agency's publication, *Introduction of Nuclear Desalination: A Guidebook* (Technical Report Series No. 400), to reflect lessons learned from desalination projects, especially from the retrofitting of nuclear desalination demonstration plants in India and Pakistan. Further recommended actions are for the Agency to emphasize the added value of nuclear desalination through cogeneration, encourage the launch of a coordinated research project (CRP) on the application of advanced low temperature desalination systems to support nuclear power plants (NPPs), and re-assess the economics of small and medium sized research reactors (SMRs) and large NPPs for single purpose or cogeneration nuclear desalination.

4. The CRP entitled “New Technologies for Seawater Desalination Using Nuclear Energy” was completed in 2011. Collaboration among researchers from nine Member States on various subjects related to seawater desalination using nuclear energy resulted in an effective exchange of information and the development of new models. In addition, the participants in the CRP undertook feasibility studies of desalination projects and identified potential new technologies (such as the use of heat pipes and low temperature processes for desalination) that are expected to enhance the use of waste heat from NPPs for seawater desalination. An IAEA-TECDOC publication, including the data and results of the CRP, will be published in 2014.

5. An updated version of DEEP (DEEP 5.0) was released in May 2013 with new features including a detailed cash flow analysis and summary of project financing; this analysis is beneficial for economic feasibility studies. In addition, a scenario manager screen is now included for easy analysis of results and there is an overall improvement in the interface to allow easier navigation between inputs, analysis, and results. The Agency also released an updated version of DE-TOP (DE-TOP 2.0b) with new features including a robust model to analyse cogeneration plants in energy or exergy modes; fully customizable parameters for water cooled reactors (PWR, BWR, SMRs) as well as fossil fuel plants; and a capability to analyse cogeneration systems relating to non-electric applications such as desalination, district heating or process heat for industrial applications. An updated version of the Agency toolkit on nuclear desalination, intended for Member States considering nuclear power for seawater desalination, was also released in May 2013 with many new features including the latest news on the Agency’s activities in this area.

6. The Agency organized three consecutive consultancy meetings in November 2011, December 2012 and June 2013 to produce a technical report covering all the aspects that need to be considered for a technical and economic feasibility study of seawater desalination, including cogeneration options. The technical report, *Opportunities for Cogeneration Using Nuclear Energy*, will be submitted for publication in November 2013. An additional outcome of the consultancy meetings is a technical report on the prospects for industrial applications of nuclear energy. The draft of this second report has been completed and will be published in 2014.

7. In August 2012, *Efficient Water Management in Water Cooled Reactors* (IAEA Nuclear Energy Series No. NP-T-2.6) was published. It addresses the issue of securing water for construction of NPPs (during flushing phase), for condenser cooling during operation, as well as inventory control including makeup to primary coolant system and discharge from radioactive liquid waste treatment system. The report was compiled based on the experiences, best practices and expectations for the foreseeable future of nuclear power technology. The information presented in the report is intended to clarify the technical issues, available solutions and strategies, and economic implications for nuclear power plants. Based on this report, a new Agency tool called Water Management Program in Nuclear Power Plants (WAMP) was developed and released in November 2012.

8. In November 2012, the Technical Meeting/Workshop on Management for Efficient Water Use and Consumption in Nuclear Power Plants was held in Vienna. It provided an opportunity to exchange information and good practices in water management for Member States that might be considering the deployment of NPPs, particularly in areas suffering from a lack of sufficient water resources. During the workshop, the Agency released the newly developed WAMP software and organized working sessions on its use in analysing water requirements at different NPP sites based on participants’ input. Workshop participants found WAMP to be a very useful tool for the evaluation and selection of an NPP site, especially for newcomer countries.

9. In July 2012, a Technical Meeting on Advances in Seawater Desalination using Nuclear Power was held in Vienna to exchange information that could improve the efficiency of nuclear desalination, the use of waste heat to improve the economics of nuclear desalination, use of off-peak

electricity/steam for seawater desalination, the status and maturity of novel low temperature desalination processes, and the effect of such advances on the economics of seawater desalination, both for single purpose desalination and for the cogeneration of electricity and water. In November 2012, the Agency held a national training workshop on potable water production through desalination of seawater by using the light water NPP at Bushehr, Islamic Republic of Iran. The workshop focused on raising awareness of the economic assessment, environmental issues, the use of Agency tools (DEEP, DE-TOP and the toolkit on nuclear desalination) for feasibility studies, and the benefits of seawater nuclear desalination when harnessing waste heat from light water reactors in order to apply these concepts for a successful and safe desalination project at Bushehr.

## C. Activities in Member States

10. The following paragraphs summarize the activities in Member States, based largely on reports presented at TWG-ND meetings.

11. In Algeria, a national strategy has been devised and implemented to address the country's water concerns. Seawater desalination is considered a key aspect of this strategy and the desalination programme is significant with a total capacity expected to reach  $2.5 \times 10^6$  m<sup>3</sup>/day by the end of 2015. As seawater desalination consumes a large amount of energy, and because power generation in Algeria currently depends on the use of fossil fuels, a diversification of energy sources is foreseen in the future and a study has been launched to assess the introduction of nuclear energy for the production of electricity and potable water.

12. In Argentina, the CAREM nuclear reactor is close to being licensed for construction. The National Atomic Energy Commission of Argentina (CNEA) has decided to set up a permanent group whose tasks include an analysis of the optimal coupling configuration between the desalination thermal plant and the balance of the reactor using an intermediate loop. For a cogeneration plant, the preliminary results have shown that the best electricity/water generation ratio obtained by CAREM would be suitable for a population of 70 000 people, representing a small city. The thermal efficiency of the plant would be reduced to 5-7% due to this cogeneration, which is relatively low when compared to a standalone plant solely for electricity generation. The permanent group is also considering the environmental impacts resulting from the provision of demineralized water using a cogeneration plant. The system being considered is seen as a suitable option to provide water for drinking purposes and for the reactor circuits as well. Furthermore, the CNEA Reactor Dynamics Group will collaborate on the study of transients while the nuclear desalination plant is connected/disconnected from operation, and it will also assess the economic consequences for the configurations mentioned above when considering different sites in the country.

13. In China, the national capacity for desalination reached 660 000 m<sup>3</sup>/day at the end of 2010 and the planned capacity for desalination is expected to reach  $2.2 \times 10^6$  m<sup>3</sup>/day by 2015. The development of NPPs capable of providing desalination is on the rise with more than 10 NPPs currently being built. However, until now the only NPP coupled with a desalination plant (using reverse-osmosis) is the Hongyanhe NPP. In support of the development of nuclear desalination technologies, the Dalian University of Technology has performed intensive research on multi-effect distillation (MED) desalination, including analysis of falling film evaporation, condensing in a horizontal tube, development of spray nozzles and demister and anti-corrosion measures.

14. In India, it was recognized that there is a requirement for large, medium and small size desalination and water purification units as part of an integrated water resource management plan and

nuclear desalination projects are already in regular operation. The 6300 m<sup>3</sup>/day nuclear desalination demonstration plant in Kalpakkam uses hybrid multi-stage flash-reverse osmosis (MSF-RO) technology and is coupled to the Madras Atomic Power Station. High quality distilled water produced from a MSF process is supplied for high end applications in the NPP. The rest of the water produced at the plant is supplied to a water reservoir that augments the regional water supply with additional water produced from a reverse osmosis plant. Earlier, the feasibility of a low temperature desalination plant coupled to a nuclear research reactor at Trombay was demonstrated. For the future, it is planned to integrate a 3x800 m<sup>3</sup>/day multi-effect distillation-thermal vapour compression (MED-TVC) nuclear desalination plant together with an advanced heavy water reactor. It is also planned to set up a hybrid seawater desalination plant based on indigenous reverse osmosis multi-effect distillation (RO-MED) technology. There are also ongoing research activities on the environmental aspects to be considered in the application of nuclear desalination, as well as the development of zero liquid discharge concepts. With the successful and widespread demonstration of nuclear desalination in India, there is an opportunity to provide technical training on nuclear desalination to interested Member States through the Agency's technical cooperation programme.

15. In Kazakhstan, water scarcity is increasing as water demand rises along with population growth, urbanization and higher household and industrial water usage. The past five years have seen a 57% increase in the capacity of desalination plants and there is consequently renewed interest in nuclear desalination as an option. There is also a search for new options, such as the use of radioisotope thermoelectric generators to power self-contained nuclear desalination plants with a small capacity.

16. In Pakistan, a 1600 m<sup>3</sup>/day capacity nuclear desalination demonstration plant coupled with the Karachi NPP was commissioned in January 2010. The safe operation of the nuclear desalination demonstration plant has paved the way for a larger desalination plant to be coupled with an NPP. Remineralization of product water and its use for drinking purposes has further strengthened prospects for nuclear desalination in Pakistan. In recent years, the annual per capita availability of water has been decreasing fast. The annual per capita availability of potable water was 1672 m<sup>3</sup> in 1990 and is forecast to be only 837 m<sup>3</sup> in 2025. Chronic water stress will be experienced when the supply falls below 1000 m<sup>3</sup>/year per capita. Large scale desalination plants are seen as a solution to this challenge.

17. Saudi Arabia's desalination programme is one of the largest in the world. The main challenges driving its power and desalination programme are the rapid increase in population and in water demand, high per-capita consumption, scarce natural water sources and rapid industrialization. Since the end of 2008, nine desalination plants have been built with a total capacity of 1.8 x10<sup>6</sup> m<sup>3</sup>/day. Saudi Arabia is interested in the development and introduction of a nuclear energy programme for both electrical power generation and water desalination.

18. Argonne National Laboratory (ANL) is the official representative of the USA to the Agency regarding all nuclear desalination and non-electrical nuclear energy cogeneration issues. Experts from ANL take part in the work of the standing TWG-ND. In 2012, ANL completed a study of the financial feasibility of nuclear desalination and a report was submitted to the Agency as part of an ongoing CRP on the subject. SMRs could very well catalyse the deployment of future plants dedicated to desalination, co-located desalination or other cogeneration facilities with NPPs and the US Department of Energy continues to strongly support the design and licensing of SMRs. The smaller generation capacity of SMRs is considered by many as ideal for nuclear desalination operations, especially in remote, off-grid locations and small regions. This does not preclude nuclear desalination and other cogeneration activities using larger reactors. SMRs are the subject of a complementary report to the General Conference (Annex 8).

19. Other countries that are investigating or considering launching nuclear desalination programmes, either on a national or a multilateral basis include Indonesia, Jordan, Kuwait, Oman, Qatar, and the United Arab Emirates.



# Agency Activities in the Development of Innovative Nuclear Technology

## A. Background

1. In resolution GC(56)/RES/12.B.2 the General Conference noted the progress that has been achieved in a number of Member States in the development of innovative nuclear energy systems technology and the high technical and economic potential of international collaboration in the development of such technology. The General Conference also noted that membership of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), which was launched in 2000, continues to grow and expressed satisfaction that, in response to previous calls on the Secretariat to strengthen the INPRO management structure, the INPRO Group was established as within the Department of Nuclear Energy in 2012.

2. The General Conference noted that INPRO fosters collaboration and provides a forum for technology users and technology holders to study and integrate national, regional and global nuclear energy scenarios and that it has successfully completed the collaborative project Global Architectures of Innovative Nuclear Energy Systems Based on Thermal and Fast Reactors Including a Closed Fuel Cycle (GAINS), which developed a comprehensive set of analytical tools, assumptions and considerations (relating to power production, nuclear material resources, discharged fuel, radioactive waste and minor actinides, nuclear fuel cycle services, system safety, and costs and investment) and identified scenarios for transitioning to nuclear energy systems that preserve nuclear material, restrain the accumulation of used fuel and enhance proliferation resistance, highlighting the role of technical and institutional innovations and international cooperation in this respect.

3. In resolution GC(56)/RES/12.B.2, the General Conference requested the Director General to report on the progress made in implementation of the Agency's activities in the development of innovative nuclear technology to the Board of Governors and General Conference at its 57th (2013) regular session under an appropriate agenda item. This report responds to that request by summarizing those activities, including those activities carried out under INPRO.

## B. INPRO Activities

### B.1. Overall Project Status

4. As of May 2013, INPRO had increased its membership by two countries (Kenya and Romania) and had 39 members: Algeria, Argentina, Armenia, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Egypt, France, Germany, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Republic of Korea, Malaysia, Morocco, Netherlands, Pakistan, Poland, Romania, Russian Federation, Slovakia, South Africa, Spain, Switzerland, Turkey, Ukraine, United States of America, Vietnam and the European Commission (EC).

5. During 2012 and 2013, the INPRO Action Plan for the biennium was implemented as approved at the 18th meeting of the INPRO Steering Committee in 2011. According to this plan, INPRO's activities were organized in four major projects.

Project 1: National Long Range Nuclear Energy Strategies

Project 2: Global Nuclear Energy Scenarios

Project 3: Innovations

Project 4: Policy and Dialogue

6. In line with the INPRO Development Vision 2012–2017, the INPRO Action Plan for 2012–2013 puts more emphasis on the integration of all activities under INPRO to provide practical decision making support to Member States in their national nuclear energy strategy development.

7. INPRO has maintained good progress in implementing the INPRO Action Plan 2012–2013, although it continues to rely mainly on in-kind and extrabudgetary contributions from its members. In May 2013, the INPRO Steering Committee discussed and endorsed the INPRO Action Plan for 2014-2015.

8. As of May 2013, 15 cost-free experts have worked in the INPRO Group, bringing the total number of staff involved in INPRO activities since INPRO's establishment to 50.

9. INPRO's communication activities continued to support cooperation with its stakeholders in Member States and to provide them with up to date information on the project's activities and results. A briefing on INPRO was presented at a side event during the 56th regular session of the General Conference in September 2012. The INPRO event focused on the benefits countries derive from INPRO membership and how INPRO's studies and projects can contribute to sustainable nuclear energy systems in Member States. INPRO also participated in a joint side event, which presented the integrated services of the Department of Nuclear Energy to Member States that are considering the development of nuclear energy programmes. In May 2013, the 2012 INPRO Progress Report was published. It provides an overview of INPRO and summarizes progress and results achieved during 2012.

10. Coordination and cooperation with other international initiatives and organizations continued in 2012 and 2013 including with the EC, acting as a full member of INPRO, and with the Joint Research Centre (JRC). Cooperation with the European Union's Sustainable Nuclear Energy Technology Platform (SNETP), the International Framework for Nuclear Energy Cooperation (IFNEC), the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA) and the World Nuclear Association (WNA) also continued. Representatives of these organizations participated in the 19th INPRO Steering Committee in July 2012 and in INPRO meetings. INPRO has also cooperated extensively with the Generation IV International Forum (GIF) and is represented at meetings of the GIF Policy Group and the GIF Risk and Safety Working Group, Proliferation Resistance and Physical Protection Working Group, and Economic Modeling Working Group, while GIF experts participate in meetings of the INPRO Steering Committee and in joint technical workshops. INPRO collaboration with GIF, and efforts made within the complementary frameworks, are strongly supported by the Agency's Member States. The 7th IAEA-INPRO-GIF Interface Meeting took place in March 2013 in Vienna. Special attention was given to safety, proliferation resistance and the economics of innovative nuclear reactors. The results of the joint IAEA-GIF Workshop on Safety Design Criteria for Sodium Cooled Fast Reactors (SFRs), held in February 2013, were presented. Topics for future GIF-INPRO workshops on SFRs were also discussed.

## **B.2. National Long Range Nuclear Energy Strategies**

11. Under Project 1, National Long Range Nuclear Energy Strategies, INPRO seeks to assist Member States in building national long range nuclear energy strategies and in making decisions about

sustainable nuclear energy development and deployment through use of the INPRO methodology and other tools. Nuclear Energy System Assessments (NESAs) use the INPRO methodology to analyse the long range sustainability of a planned or existing nuclear energy system. The Agency provides practical support and training in the application of the INPRO methodology.

12. During 2012–2013, NESAs were ongoing or completed in Belarus, Indonesia and Ukraine.

13. In 2012, Belarus concluded a three-year project which assessed the sustainability of its planned nuclear energy system using the INPRO methodology. The final report, which discusses the installation of two AES-2006 reactors of Russian design, was cleared by all national institutions involved in the project and by the Agency. The Belarus NESA was a full scope reference study for the INPRO methodology and covers all assessment areas. It is planned to publish the results in an Agency publication in late 2013.

14. The Indonesian NESA was started in 2011 and has a complex scope. The study is in the first of four stages, i.e. familiarization with the NESA for all assessment areas of the INPRO methodology for a selected nuclear energy system, with the fourth and final stage being a full scope NESA. In 2012, Indonesia hosted a NESA review mission to discuss major results achieved to date and to make recommendations on the application of the INPRO methodology for several specific criteria in all assessment areas.

15. The Ukrainian NESA, which was also initiated in 2011, focuses on three areas of the INPRO methodology: economics, infrastructure and waste management. A training workshop on the INPRO methodology in these areas was organized, in which 15 experts from national authorities, nuclear utilities and scientific and research institutions participated. In 2012, Ukraine submitted an intermediate report on energy planning, nuclear system modelling and options for nuclear energy systems to be assessed. These results are necessary prerequisites for the NESA that is to be completed in 2013.

16. In 2012, an interactive online training course on performing a NESA (NESA-ITC) was added to the NESA support package, available to support Member States in the assessment. The NESA-ITC can be downloaded from the INPRO website and is available on CD-ROM.

17. In 2013, a technical update of the INPRO Manual (IAEA-TECDOC-1575 Rev. 1) was begun, including all nine volumes, taking into account existing proposals from Member States, as documented in the publication *Lessons Learned from Nuclear Energy System Assessments (NESA) Using the INPRO Methodology* (IAEA-TECDOC-1636), from the INPRO Group and other Agency experts.

18. In 2012, the Agency published *INPRO Collaborative Project: Proliferation Resistance: Acquisition/Diversion Pathway Analysis (PRADA)* (IAEA-TECDOC-1684) and *Role of Thorium to Supplement Fuel Cycles of Future Nuclear Energy Systems*, (IAEA Nuclear Energy Series No. NF-T-2.4). Four additional publications on completed INPRO collaborative projects were approved for publication.

19. The collaborative project entitled “Environmental Impact of Potential Accidental Releases from Nuclear Energy Systems (ENV-PE)”, which is a follow-up activity of the collaborative project entitled Environmental Impact Benchmarking Applicable for Nuclear Energy Systems under Normal Operation (ENV), was launched in October 2012. It will provide guidance on evaluating accidental or unplanned releases in terms of radionuclide specific dose contribution.

20. The collaborative project entitled Proliferation Resistance and Safeguardability Assessment Tools (PROSA) was launched early in 2012 with the participation of Canada, Germany, Italy, Japan, the Republic of Korea, Romania, the Russian Federation, the USA and the EC’s JRC and

Directorate-General for Energy. The two-year project is continuing to develop a coordinated set of tools based on methodologies to assess proliferation resistance and safeguardability of nuclear energy systems. The goal is to make the assessment process and the results more easily understood by the users.

### **B.3. Global Nuclear Energy Scenarios**

21. The objective of this project is to develop global and regional nuclear energy scenarios on the basis of a scientific–technical analysis, leading to a global vision of sustainable nuclear energy development and deployment options in the 21st century. By developing those scenarios in collaborative projects, INPRO helps both newcomers and existing nuclear countries to understand the key issues in a transition to future sustainable nuclear energy systems. The benefits of international cooperation in facilitating such a transition, the identification of key activities and actions to be performed and recognizing its corresponding actors, are other aspects to be clarified in this area.

22. In 2012, the report of the INPRO collaborative project GAINS was finalized and approved by the Agency for publication. It will be issued in the near future as, *Framework for Assessing Dynamic Nuclear Energy Systems for Sustainability — Final Report of the INPRO Collaborative Project on Global Architecture of Innovative Nuclear Energy Systems Based on Thermal and Fast Reactors in a Closed Fuel Cycle* (IAEA Nuclear Energy Series No. NP-T-1.14).

23. The Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability (SYNERGIES) project (was established in 2012 with the objective of identifying and evaluating mutually beneficial collaborative architectures and the driving forces for, and impediments to, achieving globally sustainable nuclear energy systems. The project is expected to produce a final report in 2014. Algeria, Argentina, Armenia, Belarus, Belgium, Bulgaria, Canada, China, Egypt, France, India, Indonesia, Israel, Italy, Japan, the Republic of Korea, Malaysia, Pakistan, Poland, Romania, the Russian Federation, Spain, Ukraine, the USA, Vietnam and the OECD/NEA are participants or observers in the four project tasks.

24. Integrating the outputs of GAINS and SYNERGIES and other Agency projects, a new activity entitled ROADMAPS will develop roadmaps (who does what, where and when), i.e. flowcharts of structured actions, scope of work and time frames for individual stakeholders in a collaborative scenario that would facilitate a transition to globally sustainable nuclear energy systems. In 2013, preparations were under way for launching this new collaborative project in 2014. The implementation of the ROADMAPS project is scheduled for the biennium 2014–2015 and foresees cooperation within the Agency and with other international agencies, such as the OECD/NEA and the WNA. The wording ‘globally sustainable nuclear energy systems’ will be used — to denote not only the global nuclear energy system but also those national and regional systems that effectively contribute to, and benefit from, sustainability of the global system.

### **B.4. Innovations**

25. This project investigates innovations in selected nuclear energy technologies and related R&D and is intended to support Member States in pursuing such innovations. Institutional arrangements are also an important part of nuclear energy systems, including agreements, treaties, legal frameworks or regimes, and conventions and these aspects are also included in the project as deploying new reactor designs may require innovative approaches to institutional measures, in particular for non-stationary SMRs. INPRO fosters collaboration in this area and supports countries in developing and implementing innovative arrangements.

26. Preparations were made for a new collaborative project to be launched later in 2013 entitled “Review of Innovative Reactor Concepts for Prevention of Severe Accidents and Mitigation of their Consequences (RISC)”. Ensuring safety under normal and design basis accident conditions is a key requirement for the development of nuclear power. Severe accident prevention and mitigation measures are equally important and are receiving increased attention following the Fukushima Daiichi accident. The INPRO methodology in the area of reactor safety requires that the off-site release of radioactive substances above a certain limit be ‘practically impossible’. Satisfying this requirement is crucial for public acceptance and for the sustainability of nuclear energy. The objective of the RISC project is to demonstrate that the evolution of safety requirements and related technical and institutional innovations in nuclear technologies provide continued progress to avoid relocation or evacuation measures outside NPP sites. Existing or proposed advanced nuclear energy systems will be evaluated with respect to the above INPRO requirement, i.e. no need for evacuation beyond the site of the NPP following any type of accident.

27. The final report of the INPRO study on legal and institutional issues associated with transportable nuclear power plants (TNPPs) was approved for publication by the Agency’s Publications Committee in 2013. The study aims at helping designers and potential users of TNPPs to understand the legal, institutional and infrastructure issues relevant to deployment in countries other than the country of origin. To achieve its objective, the study considered different deployment scenarios and options of operation and ownership of TNPPs.

28. In 2013, new activity options for international cooperation on fast reactors, fuel cycles and materials R&D are being prepared. The objective is to perform a preliminary investigation for enhancing collaboration between developers of innovative nuclear technologies. This objective can be accomplished by developing an anticipated international scientific and technical framework for innovative technology studies, utilizing existing and future research and test reactors.

## **B.5. Policy and Dialogue**

29. The main activity in this project is the continuation of the INPRO Dialogue Forum on Nuclear Energy Sustainability, implemented in close cooperation with the Department of Technical Cooperation and thematically with other Agency Departments. The INPRO Dialogue Forum brings together technology holders, users and other stakeholders to share information and knowledge on issues related to sustainable nuclear energy development. In 2012, two forums focused on drivers of, and impediments to, regional cooperation on sustainable nuclear energy systems and on long term prospects for nuclear energy in the post-Fukushima era. The Sixth Dialogue Forum was held in July-August 2013 on the safety and licensing of SMRs and a further forum is planned on revision of the INPRO methodology.

## **C. Other Agency Activities in Relation to Innovative Nuclear Technology**

30. The benefits of fast reactor technology appear to be gaining acceptance in response to continuing waste storage issues and the prevailing need for energy providers to cope with industrial and household energy demand. The Agency’s activities in the field of advanced fast neutron systems research and technology development are implemented within the framework of the Technical Working Group on Fast Reactors (TWG-FR), which also deals with accelerator-driven systems. The

TWG-FR is exploiting synergies by working with the INPRO initiative on the long term sustainability of nuclear energy.

31. An important event organized by the Agency in Paris in 2013 was the International Conference on Fast Reactors and Related Fuel Cycles: Safe Technologies and Sustainable Scenarios (*FR13*). Seven hundred experts from 27 Member States and 4 international organizations participated in the conference, demonstrating a robust and growing interest in the fast reactor and related fuel cycle technology. Significant advances in key areas of technological development were presented during the 41 technical sessions of the conference, including reports on progress in fast reactor and fuel cycle technology, safety, and economic and proliferation-resistance related issues. The conference also identified gaps and key issues that need to be addressed for advancing towards industrial-scale fast reactors, including public acceptance.

32. The CRP on benchmark analysis of an EBR-II shutdown heat removal test was launched in 2012 and includes participation of 20 organizations from 11 Member States. A new CRP proposed by France on sodium properties and safe operation of experimental facilities in support of the development and deployment of sodium-cooled fast reactors has been recently approved by the Committee for Coordinated Research Activities. The first RCM of this new CRP is being held in September 2013. A third CRP proposed by India on the source term for radioactivity release under fast reactor core disruptive accident situations is planned to be initiated by the end of 2013.

33. A comprehensive report *Status of Fast Reactor Research and Technology Development* (IAEA-TECDOC-1691), summarizing the state-of-the-art and future developments in this area, was published at the end of 2012, and a similar effort is underway for a parallel report *Status of Accelerator Driven Systems Research and Development*. These two reports will be complemented by a booklet entitled *Status of Innovative Fast Reactor Designs* which is currently being prepared. The publication *Liquid Metal Coolants for Fast Reactors Cooled by Sodium, Lead, and Lead-Bismuth Eutectic* (IAEA Nuclear Energy Series No. NP-T-1.6) was also issued in 2012, and various IAEA-TECDOC publications highlighting the results of recently completed CRPs on the MonjuU and Phénix reactors will be published shortly. These publications are complemented by eight papers submitted to international conferences and peer-reviewed journals.

34. The TWG-FR met in May 2013 to exchange information on the status of national programmes and provide recommendations for the implementation of the Agency fast reactor-related activities in 2014–2015 and beyond. A joint IAEA-GIF Workshop on Safety Design Criteria for Sodium Cooled Fast Reactors was held in February 2013: the Agency is focused on the timely issue of internationally agreed safety requirements for innovative (Generation IV) fast reactors and will ensure that the lessons of the Fukushima Daiichi accident are phased in early enough to adequately address all aspects during development.

35. Two Technical Meetings relating to safety issues for high temperature gas cooled reactors (HTGRs) were held in 2012 on the re-evaluation of the maximum operating temperatures for HTGR fuel and structural materials and on high temperatures in core instrumentation for use in HTGRs. The purpose of both Technical Meetings was to revisit some open issues regarding HTGR safety, especially in the light of the Fukushima nuclear accident. A new CRP on HTGR neutronics, thermal-hydraulics and depletion uncertainty analysis was launched in 2012. The objective of the CRP is to provide a platform for development of uncertainty analysis methods for incorporation into computer codes used in the safety analysis of HTGRs. In the area of education and training, an international training course on HTGR technology was conducted in Beijing, China, in October 2012. The course, attended by 35 participants from 10 Member States, was a part of the Agency's efforts to preserve knowledge in HTGR technology by imparting it to the younger generation of scientists and engineers. In 2013, the publication *Evaluation of High Temperature Gas Cooled Reactor*

*Performance: Benchmark Analysis Related to the PBMR-400, PBMM, GT-MHR, HTR-10 and the ASTRA Critical Facility* (IAEA-TECDOC-1694) was issued, summarizing the results of the CRP on advances in HTGR performance in which 10 Member States participated.

36. In November 2012, the Agency convened the first RCM relating to the CRP on the techno-economic aspects of hydrogen production using nuclear energy and benchmarking of HEEP. During this meeting, the Agency released an updated version of its Hydrogen Economic Evaluation Program (HEEP). The updated version has a more user-friendly interface and updated economic models. In July 2013, the Agency released the beta-version of the toolkit on nuclear hydrogen production. In addition to having links to all technical publications on nuclear hydrogen production, the toolkit has new features that enable users to readily calculate the cost of nuclear hydrogen production based on various methodologies and to estimate their environmental impacts.

37. In the area of light and heavy water reactors, two CRPs were completed entitled “Heat Transfer Behaviour and Thermal-hydraulics Code Testing for SCWRs” and “Benchmarking Severe Accident Computer Codes for Heavy Water Reactor Applications”; while two CRPs were launched entitled “Prediction of Axial and Radial Creep in Pressure Tubes” and “Computational Fluid Dynamics (CFD) Codes for Nuclear Reactor Design”. Training courses were held on the science and technology of SCWRs and natural circulation phenomena and passive safety systems in advanced water cooled reactors. The Agency published *Comparison of Heavy Water Reactor Thermalhydraulic Code Predictions with Small Break LOCA Experimental Data* (IAEA-TECDOC-1688) and, *Nuclear Reactor Technology Assessment for Near Term Deployment* (IAEA Nuclear Energy Series No. NP-T-1.10). Technical Meetings included meetings held on advanced code suite for design’s Safety analysis and operation of HWRs; integral PWR design natural circulation flow stability and thermohydraulic coupling of containment and primary system during accidents; HWR moderator sub-cooling requirements to demonstrate backup heat sink capabilities of moderators during accidents; and reactor technology assessment for embarking countries.



# Small and Medium Sized Reactors (SMRs) – Development and Deployment

## A. Background

1. In resolution GC(55)/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 (SMRs), including for nuclear desalination and hydrogen production. The General Conference requested the Director General to report to the Board of Governors and to the General Conference on (i) the status of the programme initiated to assist developing countries interested in SMRs; (ii) progress made in the research, development, demonstration and deployment of SMRs in interested Member States; and (iii) progress made in the implementation of the Agency's activities in the development of innovative nuclear technology. This report responds to that request.

## B. Activities of the Agency

2. In the framework of supporting the IAEA Action Plan on Nuclear Safety, and specifically action 12, on utilizing effective R&D, the Agency in June 2012 started an activity to incorporate lessons learned from the Fukushima Daiichi accident into an SMR technology assessment of the design of engineered safety features. The activity was funded by an extrabudgetary contribution from the Republic of Korea, as a follow-up to the Workshop on Technology Assessment of Small and Medium Sized Reactors for Near Term Deployment, held in December 2011. That workshop's main objective was to help Member States identify commercially available SMR designs for near term deployment and to introduce the process of technology assessment as a step towards informed decision making. A second activity initiated in 2012, funded through the Peaceful Uses Initiative, is the development of a toolkit for SMR technology assessment on the reliability of engineered safety features.

3. With regard to the regulatory infrastructure needed in preparation for the deployment of SMRs, the Agency is developing a report, to be published in the IAEA Nuclear Energy Series, on approaches for environmental impact assessments for advanced SMRs in collaboration with nuclear regulatory authorities in leading nuclear countries. In support of this, two consultancy meetings were held in April and October 2012.

4. In the area of advanced energy concepts related to SMRs, the Agency has been developing an IAEA Nuclear Energy Series Report entitled *Options to Enhance Energy Supply Security using Hybrid Energy Systems based on SMRs – Synergizing Nuclear and Renewable Energies*. This is being developed in cooperation with the EC's JRC, INPRO and the Agency's Planning and Economic Studies Section and the work investigates the viability of integrating SMRs with renewable energy resources to improve energy system cost-effectiveness and sustainability.

5. A four year CRP on the 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. In the CRP, natural circulation tests were performed in Italy. The test data were 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 RCMS were held and attended by five Member States representing seven research institutions and organizations in Argentina, France, India, Italy, and the Russian Federation. The preparation of an IAEA-TECDOC publication is in progress along with the CRP report.

6. A third Technical Meeting was held in August 2011 in support of the production of an IAEA Nuclear Energy Series Report entitled *Options to Incorporate Intrinsic Proliferation Resistance Features into NPPs with Innovative SMRs and their Associated Fuel Cycle*. The objective of this NE Series Report is to harmonize the methods developed by INPRO and the Generation IV International Forum (GIF) on proliferation resistance and physical protection. Examples of previously performed proliferation resistance assessments for energy systems were presented at the Technical Meeting and progress achieved in the development of a template for collecting designers' data on proliferation resistance was reviewed. The IAEA Nuclear Energy Series Report has been finalized for publication in 2013.

7. As a supplement to its Advanced Reactors Information System (ARIS), the Agency published the annually updated booklet *Status of Small and Medium Sized Reactor Designs* in September 2011 and November 2012.

8. The study on legal and institutional issues for TNPPs, approved for publication by the Agency's Publications Committee, is described in Annex 7.

9. In October 2011, the Agency organized a Technical Meeting on Fuel and Fuel Cycle Options for Small and Medium Sized Reactors, in Vienna, which more than 32 participants from 20 Member States attended. The meeting reviewed the status of fuel and fuel cycle options for SMRs, based on LWR, PHWR, HTR and fast reactor technologies. Following from the meeting, a document highlighting the issues related to fuel and fuel cycle for SMRs is being finalized and publication is expected by end of 2013.

## C. Activities in Member States

10. There is increasing global activity supporting SMR design and technology development for near term deployment. SMRs are under development for all principal reactor lines, i.e. water cooled reactors, liquid metal cooled reactors and gas cooled reactors. Worldwide, 131 SMR units are in operation in 26 Member States, with a capacity of 59 GW(e). At present, 14 SMRs are under construction in 6 countries: Argentina, China, India, Pakistan, the Russian Federation and Slovakia. Research is being carried out on approximately 45 advanced SMR concepts for electricity generation, process heat production, desalination, hydrogen generation and other applications in 12 Member States: Argentina, Brazil, Canada, China, France, India, Italy, Japan, Republic of Korea, the Russian Federation, South Africa, and the USA. The following paragraphs summarize the activities of Member States in the development of SMRs.

11. Light water cooled SMRs are being developed in Argentina, China, France, the Republic of Korea, the Russian Federation and the USA. In Argentina the CAREM-25 reactor, a 27 MW(e) prototype for an eventual 150–300 MW(e) reactor, has been developed with all primary components located inside the reactor vessel. Civil engineering work for the construction of the CAREM-25 prototype reactor started in 2012 at the Atucha site and the reactor is scheduled to be commissioned in 2016. The construction of a larger plant, adopting the CAREM-25 design but with >150 MW(e)

capacity, is envisioned for a site in Formosa Province. China has also developed pressurized light water cooled designs of 300 MW(e) and 600 MW(e) reactors, with two CNP-300 units under construction in Pakistan and three CNP-600 units in China. Recently, China has also announced its own small pressurized water reactor (PWR) integral design, called ACP100, which is likely to be deployed at a site in Fujian Province within a few years. France is developing the Flexblue design, which is a small subsea NPP with an output rating of 160 MW(e). Its development is based on extensive reactor operating experience in submarines. In July 2012, the Nuclear Safety and Security Commission of the Republic of Korea issued the standard design approval for the 100 MW(e) SMART reactor design. SMART has a thermal capacity of 330 MW and is planned particularly for electric power and seawater desalination. The Russian Federation has deployed many WWER-440 units and is developing several WWER designs in the SMR category. In addition, two smaller units of the KLT-40S series are near completion and are to be mounted on a barge and used for the cogeneration of process heat and electricity. The development of the KLT-40S series was based on experience with reactors used to power icebreakers.

12. In the USA, several SMRs are under development. The Department of Nuclear Energy announced a second round of competition for the SMR licensing technical support programme. According to the United States Department of Energy (DOE), this solicitation bid would share the US \$452 million funding allocation with a previous award made in November 2012. This competition targets SMR designs planned to be operable by 2025, three years later than last year's competition. These include the mPower, which envisages a deployment of twin 180 MW(e) modules, in Clinch River, Tennessee; the NuScale that aims for one NPP made up of twelve 45 MW(e) modules; the W-SMR, a 225 MW(e) PWR that uses passive safety systems and components with proven performance from the AP1000 and the SMR-160. The first two are scheduled to be submitted to the US Nuclear Regulatory Commission for design review in 2014. All four US reactors are integrated PWRs. The mPower received an award during the first round of DOE solicitation bid in April 2013.

13. Heavy water reactors (HWRs) in the SMR category have been developed and designed in Canada and India. Canada has developed and deployed the CANDU series, which offers various power ratings. Several HWRs are under construction or are in operation in India. These include PHWRs of 220 MW(e), 540 MW(e) and 700 MW(e) output. In addition, the Indian advanced heavy water reactor (AHWR) with 300 MW(e) output has been designed. It incorporates a vertical calandria, uses thorium fuel and employs passive safety features.

14. There are several high temperature gas cooled reactors under development with power ratings below 700 MW(e). China has developed, constructed and operated the HTR-10, an experimental pebble-bed helium cooled high temperature reactor. A modular HTR-PM project at Shidaowan Shangdong Province was started in December 2012 consisting of two 250 MW(th) modules, with completion scheduled for 2017. The USA has developed the gas turbine modular helium cooled reactor (GT-MHR) and the Energy Multiplier Module (EM<sup>2</sup>), which are high temperature reactors with block type fuel elements and a gas turbine cycle.

15. Liquid metal cooled fast reactors in the SMR category are being investigated in several countries. The Prototype Fast Breeder Reactor (PFBR) with 500 MW(e) output is being prepared for commissioning and a start-up test in Kalpakkam, India. Japan has developed a reactor (4S), 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 SVBR-100 units, 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. The SVBR-100 pilot project and an experimental lead-cooled BREST-300 fast reactor are currently in their first stage of development. In China, the China Experimental Fast Reactor (CEFR) 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(55)/RES/12, the General Conference recognized that the development and implementation of an appropriate infrastructure is 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 role in assisting Member States in this area and noted the Agency's increasing activities, in accordance with requests of Member States. The General Conference further noted the joint efforts of the Integrated Nuclear Infrastructure Group (INIG) and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) in developing innovative infrastructure approaches for future nuclear energy systems and also recognized the value of the Agency's Integrated Nuclear Infrastructure Review (INIR) missions, which provide expert and peer-based evaluations, in helping requesting Member States to determine their nuclear infrastructure development status. The General Conference requested the further development of INIR for Phase 3 before commissioning and further requested the Agency to continue to learn lessons from INIR missions and to enhance the effectiveness of its activities.

2. The General Conference requested the Director General to report on the progress made in the implementation of the resolution to the Board of Governors and to the General Conference at its 57th session under an appropriate agenda item. This document is prepared in response to that request.

## B. Progress since the 55th Regular Session of the General Conference

### B.1. General

3. Of the countries without nuclear power that before the Fukushima Daiichi accident had strongly indicated their intention to proceed with nuclear power programmes, a few subsequently cancelled or revised their plans, others took a 'wait-and-see' approach, but most continued. Notably, in 2012, the United Arab Emirates became the first country in nearly three decades to start construction on its first NPP. Other countries such as Belarus and Turkey have signed contracts and are preparing for construction.

4. Extrabudgetary contributions to the Agency in support of nuclear power infrastructure have increased since 2011 particularly from donors to the Peaceful Uses Initiative (PUI). These additional funds have allowed the Agency to rebuild services which could not be offered for some time, notably for future owner-operators who will have the prime responsibility for nuclear safety. Some areas of particular interest that have been enabled by the PUI include the expansion of the legislative assistance programme and establishment of the Nuclear Law Institute, development and application of a workforce planning modelling tool, and guidance documents and workshops 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 TC footnote a/ projects. Some specific projects include support for human resources development in Nigeria through the purchase of a simulator, and support for capacity building in Vietnam through workshops and expert missions on several topics.

6. At the June 2011 IAEA Ministerial Conference on Nuclear Safety, the Director General announced the preparation of an Action Plan on Nuclear Safety. The Action Plan was adopted by the Board of Governors and later endorsed by the General Conference in September 2011. Action 8 relates to Member States planning to embark on a nuclear power programme and Action 9 relates to capacity building in those Member States embarking on a nuclear power programme, as well as those with operating NPPs. The Action Plan asks Member States to develop an appropriate infrastructure and to voluntarily host peer review missions. Several tasks have been undertaken to support these actions.

7. 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 for embarking countries following the Milestones approach.

8. A comprehensive catalogue of Agency services available to Member States in all areas of infrastructure development is being finalized and is expected to be published on the Agency's website by the fourth quarter of 2013.

9. Action 9 of the Action Plan addresses the main requirements to strengthen and maintain capacity building for newcomer countries. Member States that are planning to embark on a nuclear power programme are asked to strengthen, develop, maintain and implement their capacity building programmes, including education, training and exercises at the national, regional and international levels. A Technical Meeting on this topic was held in 2012 and resulting from this a draft self-assessment methodology is being prepared, to be available by the end of 2013.

## **B.2. Technical Working Group on Nuclear Power Infrastructure**

10. Since its establishment in 2011, the Technical Working Group on Nuclear Power Infrastructure (TWG-NPI) has met 4 times, the last two meetings being in April 2012 and May 2013. The TWG-NPI gathers international experts to provide advice to the Agency for the development and implementation of national nuclear power programmes. The TWG-NPI shares information and recommendations based on recent developments and good practices on infrastructure development for national nuclear power programmes; provides guidance to the Agency on approaches, strategy, policy and implementing actions for the establishment of a national nuclear power programme; assists the Agency in the evaluation of experience gained from its support activities and missions; provides feedback on the use of the Agency's documents; provides advice on adjustment and optimization of the Agency actions and approaches accordingly; shares information on developments and activities in Member States, including regarding bilateral assistance and national efforts; and explores ways of coordinating Agency and bilateral assistance.

## **B.3. Technical Cooperation**

11. The Agency has seen an increase in activities in countries that have taken the decision to start a nuclear power programme or have a first NPP under construction. There are currently over forty national, regional and interregional TC projects supporting countries considering or planning for

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 newcomer-to-newcomer sharing of lessons learned is especially useful given the length of time since the last newcomer prior to the United Arab Emirates started construction on an NPP.

#### **B.4. Assessment of Nuclear Infrastructure**

12. Integrated Nuclear Infrastructure Review Missions (INIR) 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 a country's situation and Member States that have received an INIR mission have found it very useful for supporting further development. International experts involved in the missions review progress in infrastructure development and make recommendations and suggestions for how the country can advance.

13. In November 2011, an INIR mission to Bangladesh was conducted to review progress in nuclear infrastructure development of nuclear power and to make recommendations. In January 2012, the first follow-up mission to Jordan took place to review the action plan addressing feedback from the INIR mission in 2009. Also in 2012, Belarus hosted an INIR mission for Phases 1 and 2. Vietnam hosted its second INIR mission in December 2012. Poland hosted an INIR mission in April 2013.

14. The first INIR mission to a country with an operating NPP was conducted in January 2013 in South Africa. South Africa requested the mission because it had been decades since the Koeberg NPP was built and officials wanted to review the status of the national infrastructure to support the construction of new plants.

15. Upcoming INIR missions include Turkey, scheduled for November 2013, while Morocco and Nigeria have officially requested INIR missions tentatively planned for 2014. Additional countries have also informally expressed interest.

16. The IAEA Action Plan on Nuclear Safety requested the Agency to extend its INIR mission to cover Phase 3, prior to commissioning. This was originally not envisioned when the INIR was launched in 2009 because of the existence of other Agency review services that are either organizationally or topically focused (e.g. Operational Safety Review Team (OSART), Integrated Regulatory Review Service (IRRS), International Physical Protection Advisory Service (IPPAS) etc.). Member States are now interested in a comprehensive mission that looks across the supporting infrastructure to ensure readiness for commercial operation. An approach and methodology are being developed, and discussions with some potential hosts to pilot a Phase 3 mission in 2014 or 2015 are ongoing.

17. Based on continuous feedback from Member States and lessons learned from INIR missions, the publication *Evaluation of the Status of National Nuclear Infrastructure Development* (IAEA Nuclear Energy Series No. NG-T-3.2) has been updated in the form of a supplemental working paper and is being piloted with INIR missions in 2013. After that experience is analysed, it will be published with a revision of the Milestones document in 2014.

#### **B.5. Support for Human Resource Development**

18. Human resource development continues to be a high priority for Member States and the Agency. Several activities are ongoing.

19. Bangladesh, Indonesia, Malaysia, Thailand and Vietnam were trained by the Agency on the nuclear power human resource modelling tool in April 2012, receiving key insights into the national

workforce planning process. The Agency supports countries in the development and implementation of the model, which can be adapted to closely reflect a country's national needs.

20. An e-learning project funded by Korean extrabudgetary funds under the PUI has developed several modules based on existing Agency publications on nuclear infrastructure development and as a result of feedback from Member States. The first five modules are available on the Agency website and they cover the Milestones approach, human resource development, management, stakeholder involvement and construction management. An additional 5 modules will be available in early 2014. The goal of this project is to produce interactive and engaging learning materials.

21. The Massachusetts Institute of Technology (MIT) has recently launched the International Nuclear Leadership Education Program with the support of the Institute of Nuclear Power Operations and the Agency. This course focuses on governance strategies, operational practices, and technologies required for a successful nuclear energy programme. The first programme is being conducted in two parts, in June and October 2013.

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

## **B.6. Conferences and Workshops**

23. An International Ministerial Conference on Nuclear Power in the 21<sup>st</sup> Century was held in St. 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.

24. A Technical Meeting on Building a National Position on Nuclear Power was held in Vienna in July 2012 to provide an opportunity for the exchange of information on the development of national positions regarding new nuclear power programmes and to gather Member States' feedback for an IAEA-TECDOC publication on building a national position on a new nuclear power programme, which is currently being drafted.

25. The Agency held an Interregional Workshop on New Nuclear Power Programmes: Becoming a Knowledgeable Customer in Paris and Flamanville, France, in November 2012 to provide recommendations and guidance to future NPP owner/operators on how to develop the capacity, competence, and partnerships necessary for successful planning, bidding, awarding and initiating the construction of an NPP. A second workshop is planned for October 2013 in Moscow which will include a visit to an NPP under construction.

26. The Agency organized a Technical Meeting on Information Exchange among Experienced and Future Operators in October 2012 to share experience on the establishment of owner/operator organizations and discuss challenges and potential solutions in newcomer countries.

27. A Technical Meeting on Safety, Security, and Safeguards: Interfaces and Synergies for the Development of a Nuclear Power Programme was held in November 2012 in Vienna, which provided a forum for the exchange of views on identifying the interfaces and synergies between the three areas of safety, security, and safeguards, as well as the practical elements and lessons learned.

28. Since the 55th regular session of the General Conference, two workshops on nuclear infrastructure development have been held in January 2012 and February 2013 respectively. These workshops attracted around 100 participants at the decision-making level and offered a venue for

transparency about national plans and expectations, sharing of experiences, and feedback. The workshop in 2012 focused on management and lessons learned from the Fukushima Daiichi accident. The workshop in 2013 covered topics related to building knowledgeable organizations and assessment and infrastructure reviews. Member States found these opportunities a very useful way to exchange information and good practices and acquire information on other countries' experiences.

29. The country nuclear power profiles (CNPP) is both a database and a technical publication which describes the economic situation, energy and electricity sectors and the primary organizations involved in nuclear power in Member States. The 2012 edition of the CNPP publication includes 29 countries that have operating NPPs, as well as 17 countries planning for nuclear power. A Technical Meeting was organized in March 2013 to discuss the CNPP and its further development.

## **B.7. Publications Under Preparation**

30. The publication *Milestones in the Development of a National Infrastructure for Nuclear Power* (IAEA Nuclear Energy Series Guide No. NG-G-3.1) is currently being reviewed in line with expectations that IAEA Nuclear Energy Series guidelines are re-examined and updated as necessary every five years. A Technical Meeting to solicit Member State feedback is planned for the first half of 2014, and the draft publication is expected by the end of 2014.

31. IAEA Nuclear Energy Series reports or IAEA-TECDOC publications are in preparation or due for publication on topics such as development of a national position, environmental impact assessment, alternative contracting and ownership and industrial infrastructure.

32. The publications *Invitation and Evaluation of Bids for Nuclear Power Plants* (IAEA Nuclear Energy Series No. NG-T-3.9) and *Managing Siting Activities for Nuclear Power Plants* (IAEA Nuclear Energy Series No. NG-T-3.7) were issued in 2012.

## **B.8. Future Events**

33. An International Conference on Human Resource Development of Nuclear Power Programmes: Building and Sustaining Capacity will be held in Vienna, Austria, from 12 to 16 May 2014. This conference follows on from the one held in Abu Dhabi in 2010.