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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(54)/RES/10 and GC(55)/RES/12, this document contains progress reports on the development of the Sterile Insect Technique for the control or eradication of malaria-transmitting mosquitoes (Annex 1); support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC) (Annex 2); strengthening support to Member States in food and agriculture (Annex 3); nuclear energy activities (Annex 4); nuclear knowledge management (Annex 5); and Agency activities in the development of innovative nuclear technology (Annex 6).
- Further information on the Agency's activities related to nuclear science, technology and applications can be found in the Nuclear Technology Review 2012 (document GC(56)/INF/3), the Agency's Annual Report 2011 (GC(56)/2), in particular the Technology section, and the Technical Cooperation Report for 2011 (GC(56)/INF/4).

Recommended Action

- It is recommended that the Board take note of Annexes 1-6 of this report and authorize the Director General to submit the report to the General Conference at its fifty-sixth session.

Development of the Sterile Insect Technique for the Control or Eradication of Malaria-Transmitting Mosquitoes

A. Background

1. In resolution GC(54)/RES/10 the General Conference noted with concern that malaria, transmitted by mosquitoes, causes about two million deaths a year and about 300-500 million cases of clinical malaria annually; that over 90% of the world's malaria cases occur in Africa, slowing down annual economic growth by 1.3%, and that malaria therefore constitutes a major obstacle to poverty reduction in Africa. The General Conference also noted that the malaria parasite has continued to develop resistance to drugs and that mosquitoes too have continued to develop resistance to insecticides, and that it is envisaged that the sterile insect technique (SIT) would be used under specific conditions as an adjunct to conventional technologies, conforming to the World Health Organization's roll-back strategy, including integrated vector management, of not relying on any single approach to control malaria. The General Conference further noted that the control of malaria-transmitting mosquitoes over large areas will require an area-wide approach of which SIT is often a part in agricultural pest control programmes and that this characteristic represents a novel and potentially powerful supplement to existing community-based programmes. The General Conference noted with appreciation the interest shown by some donors and their support for research and development (R&D) on SIT for combating malaria-transmitting mosquitoes, and acknowledged with appreciation the support given by the Agency to the development of the SIT for the control of malaria-transmitting mosquitoes as outlined in the report by the Director General in document GC(54)/10, Annex 2. The General Conference welcomed the fact that R&D on malaria-transmitting mosquitoes, which commenced with GC(45)/RES/12 in 2001 and the inauguration of the SIT-Malaria Facility in the Agency's Laboratories in Seibersdorf on 26 June 2003, continued during 2009-2011.

2. The General Conference requested the Agency to continue to strengthen, through the activities mentioned above, the research, both in the laboratory and in the field, required to use SIT for the control of malaria transmitting mosquitoes. It requested the Agency to increasingly involve African and other developing Member States' scientific and research institutes in the research programme in order to ensure their participation, leading to ownership by the affected countries; to increase its efforts to raise funds for the research programme; and invited the donors to continue with their financial support, and other Member States to make financial contributions to the research programme. It requested the Director General to report on the progress made in the implementation of this resolution to the General Conference at its fifty-sixth session (2012).

3. The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture has been responding to General Conference resolution GC (54)/RES/10 that requests that the IAEA increase efforts to develop the SIT for disease transmitting mosquitoes. However, these efforts do not include the development of methods to directly control these diseases, such as malaria (including the

development of vaccines). While the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture has continued to work to respond to the above resolution and has increased its efforts to develop the SIT for disease transmitting mosquitoes, it should be noted that these efforts do not include the development of methods to directly control diseases such as malaria (including the development of vaccines). The development of the SIT package for mosquitoes is a long-term initiative and its final successful implementation will also largely depend on the technical and managerial efforts of the respective Member States.

B. Work since the 54th General Conference

4. In response to the GC(54)/RES/10 resolution, the Insect Pest Control Laboratory (IPCL) of the Joint FAO/IAEA Division in Seibersdorf continued to work on the development of the SIT package for disease transmitting mosquitoes, i.e. the malaria vector *Anopheles arabiensis* and the vector for dengue and chikungunya, *Aedes albopictus*. The IPCL continued to maintain cultures of *An. arabiensis* originating from Sudan and Zimbabwe and of *Ae. albopictus* from France (La Réunion) and Italy.

5. A new larval diet for *An. arabiensis* and *Ae. albopictus* composed of ingredients that are widely and readily available was further improved at the IPCL resulting in better mosquito production. The diet was transferred to, Benin, Burkina Faso, France (La Réunion), South Africa, Sudan and the UK; and preliminary tests showed good results not only for *An. arabiensis* and *Ae. albopictus* but also for other important mosquito pest species such as *An. funestus*, *An. gambiae*, *An. melas*, *Ae. aegypti* and *Ae. polynesiensis*. Several research institutes in France, French Polynesia, Italy, Mauritius, Trinidad & Tobago, the UK, and the USA are now testing and using this larval diet developed at the FAO/IAEA IPCL.

6. A larva-pupa separator designed and developed at the IPCL to mechanically separate both stages was transferred to Sudan and is being evaluated under local conditions. This system allows the efficient separation of a 30 000 larvae-pupae mixture in only two minutes and will benefit all Member States working with malaria vector species such as France (La Réunion), Mauritius and South Africa.

7. Prototypes of adult oviposition cages that allow easy collection of *An. arabiensis* and *Ae. albopictus* eggs, cleaning, blood feeding, and sugar delivery, have been developed and are being tested at the IPCL and the Centro Agricoltura Ambiente G. Nicoli (CAA), an IAEA Collaborating Center in Italy since November 2011. Preliminary trials demonstrated that the cage could hold 20 000 adult mosquitoes that produced up to 300 000 eggs per day.

8. Irradiation protocols for effective sterilization of *An. arabiensis* and *Ae. albopictus* were developed using gamma- and X-ray irradiators. Similar results were obtained for the different radiation sources and *Ae. albopictus* and *An. arabiensis* were fully sterilized with a dose rate of 40 Gy and 100 Gy, respectively. These protocols have been transferred to Italy, South Africa and Sudan.

9. Studies in semi-field settings carried out in La Réunion with *Ae. albopictus* assessed the effect of various sterile to wild male ratios and the age of the sterile males on their mating competitiveness. These preliminary data provided information to improve the competitiveness of the sterile males, which is a crucial factor for release in an SIT programme.

10. The main challenge that needs to be addressed in the coming years is the development of good productive genetic sexing strains that allows easy and safe elimination of the female segment of the production line. A Genetic Sexing Strain (GSS) of *An. arabiensis* requires a dieldrin treatment to kill

all the female mosquitoes (this allows the release of only male mosquitoes, which is important as only the female mosquitoes are vectors of the disease). Further tests were conducted to assess the optimal development stages and the dose for the treatments without having any or minimal negative impact on the surviving male mosquitoes. Additional tests are being conducted to assess the level of insecticide residues in treated mosquitoes.

11. Studies were pursued to examine the effect of various biological attributes of sterile male mosquitoes that could impact the efficacy of a potential SIT programme, i.e. multiple mating capacity, factors influencing sperm transfer, sperm precedence in females after multiple mating with fertile and sterile males, refractory period between matings, effect of sterilisation on male maturation, sperm production of male mosquitoes in relation to dieldrin treatment, irradiation and genetic manipulation, etc.

12. The insect greenhouse at the IPCL in Seibersdorf that simulates semi-field conditions is nearing completion and has been used for preliminary trials. This greenhouse offers a good surrogate for the natural environment to carry out behavioural studies, including sterile male competitiveness, swarming, mating compatibility and dispersal. A self-sustaining mosquito population was maintained in the insect greenhouse for several months indicating adequate environmental conditions of the facility.

13. The Agency continued to manage two Coordinated Research Projects (CRPs) on related subjects. The final Research Coordination Meeting (RCM) of the CRP on "Development of Standardised Mass Rearing Systems for Male *An. arabiensis* Mosquitoes" was held in St Clotilde (La Réunion, France) in March 2011. Representatives of nine Member States attended the meeting and significant progress was reported on various aspects of the rearing of mosquitoes. An IAEA-TECDOC containing the final results of the five-year CRP is being prepared. The final RCM of the CRP on "Biology of Male Mosquitoes in Relation to Genetic Control Programmes" involving 20 Member States will take place from 4-8 March 2013 in Johannesburg, South Africa.

14. In response to Member States' requests, in 2012 five new national technical cooperation (TC) projects were initiated in Mauritius, Pakistan, South Africa, Sri Lanka and Sudan (MAR5019, PAK5049, SAF5013, SRL5044, and SUD5034,) and one regional TC project was launched for the Indian Ocean region (including Madagascar, Mauritius and Seychelles). All six projects focused on capacity building, and studies to determine the feasibility of applying SIT were undertaken in Sudan and South Africa. Since 2008, fellows from Indonesia, Pakistan, Sri Lanka, Sudan and Syria have received training at the IPCL on mosquito rearing and related activities under the Agency's TC programme. Topics included mass-rearing of mosquitoes, the use of the GSS, the use of the new larval diet, mating studies, radiation biology and quality control procedures.

15. The Agency continued its support to an earlier TC project in Sudan that aims to assess the feasibility of integrating the SIT against *An. arabiensis*. The collaboration between Sudan and the Agency was strengthened by visits of Sudanese representatives to the IPCL and of IPCL staff to Sudan. The larval diet for the mass-rearing of *An. arabiensis* developed at the IPCL was transferred to Sudan and is being distributed to the different laboratories (Dongola, Khartoum, Soba). The diet will be tested locally in Sudan for its effect on various developmental parameters and male competitiveness in order to assess its use for up-scaled production. The project has in the past focused on the collection of baseline data on *An. arabiensis* larval breeding sites in two representative locations in the project area along the Nile River in the Sudan (Dongola and Merowe). The survey provided data on larval population dynamics that is contributing to a feasibility study for the SIT mosquito project, and in collaboration with the Institut national de recherche en informatique et en automatique (INRIA) in France, to the development of a model that aims to predict temporal and spatial fluctuations of adult populations of *An. arabiensis* in Sudan. This data and model will assist with the planning of a strategy

to reduce malaria risks by the area-wide management of the vector. A stakeholders' coordination meeting with the participation of representatives of the Islamic Development Bank (IDB), the Government of Sudan, represented by the Tropical Medicine Research Institute (TMRI), the Permanent Mission of Sudan in Vienna, and the IAEA, was held from 18 to 21 April 2011 in Vienna, to discuss the required adjustments on the approach and strategies on the way forward for the mosquito project in Sudan. The coordination meeting recommended that the project should adhere to the "phased conditional approach" and that in the short term, it should focus on the establishment of a mass-rearing facility and on conducting a pilot trial (3-4 years) in a small representative area to assess the feasibility of the integrated use of the SIT on mosquitoes in Sudan. In January 2012, the IDB approved a US \$4.8 million soft loan to the Government of Sudan in support of this feasibility study. A TC project titled "Support to a feasibility study using the sterile insect technique for integrated control of *An. arabiensis* in Northern Sudan" (SUD5034) was launched on 27 February 2012 in Khartoum during an event with the participation of the different stakeholders (IDB, TMRI, the Permanent Mission of Sudan in Vienna, and the Joint FAO/IAEA Division). During this meeting, the earlier recommendations that had emanated from the stakeholders meeting in Vienna were reconfirmed.

16. Following the signing of Practical Arrangements in September 2008 between the Institut de Recherche pour le Développement (IRD) and the Agency, in order to formalize the roles of both organizations for collaborative work on mosquito SIT, the Agency has continued to provide technical support to the four-year SIT project in La Réunion, France, entitled "Feasibility study on the use of the sterile insect technique (SIT) to control the malaria vector *An. arabiensis*, and the chikungunya/dengue vector *Ae. albopictus* on La Réunion". The project is a collaborative effort between the Centre de recherche et de veille sur les maladies émergentes dans l'Océan Indien (CRVOI) in La Réunion, the IRD and the Agency. The project is funded by the French Ministry of Health, the Regional Council of La Réunion and the IRD, with scientific support provided by the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) and the University of La Réunion. The Agency is responsible for the development of mass-rearing technologies, sex separation methods, sterilization and release procedures for *An. arabiensis* and *Ae. albopictus*. Agency staff participated in the meeting of the steering and scientific committees of the project on 4-5 April 2012 at the CRVOI in La Réunion. The meeting ascertained that adequate baseline data were collected for *Ae. albopictus* but noted that the objectives were not attained for *An. arabiensis* due to problems with colonizing this mosquito species. The project will be extended until the end of 2013 and will shift its focus to *Ae. albopictus* which represents the main health threat (chikungunya) in La Réunion. Ministry of Health officials in La Réunion requested that studies be carried out to assess the acceptance of the SIT by the human population in order to develop a public relation campaign.

17. This project has generated great interest among representatives of the countries in the area. As a result, a national TC project in Mauritius and one regional TC project in Africa were approved by the Board of Governors for the 2012-2013 TC cycle. The kick-off meeting for the regional project entitled "Promoting the sharing of expertise and physical infrastructure for mass rearing mosquitoes and integration of the sterile insect technique (SIT) with conventional methods for vector control, among countries of the region" was held in April 2012 in Mauritius with all the participating countries.

18. A Reserve Fund Project in Pakistan was established in 2012 in response to the outbreak of dengue in Pakistan, which negatively impacts human health and the country's economy. The project is supporting capacity building in baseline data collection for mosquito dengue vector management in Pakistan.

19. The Agency continued to give support to a Pilot Field Programme conducted by the CAA in Bologna, Italy, which is implementing an SIT trial on the invasive *Ae. albopictus*. The trial demonstrated that the sterile mosquitoes were effective and that the pest population could be

significantly reduced. In connection with the official inauguration of the CAA as an IAEA collaborating centre on 11 May 2012, a four-year workplan (2012-2015) was elaborated between the CAA and the IAEA mainly to develop mass-rearing procedures for *Ae. albopictus*, to scale up mosquito production, to establish mosquito surveillance and to assess the use of SIT to control *Ae. albopictus* in several pilot sites.

C. Conclusion

20. Mosquito-borne diseases such as malaria, dengue, yellow fever and chikungunya remain among the most severe threats to the health of millions of people worldwide. Due to globalisation and climate change, many species of mosquitoes are expanding and have spread to previously mosquito-free areas. This has resulted in more frequent outbreaks of these diseases in the past decade. Most of these mosquito populations are currently being controlled using insecticide-based methods, which result in other health threats and resistance in the mosquitoes. The Sterile Insect Technique (SIT), as part of an area-wide integrated pest management approach offers some hope as an environmentally friendly control method. However, the development of the SIT package for mosquitoes is still in its infancy and a long-term strategy with adequate human and financial resources is needed to develop the tools necessary to be able to implement a fully operational programme in Member States. The main challenge that needs to be addressed in the coming years is the development of good, productive genetic sexing strains that allow the easy and safe elimination of the female segment of the production line.

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

A. Background

1. In resolution GC(55)/RES/12 A.3. the General Conference expressed its appreciation of the importance of livestock development in rural communities affected by tsetse flies and trypanosomosis (T&T) as a pathway out of poverty and hunger and a basis for food security and socio-economic development. In this context it appreciated the continued high priority assigned by the Agency to agricultural development in Member States, including efforts to further develop and build capacity for integrating the sterile insect technique (SIT) with other control techniques. It expressed appreciation for the efforts made by the Secretariat, in close cooperation with the Pan African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC) and other mandated specialized UN organizations and some donor Member States, in creating awareness regarding the tsetse fly and trypanosomosis problem, developing maps, manuals and technical guidelines, and providing, through the Technical Cooperation Programme and the Regular Budget Programme, operational assistance to field projects as well as advice regarding project management and policy and strategy development in support of national and subregional AU-PATTEC projects, to enable a standardized, phased and conditional project planning and implementation approach.

2. The General Conference took note of the request of AU-PATTEC to the Agency to continue providing support in further developing and applying the SIT against tsetse flies as part of an area-wide integrated pest management (AW-IPM) effort, and specifically in tsetse mass rearing, relevant operational research, project management, baseline data collection and feasibility assessment in field project, and it acknowledged the reported benefits already generated for affected communities in the Ethiopian Southern Rift Valley and the technical progress in Senegal. The General Conference stressed the need for continued harmonized, synergetic efforts by the Agency and other international partners, and it urged the Secretariat to strengthen capacity development as necessary for implementing the operational national and regional PATTEC projects. The General Conference further requested the Secretariat, in cooperation with Member States and international organizations, to maintain funding – through the Regular Budget, the Technical Cooperation Fund and other partnerships – and to strengthen its support for R&D and technology transfer to African Member States to complement their efforts to create and subsequently expand tsetse-free zones. It urged the Secretariat to support the establishment of regional training centres in the affected Member States so as to promote the development of the human resources necessary for implementing the operational national and regional PATTEC projects.

3. The General Conference stressed the need for continued harmonized, synergetic efforts by the Agency and other international partners, particularly the Food and Agriculture Organization (FAO) and World Health Organization (WHO), with the aim of supporting the African Union Commission (AUC) and Member States through the provision of guidance and quality assurance in planning and implementing national and subregional AU-PATTEC projects. It requested the Director General to report on the progress made in the implementation of this resolution to the Board of Governors and to the General Conference at its fifty-sixth (2012) regular session.

B. Work since the 55th General Conference

4. In consultation with its international partners, particularly FAO and WHO, the Agency maintained close interaction with AU-PATTEC and provided, based on the existing memorandum of understanding (MoU) with the IAEA, assistance to the six current national PATTEC projects in Burkina Faso, Ethiopia, Ghana, Kenya, Mali and Uganda. In August 2011 the African Union Office of the Director of Rural Economy and Agriculture (DREA) appointed Dr Hassane Mahamat as new PATTEC Coordinator.

5. The AUC invited 25 participants from T&T affected countries and international and regional organisations (including IAEA) to a workshop in Addis Ababa, Ethiopia, 24–25 November 2011, to review the PATTEC Plan of Action which had been developed ten years earlier and approved by the African Heads of States and Government at the African Union (AU) Summit in Lusaka, Zambia, 2001. Participants discussed lessons learned from implementing activities under the PATTEC Plan of Action during the past ten years and initiated the development of a new PATTEC Strategic Framework document by establishing four working groups for the following topics: a) vector control/eradication; b) human trypanosomosis; c) animal trypanosomosis; and d) land use development. The PATTEC Coordination Office intends to submit the new PATTEC Strategic Framework document for consideration to the AU Summit in 2012. The IAEA also participated in the 3rd PATTEC Partners' Conference in Nairobi, Kenya, 9 December 2011, where Ministers of T&T affected countries and representatives of major international stakeholders, including the mandated UN organisations, international and national research institutions, African regional economic communities (RECs), non-government organisations (NGOs) and the private sector, reported on their on-going and planned activities against T&T. The IAEA also participated in the 10th PATTEC Coordinators' meeting in Accra, Ghana, held on 13–15 June 2012.

6. The FAO, the IAEA and WHO continued to cooperate, together with other partners, in the Programme Against African Trypanosomosis (PAAT), as a means to synergise their support to Member States' T&T efforts. During the past two years, a panel of external experts reviewed PAAT and identified a list of action to be taken to ensure that the activities of PAAT will be properly harmonised and aligned to support the mandate of the new PATTEC coordination unit. Further consultation between PAAT and PATTEC will be needed.

7. Following close consultations with PATTEC, FAO, WHO and several national PATTEC coordinators, the IAEA organized two regional training courses on 'Standardized Collection and Processing of Tsetse Flies for Molecular Tsetse Population Genetic and Morphometric Analyses' and on 'Standardized Entomological Monitoring, Data Collection and GIS-aided Data Processing as needed for Area-wide Integrated Pest Management campaigns against the Tsetse and Trypanosomosis Problem' in Nairobi, Kenya, 23 January – 3 February 2012, and in Bobo-Dioulasso, Burkina Faso, 6–24 February 2012, respectively. The course in Bobo-Dioulasso, Burkina Faso, was hosted by the Centre international de recherche-développement sur l'élevage en zone sub-humide (CIRDES), which is the first IAEA Collaborating Centre in Africa.

8. The Insect Pest Control Laboratory (IPCL) of the Joint FAO/IAEA Division in Seibersdorf worked to develop an integrated management system for the tsetse salivary gland (SG) virus that is hampering the mass-rearing of *Glossina pallidipes* (*G. pallidipes*), one of the economically most important tsetse fly species. A combination of virus management tactics such as an anti-viral drug and a modified feeding regimen was successfully validated at the IPCL and introduced for improved rearing of *G. pallidipes* at the Institute of Zoology, Slovak Academy of Sciences (IZ-SAS) in Bratislava, Slovakia. The protocol was also transferred to the tsetse mass rearing and irradiation centre of the Southern Tsetse Eradication Project (STEP) at Kaliti, Addis Ababa, Ethiopia.

9. 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 Trypanosomosis Problem’. The funding is being used to validate in the field methods developed by the IPCL in the framework of IAEA Coordinated Research Projects (CRPs) in support of a tsetse SIT project in Senegal-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. The results are expected to benefit several AU-PATTEC tsetse control and eradication programmes in Africa and to contribute to agricultural development and food security.

10. The Agency continued to manage two T&T CRPs involving 21 Member States: ‘Improving SIT for Tsetse Flies through Research on their Symbionts¹ and Pathogens’ and ‘Applying GIS and Population Genetics for Managing Livestock Insect Pests’. During this reporting period, two research coordination meetings (RCMs) were held at CIRDES in Bobo-Dioulasso, Burkina Faso, from 10–14 October 2011, and at the IAEA in Vienna, Austria, from 26–30 March 2012, respectively. During the RCM at CIRDES, participants benefitted from practical tutorials and working sessions on the use of free open source software (FOSS) for geographic information system (GIS) aided field work. The meeting generated specific technical recommendations regarding individual work plans. As a result, population, genetic, and other studies are being pursued; geo-referenced information will be gathered to assess the differences between *Glossina pallidipes* populations; detailed information is being obtained on the northern distribution limits for *G. pallidipes*, *Glossina palpalis gambiensis* and *G. tachinoides* in Burkina Faso; and a standardized spatial platform to be linked with FOSS GIS software is being developed for use by the CRP participants. The CRP on tsetse symbionts and pathogens studied interactions between tsetse flies and their symbionts. The tsetse SG virus was characterized and classified, which enabled developing strategies to effectively manage the virus in tsetse mass-rearing. The CRP also resulted in a better understanding of the tsetse flies’ nutritional ecology and of tsetse-pathogen interactions that could lead to improved mass-rearing procedures and control methods.

11. A consultants meeting on ‘Enhancing Vector Refractoriness to Trypanosome Infection’, was organized in Vienna, Austria, 10–14 October 2011, to discuss the current state of knowledge on controlling the susceptibility of the vectors of trypanosomes to their pathogens, on-going research on methods to change the susceptibility, and the need for future research and development in this area. The meeting reviewed options for developing strains of tsetse fly species for use in SIT operations that are unable to transmit trypanosomes. Several approaches are currently being investigated in this respect, including drug treatment, manipulation through infection with symbionts and their modification to express anti-trypanosome peptides. The meeting concluded that more work on these approaches is needed to better understand the mechanisms involved, to determine the level of refractoriness achievable, and to develop the necessary tools to produce refractory tsetse fly strains. The meeting drafted a proposal for a new CRP to address the identified research needs.

12. Currently, the Agency supports the AU-PATTEC Plan of Action through two regional technical cooperation (TC) projects in Africa and six national TC projects in Chad, Ethiopia, Senegal, Uganda, Tanzania and Zimbabwe (CHD5003, ETH5016, SEN5033, UGA5033, URT5027 and ZIM5017). In the past year the Agency provided assistance, 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.

¹ Beneficiary microbes

13. The IAEA has been providing support to STEP for the last 14 years. This large and complex project aims at controlling and eventually eliminating the T&T problem over 25 000 km² in the Ethiopian Southern Rift Valley by developing and applying an AW-IPM approach, involving an SIT component. The project has implemented the phases of baseline data collection and feasibility assessment and is currently in the pre-operational and capacity building phase. In order for STEP to enter, and receive Agency support for, the operational phase, several action points were identified that require attention. In August 2011 the Ethiopian Government and IAEA agreed that before entering the operational phase, good progress needs to be achieved on all identified action points by August 2012. A review carried out on 23-24 April 2012 in Addis Ababa, Ethiopia, by the International Management Advisory Committee, which provides technical and management review and oversight to STEP, and a High Level Meeting held in Ethiopia from 23 to 26 April 2012 concluded that STEP had made good progress in addressing issues that had been identified in an earlier external OIOS² study conducted in September 2008. The Advisory Committee review includes the introduction of an appropriate mechanism for project oversight, the revision of the managerial set-up and the implementation of recommended actions in several technical areas related to the mass production of sterile male tsetse flies and field operations. Furthermore, weekly aerial releases of sterile *Glossina fuscipes fuscipes* (*G. f. fuscipes*) male flies were initiated in early April 2012 in the Deme basin. The progress made in this project was recognized in recent hearings in the Ethiopian House of Representatives and was broadly conveyed to the Ethiopian public through TV, radio and newspaper articles.

14. Collaborators in Uganda have made progress with the standardized collection and processing of field data relevant to the tsetse and trypanosomosis 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 meanwhile appears to be in a position to produce substantially more sterile male flies of this species than required for the SIT operations in the STEP project area, Ethiopia and Uganda entered into negotiations and elaborated plans for the procurement of sterile males for an SIT feasibility demonstration in a small pilot area in Lake Victoria in Uganda. The Agency is supporting the Ugandan Government's efforts during the 2012-2013 biennium through a regional TC project in Africa and a national TC project.

15. In close collaboration with other partners, namely CIRDES in Bobo-Dioulasso, Burkina Faso, FAO, the IZ-SAS, the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), and the US Government via the PUI, the Agency continued to support Senegal in implementing the pre-operational phase of an AW-IPM campaign that includes the SIT to create a zone free of *G. p. gambiensis*. Pre-release population suppression in the northernmost part of the target area (the Niayes zone in Senegal) demonstrated the efficiency of the selected control tactics. Following weekly shipments of sterilized male *G. p. gambiensis* pupae from CIRDES (in 2011-2012) and the IZ-SAS (in 2012) to Dakar, weekly trial releases in four pilot areas showed excellent survival, dispersal and mating competitiveness of the sterile male flies that were irradiated and transported in the late pupal stage. In late 2011, a Central American specialist company (Mubarqui) donated a prototype chill fly aerial release system for tsetse SIT, together with some special navigation equipment, and software for recording and navigation. Also in Senegal, the IAEA support strictly adheres to the phased and conditional planning and implementation approach for AW-IPM projects that include an SIT component, whereby the project advances from baseline data collection to feasibility assessment to capacity building and pre-operational assistance, followed by an independent external status review, before a decision can be made to initiate the operational phase. In May 2012, the Senegal tsetse project was positively evaluated by the external review, following which operational

² IAEA Office for Internal Oversight Services

pre-release suppression activities were initiated in the central part of the target area, while the northern part of the target area was covered with area-wide releases of sterile males.

16. The third regional coordination meeting of a TC regional project in Africa was held in Pretoria, South Africa, in November 2011, and was hosted by the Onderstepoort Veterinary Institute (OVI). Scientists from the OVI, the Department of Veterinary Services, KwaZulu Natal (KZN), the Ministry of Agriculture, Mozambique and the Eduardo Mondlane University (EMU), Maputo, Mozambique, as well as Dr Hassane Mahamat, the new Coordinator of the AU-PATTEC, attended the meeting. Two tsetse fly species, *G. brevipalpis* and *G. austeni*, exist in large parts of KZN and the trypanosomosis prevalence averages around 19%. The disease is mainly managed through the curative administration of trypanocidal drugs, usually after clinical diagnosis. In Mozambique, preliminary veterinary surveys of about 2'000 cattle revealed a trypanosomosis prevalence of about 15%, which confirms the need for intervention measures. However, to develop an appropriate intervention strategy, further entomological and veterinary baseline data surveys will be needed to collect essential base line data. In order to effectively and efficiently plan and implement these baseline data collection efforts, customized land cover maps are being developed. Project counterparts disclosed at the regional coordinators' meeting that the Department of Agriculture, Environmental Affairs and Rural Development and the KZN Ezemvelo Wildlife had signed a formal document endorsing a programme to eradicate tsetse from KZN. It is anticipated that this document will clear the way towards implementing a tsetse eradication programme in KZN.

C. Conclusion

17. Tsetse and trypanosomosis remain a major obstacle to rural development in significant parts of Africa. In several areas that are currently not subjected to intervention measures, 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 integrated pest control approach, maintains its appeal as a unique and environmentally friendly nuclear application. Yet there remain challenges, including the establishment of appropriate management structures to appropriately deal with such complex and logistically demanding programmes, the development of the SIT for different species with different biologies, and the adaptation of each project to unique ecological and socio-economic conditions and requirements needed for success.

18. Area-wide activities in Ethiopia, in support of Resolution GC(55)/RES/12.A.3 have resulted in the suppression of *Glossina pallidipes* tsetse populations over ca. 10'000 km² of the Southern Rift Valley, thereby protecting livestock from trypanosomosis infection. The experienced substantial reduction of the tsetse and trypanosomosis problem has already permitted an increase of productive livestock and opened up opportunities for sustainable agricultural and rural development, benefitting thousands of farmers. Similar efforts against tsetse in the Niayes region of Senegal to suppress *G. palpalis* gambiensis populations are making good progress. In both Member States sterile fly releases have been initiated with the goal to eventually achieve eradication. Despite this progress, challenges remain. The scarcity of sterile male tsetse production facilities in Africa remains the most critical bottleneck for the expanded application of SIT against tsetse. Besides just five institutes holding seed- or back-up tsetse fly colonies, there are only two large tsetse mass-rearing centres, in Addis Ababa, Ethiopia, and in Bobo-Dioulasso, Burkina Faso (the latter is anticipated to be completed only by late 2012). The lack of tsetse SIT capacity and the need for a more harmonized sub-regional utilization of the existing fly production capacity should be addressed by the different partners, possibly with the involvement of the private sector.

Strengthening the Support to Member States in Food and Agriculture

A. Background

1. At its fifty-second session in 2008, the General Conference, through resolution GC(52)/RES/12.A.5, requested the Director General to report on the progress made in the implementation of the resolution on “Strengthening the support to Member States in food and agriculture” to the Board of Governors and the General Conference at its fifty-fourth (2010) regular session and subsequently every two years. Following the Report to the General Conference at its fifty-fourth session in September 2010, the General Conference, through resolution GC(54)/RES/10.A.4, urged the Secretariat to address the impacts of climate change on food and agriculture through the use of nuclear technologies, with priority on adaptation and mitigation of climate change in the areas of soil and water management, insect pest control, plant breeding, livestock production and food safety; to continue to strengthen its activities in the field of food and agriculture through inter-regional, regional and national capacity building, to facilitate the transfer of technologies to developing Member States; and to seek extrabudgetary funding for infrastructure improvement and modernization of the Seibersdorf Laboratories, especially the Food and Agriculture (FAO)/IAEA Agriculture & Biotechnology Laboratories.

2. The General Conference further encouraged the Secretariat to further strengthen its partnership with the FAO and to continue adjusting and adapting its technology development, capacity building and technology transfer and services in response to Member States’ demands and needs in food and agriculture; and requested the Secretariat to expand, in an integrated and holistic manner, its efforts to address, inter alia, food insecurity in Member States and to increase its contribution to raising agricultural productivity and sustainability through the development and integrated application of nuclear science and technology; and to work towards the modernization of the FAO/IAEA Agriculture & Biotechnology Laboratories in Seibersdorf, in conjunction with the other programmatic entities of the laboratories of the Department of Nuclear Sciences and Applications, in order to assist Member States’ research and development activities. Finally, the General Conference requested the Director General to report on the progress made in the implementation of this resolution to the Board of Governors and the General Conference at its fifty-sixth (2012) regular session.

B. Work since the 54th General Conference

B.1. Strengthening the FAO/IAEA partnership

3. By actively contributing to the development of the FAO Programme of Work and Budget for 2012-2013, the Joint FAO/IAEA Division was able to fully capitalize on synergies to link the programmatic goals of the FAO with those of the IAEA. In particular, it will be able to make important contributions in five of FAO’s 13 specific strategic objectives through capacity building,

research and development, and the provision of technical support for the application of nuclear techniques in Member States, namely: 1) sustainable intensification of crop production; 2) increased sustainable livestock production; 3) improved quality and safety of foods at all stages of the food production chain; 4) sustainable management of land, water and genetic resources; and 5) improved responses to global environmental challenges affecting food and agriculture.

4. To further strengthen and consolidate the Joint Division's partnership with the FAO and to ensure full cooperation and a rapid response at the field level to Member States' requests and needs in food and agriculture, consistent involvement of the Joint Division at FAO regional conferences and reporting to country and regional offices has been instituted. This has contributed substantially to raising the visibility of the Joint FAO/IAEA Programme with Member States' agricultural authorities, to obtaining feedback on evolving Member States' needs in food and agriculture, to improving the demand-driven process of the Joint Programme and to further strengthening and expanding the cooperative network with external stakeholders.

5. Coordination with FAO sister divisions in the implementation of programmatic activities in the field has been substantially improved through the involvement of FAO Rome and of FAO Regional, Sub-regional, and Country offices at all stages of programme planning and implementation; through the involvement of FAO experts in IAEA Technical Cooperation Projects (TCPs) and Coordinated Research Projects (CRPs); through reciprocal visits during duty travels and regular communication with counterparts. The Joint Division also strengthened coordination with sister divisions and departments in FAO headquarters to improve programming synergy and increase contributions to FAO strategic objectives.

6. Substantial efforts have been made in the past biennium to increase outreach activities promoting the activities and achieved impacts of the Joint FAO/IAEA programme and encouraging external stakeholders and Member States to capitalize on the strengths and technologies endorsed by the Joint Division. This included a Study Tour by the Rome-based FAO Permanent Representatives of 22 Asian countries to the Joint Division (Vienna and Seibersdorf); the distribution of more than 50 country impact reports, numerous presentations to scientific and non-scientific audiences, and the preparation of almost 80 publications. A similar study tour for African representatives will take place later in 2012.

7. Mr José Graziano da Silva, elected as the new Director-General of the FAO in January 2012, declared the following as the five pillars for FAO's new strategy: eradication of hunger; sustainable food production and consumption; greater fairness in global food management; conclusion of FAO's organizational reform to improve efficiency, transparency and accountability; and expansion of partnerships and South-South cooperation. During the FAO/IAEA Steering Committee meeting in February 2012, FAO senior management noted that the Joint Division is very much in line with these priorities and indicated their desire to further strengthen cooperation with the IAEA through the Joint Division.

B.2. Recent achievements of the Joint FAO/IAEA Programme

8. During the past biennium, Member States have achieved numerous successes using nuclear and related techniques with support from the Joint Programme. These techniques enable farmers, food manufacturers and government agencies to provide more, better and safer food, while reducing agricultural inputs, such as pesticides and fertilizers, and conserving soil and water resources and the biodiversity on which these products depend. Through these successes, the Joint Division continues to contribute to achieving the Millennium Development Goals. Some of the most notable achievements are highlighted below.

9. Three institutions received official designation as IAEA Collaborating Centres in Burkina Faso, Costa Rica, and Italy, bringing further strength and benefits to the Joint Division's mission.

10. Also, following the successful IAEA Scientific Forum on "Water Matters: Making a Difference with Nuclear Techniques" in 2011, the 2012 IAEA Scientific Forum is dedicated exclusively to food and agriculture. It is titled "Food for the Future: Meeting the Challenges with Nuclear Applications - Increasing Food Production, Ensuring Food Protection, Enhancing Food Safety".

11. In 2012 the IAEA Seibersdorf Laboratories celebrate half a century of dedicated support to Member States in their efforts to promote atoms for peace. Throughout these years, the activities of the FAO/IAEA Agriculture & Biotechnology Laboratories have consistently remained at the forefront in fostering the use of nuclear science and technology in Member States wherever these offer unique opportunities or provide added value.

12. The Joint Division currently coordinates 33 CRPs involving approximately 500 research institutions and experimental stations in Member States, and is responsible for providing scientific and technical support to more than 230 national, regional and interregional IAEA TCPs. During the period 2011-2012, some 65 workshops, seminars and training courses were held with the participation of about 1275 trainees from developing countries, with more than 90 per cent being held in locations in developing countries in 2011-2012.

13. New demand-driven R&D activities have been initiated at the FAO/IAEA Agriculture & Biotechnology Laboratories in Seibersdorf in response to Member States' needs, including the development of the sterile insect technique to control mosquitoes, the use of isotopes in food traceability, the investigation of irradiated animal vaccines, the application of stable isotopes in tracing technologies, and the enhancement of animal disease diagnostic applications, including for foot-and-mouth disease (FMD).

14. FAO's member countries adopted in June 2011 a Conference resolution declaring global freedom from rinderpest, the first animal disease to have ever been eradicated. This momentous achievement, in which the IAEA played an important role during the past twenty years by contributing its diagnostic capabilities and knowhow, building capacity at national and regional levels, improving epidemiological studies and data management and setting up pertinent networks, was celebrated during the IAEA's 55th General Conference. Awards in recognition of outstanding contributions towards achieving freedom from rinderpest have been bestowed on the Joint Division by the Government of Kenya, the African Union Interafrican Bureau for Animal Resources (AU-IBAR) and the FAO.

15. During the FMD outbreak in Mongolia in 2011, a vaccination initiative based on the official national FMS control programme was implemented and 200'000 doses of vaccine were delivered through a national TC project. The action proved effective and the spread of FMD was contained. Over 1'000'000 animals were saved directly, and another 10'000'000 indirectly. The Agency also assisted Mongolia in the development of a pilot facility for the production of irradiated vaccines. Additionally, cooperation with FAO, the World Organization for Animal Health OIE and neighbouring countries was pursued to establish a regional network for animal disease control.

16. With technical input from the Agency, two International Standards for Phytosanitary Measures (ISPMs) on "Fruit Fly Trapping" and "Systems Approaches for Pest Risk Management of Fruit Flies" and a total of six additional internationally agreed post-harvest phytosanitary irradiation treatments were adopted by the International Plant Protection Commission (IPPC) and included in the IPPC Standard on Phytosanitary Treatments for Regulated Pests. This is expected to lead to increased facilitation of international trade in fresh produce through the standardization and control of insect

pests of quarantine importance, improving the capacity of Member States to export produce and participate in international trade.

17. The Mediterranean fruit fly was officially declared eradicated from two areas comprising 300 000 hectares in north-western Guatemala, facilitating the export of fresh fruit and vegetables to the USA and other high-value, medfly-free international markets without the need for costly post-harvest treatments. Earnings from the export of non-traditional crops such as bell-peppers, tomatoes or papayas have increased several-fold in this and other Central American countries due to the Agency's technology transfer, which has allowed these countries to overcome phytosanitary trade barriers and creating thousands of rural jobs.

18. Area-wide efforts in Ethiopia, in support of Resolution GC(55)/RES/12.A.3 on "Support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC)", have resulted in the suppression of *Glossina pallidipes* tsetse populations over ca. 10 000 km² of the Southern Rift Valley, thereby protecting livestock from trypanosomosis infection. The experienced substantial reduction of the tsetse and trypanosomosis problem has already permitted an increase of productive livestock and opened up opportunities for sustainable agricultural and rural development, benefitting thousands of farmers. Similar efforts against tsetse in the Niayes region of Senegal to suppress *G. palpalis gambiensis* populations are making good progress. In both Member States sterile fly releases have been initiated with the goal to eventually achieve eradication. (See separate Report).

19. Guidelines on the audit and accreditation of food irradiation facilities that irradiate food as a quarantine treatment were developed with technical input from the Agency and accepted as national protocols in several countries in the Asia/Pacific region. Their proposed adoption by the Asia and Pacific Plant Protection Commission as a regional standard is currently under consideration.

20. An improved, low-cost mutation detection kit with less background noise was distributed to 12 countries through TCPs where it has proven its applicability in 12 crop species, including wheat and banana. Advantages of the kit, on which a total of 100 fellows were trained, include its ease and speed of use and, most significantly, its low cost. It is therefore ideally suited to facilitate mutation discovery in developing countries.

21. Nine mutant varieties from six species in five Member States were released in 2011 through the direct support of the Joint Division. The FAO/IAEA Mutant Variety and Genetic Stock (MVGS) database now records 3218 officially released mutant varieties, an increase of 11% over the previous biennium. A total of 1482 advanced mutant lines from 12 crop species were reported through TCPs and CRPs in 2010, and a further 1409 lines from six crop species in 2011. More than 200 000 mutant germplasms were exchanged during this period.

22. The implementation of improved agricultural water management practices was successful in 13 Member States, with field impacts reviewed and reported at the IAEA Scientific Forum 2011. A CRP demonstrated that in winter wheat in China, approximately 66% of irrigation water applied through the traditional flooding system is lost to the crop. By using deficit irrigation while retaining overall yield, water use efficiency was increased by more than 50%, a significant saving in the increasingly water-scarce environments around the globe.

23. Through support provided by the Joint Division, the Kenyan Agricultural Research Institute (KARI) developed low-cost, small-scale drip irrigation technologies affordable to resource poor farmers and improved irrigation scheduling for high-value crops to reduce overall water requirements by up to 45%. The technology has now been transferred to the Maasai farmers through collaboration with the Green Belt Movement and the African Medical and Research Foundation (AMREF). Furthermore, KARI is now providing technical assistance and training to 23 African countries aiming

to improve agricultural water management under rainfed and irrigated agriculture in arid and semi-arid regions.

24. Many activities, still on-going, were undertaken in relation to emergency preparedness and response to nuclear incidents, including the accident at the Fukushima Daiichi nuclear power plant in March 2011. These comprised the dissemination of information on food monitoring and food restrictions, the consideration of agricultural countermeasures and remediation strategies to mitigate immediate and longer term effects arising from radionuclide contamination, and support to the World Health Organization (WHO) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) dose assessments to the public affected by the Fukushima accident. The Joint Division prepared contributions to some new advanced documents on remediation of areas affected by radionuclides. Several meetings were held to draw up a harmonized road map for further activities of both IAEA and FAO in the areas of nuclear safety (IAEA) and response to radiological and nuclear emergencies (FAO).

25. During the two years covered by this report, the Joint Division was successful in securing extrabudgetary funding both for the Joint Programme in general, as well as for specific projects and for infrastructure improvements. Substantial extrabudgetary funds were secured during this period from various initiatives including the IAEA Peaceful Uses Initiative (PUI), the United States Department of Agriculture (USDA) “Identify” project, and the African Renaissance and International Cooperation Fund (ARF) of South Africa. Additional funds were made available through the IAEA’s Major Capital Investment Fund for equipment and upgrades to the FAO/IAEA Agriculture & Biotechnology Laboratories in Seibersdorf, specifically the Plant Breeding & Genetics Laboratory, the Animal Production & Health Laboratory and the Insect Pest Control Laboratory. However, these funds are not sufficient for the modernization and upgrading of these laboratories.

Nuclear Energy Activities

1. This annex summarizes highlights of Agency activities not covered in Annexes 5 and 6, which address nuclear knowledge management and innovative nuclear technology respectively.
2. The Agency annually updates its low and high projections for global growth in nuclear power. The projections made in 2011 indicated that the accident at the Fukushima Daiichi nuclear power plant was expected to delay the growth of nuclear power but not reverse it. The projections made in 2012 also reflected this conclusion, but with a greater delay in growth. In the low projection made in 2011, global nuclear power capacity grew to 501 GW(e) in 2030. In the 2012 low projection it grows to 456 GW(e). In the high projection made in 2011, global capacity grew to 746 GW(e). In the 2012 high projection, it grows to 740 GW(e).
3. At the 17th Session of the Conference of the Parties (COP 17) to the United Nations Framework Convention on Climate Change (UNFCCC), held in December in Durban, South Africa, the Agency maintained an information centre that presented the Agency's work on the linkages between climate change and nuclear power and provided an opportunity to discuss with delegates broader issues pertaining to nuclear energy. Agency publications distributed at the centre included a brochure, *Climate Change and Nuclear Power 2011*, which provides updated information on all aspects of nuclear power in the context of current climate change concerns. At the June 2012 UN Conference on Sustainable Development, 'Rio+20', the Agency organized a side event on *Sustainable Energy, Food, Water & Oceans* and an 'SD-Learning' event on *Energy Planning*. The Agency also maintained an information centre throughout the conference and participated in side events organized by Brazil's Eletrobras Eletronuclear and by UN Energy.
4. The Agency expanded its guidance and assistance for long term operation and initiated an annual 'Nuclear Industry Cooperation Forum', which recommended increased cooperation with utilities, greater interactions between operating organizations in countries with experience in the nuclear area and those introducing nuclear power, more effective communication, and strengthened dissemination of best operational practices. As part of its development of guidelines for approaches and models related to plant life management (PLiM) for long term operation, the Agency published in September 2011 *Stress Corrosion Cracking in Light Water Reactors: Good Practices and Lessons Learned* (IAEA Nuclear Energy Series No. NP-T-3.13), which describes damage mechanisms associated with stress corrosion cracking of concern to systems, structures and components (SSCs) in light water reactors. In May 2012, the Agency organized the Third International Conference on Nuclear Power Plant Life Management in Salt Lake City, Utah, USA. The conference focused on good practices related to the safety aspects of ageing, ageing management and long term operation and identified the economic impacts of PLiM programmes and methods to evaluate them.
5. Human resource development remains a high priority, particularly for Member States considering launching nuclear power programmes. A training course on leadership and management for countries introducing nuclear power was organized jointly by the Agency and Argonne National Laboratories in the USA in November 2011. In October 2011, the Republic of Korea hosted the third mentoring programme to be organized by the Agency and the Korea Hydro & Nuclear Power Company (KHNP), at which future leaders of nuclear power projects in six countries introducing nuclear power were mentored by recently retired KHNP executives. A technical meeting in November on 'Recruitment, Training and Qualification of Personnel for New Nuclear Power Programmes' provided an opportunity for both newcomers and Member States with established programmes to share experience. At the 55th regular session of the General Conference, the USA presented the Agency with 'Nuclear

Power Human Resources' (NPHR), a software modelling tool that can be adapted for workforce planning for new and expanding nuclear power programmes.

6. The Agency's assistance to Member States introducing nuclear power placed greater emphasis on preparatory activities, and a meeting in October 2011 considered the development of Integrated Nuclear Infrastructure Review (INIR) missions to be carried out prior to commissioning, as called for in the *IAEA Action Plan on Nuclear Safety*. In November, the Agency completed a sixth INIR mission to Bangladesh. In January 2012, the first INIR follow-up mission was completed, in Jordan. Also in January, the Agency held the sixth annual workshop in Vienna on *Managing the Development of a National Infrastructure for Nuclear Power Plants*, which was attended by participants from 43 Member States. The seventh INIR mission was conducted in June 2012 to Belarus.

7. The latest update of the biennial 'Red Book' — *Uranium 2011: Resources, Production and Demand* — was published jointly by the Agency and the OECD/NEA in July 2012. Identified conventional uranium resources, recoverable at a cost of less than \$130/kg U, are currently estimated at 5.3 million tonnes uranium (Mt U). This is a decrease of 1.4% compared to the 2009 edition. The small change was due largely to decreases in resources in India and Jordan combined with smaller reductions in Algeria, Australia, Canada, Kazakhstan, Namibia and Uzbekistan. However, these reductions were in part matched by substantial increases in Niger and Tanzania along with smaller increases in Mongolia, the Russian Federation, Slovakia and Ukraine.

8. The Agency helps Member States pool information and coordinate research on the development, design, manufacture, use in reactors, and performance analysis of nuclear fuel. In October 2011, the Agency published the results of a CRP on *Optimization of Water Chemistry to Ensure Reliable Water Reactor Fuel Performance at High Burnup and in Ageing Plant (FUWAC)* (IAEA-TECDOC-1666). The final report presents insights in five areas: corrosion of primary circuit materials, the composition and thickness of deposits on fuel, crud induced power shift, fuel oxide growth and thickness, and radioactivity buildup in the reactor coolant system.

9. In the area of radioactive waste management and decommissioning the Agency published *Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities* (IAEA Nuclear Energy Series No. NW-G-2.1), *Decommissioning of Small Medical, Industrial and Research Facilities: A Simplified Stepwise Approach* (IAEA Nuclear Energy Series No. NW-T-2.3), *Viability of Sharing Facilities for the Disposal of Spent Fuel and Nuclear Waste* (IAEA-TECDOC-1658) and *BOSS: Borehole Disposal of Disused Sealed Sources* (IAEA-TECDOC-1644). In Lithuania, an expert mission reviewed proposed design options for a near surface repository for short lived radioactive waste near the shutdown Ignalina nuclear power plant. In Malaysia, Agency missions reviewed both the ongoing site selection programme for a near surface repository for short lived radioactive waste and radiation safety at the Lynas rare earth processing facility. In the UK, the Agency reviewed the decommissioning programme for the fleet of first generation gas cooled reactors. In the Republic of Korea, a mission reviewed proposals for a geological disposal system for pyro-processed waste. In cooperation with the Technical University of Clausthal, Germany, the Agency organized a 6-week training course on radioactive waste management, decommissioning, environmental remediation and disused sealed source management. Finally, at the request of the Japanese Government, the Agency sent an international expert mission to Japan in October 2011 to help develop remediation plans. The mission's final report was issued to the Japanese Government in November 2011 and was made publicly available.

10. With respect to collaborative efforts between Member States to improve research reactor utilization, the final coordination meeting of a technical cooperation project on 'Enhancing the Sustainability of Research Reactors and their Safe Operation through Regional Cooperation, Networking and Coalitions' was held in December 2011. The project proposed the creation of a new

cooperative coalition of research reactor operators for the Commonwealth of Independent States (CIS) similar to those that have been established for the Baltic, Caribbean, Central African, Eastern Europe, Eurasian and Mediterranean regions.

11. The International Conference on ‘Research Reactors: Safe Management and Effective Utilization’, organized every four years by the Agency, was hosted in Rabat in November 2011 by the Government of Morocco. More than 200 participants from 42 Member States discussed key issues facing the research reactor community, including safe utilization. These included possible implications of the accident at the Fukushima Daiichi nuclear power plant for some research reactors, utilization and maintenance issues, and preparations for new research reactors.

12. The Agency contributed to the continuing conversion of research reactors from HEU to LEU. Mexico signed agreements to convert its TRIGA research reactor to LEU fuel and repatriate HEU fuel to the USA. The first of two LEU fuel shipments arrived in Mexico in December 2011. In February 2012, the second shipment arrived and all fresh and spent HEU fuel was returned to the USA. A tripartite contract was signed with the Kharkov Institute in Ukraine in October 2011, and the last fresh HEU fuel stockpile at the institute was returned to the Russian Federation in March 2012.

Nuclear Knowledge Management

1. In resolution GC (54)/RES/10.C (2010), the General Conference recognized that preserving and enhancing nuclear knowledge and ensuring the availability of qualified personnel are vital to all aspects of human activity related to the continued and expanded safe and secure utilization of all nuclear technologies for peaceful purposes, and noted continuing concerns about a shortage of personnel in nuclear fields and a possible erosion of the nuclear knowledge base.
2. The Secretariat was requested to continue to strengthen its current and planned efforts in this area, in a holistic, interdepartmental manner, while consulting and engaging Member States and other relevant international organizations, and to further increase the level of awareness of efforts in the preservation and enhancement of nuclear knowledge.
3. The General Conference requested the Director General to report on progress made to the Board of Governors and to the General Conference at its fifty-sixth session and every second year thereafter. This report responds to that request.

A. Strengthening nuclear knowledge management

4. The Agency continues its nuclear knowledge management (NKM) activities focused on formulating and providing guidance and services, facilitating knowledge sharing networks, developing pilot projects, and fostering and supporting nuclear education and training. Current activities are also to a great extent driven by the IAEA Action Plan for Nuclear Safety related to capacity building, including human resources development, education and training, knowledge management and knowledge networks, which was prepared in response to a recommendation of the Ministerial Conference on Nuclear Safety held in June 2011.
5. The value of a long term strategy on NKM within the framework of a sustainable nuclear development policy is currently broadly recognized and demand from Member States for support in implementation of NKM policies and tools has increased significantly.
6. Further documents and guides are required and, as part of an effort to meet this need, the following reports have been published since 2010: *Status and Trends in Nuclear Education* (IAEA Nuclear Energy Series No. NG-T-6.1), *Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation* (IAEA Nuclear Energy Series No. NG-T-6.7), *Workforce Planning for New Nuclear Power Programmes* (IAEA Nuclear Energy Series No. NG-T-3.10), *Evaluation of Human Resource Needs for a New Nuclear Power Plant: Armenian Case Study* (IAEA-TECDOC-1656), and *Knowledge Management for Nuclear Research and Development Organizations* (IAEA-TECDOC-1675).
7. A further fifteen documents are in preparation involving a high level of participation from Member States. In this connection, meetings have been held in 2012 to address new topics, such as knowledge management and safety culture in nuclear organizations, knowledge preservation in major nuclear accidents, innovative methods and tools for nuclear education and training, implementing knowledge management in integrated management systems and establishing, developing and maintaining capacity building in Member States.

B. Building capacity and implementing nuclear knowledge management

8. An increased number of Member States included knowledge management components in national and regional technical cooperation (TC) projects, and are providing extra budgetary funds to the Agency for this purpose, such as Japan and the Republic of Korea.

9. In 2010, the Agency launched a Nuclear Energy Management School at the International Centre for Theoretical Physics (ICTP), Trieste, Italy, to introduce young professionals from developing countries to the principles of effective nuclear energy programme management. To date, the School, held annually, has attracted 70 participants from 30 countries with 240 applications received so far for the November 2012 School.

10. The first IAEA School of Nuclear Energy Management in the Gulf Region was hosted by the Government of the United Arab Emirates (UAE) and Khalifa University of Science, Technology and Research (KUSTAR) in January 2012 and drew 40 participants from Gulf Cooperation Council (GCC) countries. In addition, 40 participants from the Asian region took part in the School in Tokaimura, Japan, in June 2012, financed by the Government of Japan. Several countries have already approached the Agency to host similar events in the future, including Japan, Russian Federation and the USA.

11. The annual School of Nuclear Knowledge Management continues to be held in cooperation with the ICTP. Each year more than 130 applications are received, and between 30 and 40 young professionals from developing countries are trained depending on funds available. The School provides a basic understanding of NKM tools and challenges, as well as opportunities for sharing experiences and good practices with peers and experts. In 2012, a pre-training course based on e-learning techniques was developed which has already been taken by 78 pre-selected applicants via the IAEA cyber learning platform for nuclear education and training (CLP4NET). The pre-training course ensures that basic knowledge is provided to the students beforehand and thus allows more time at the School itself to cover case studies, revision of implementation problems and group project development in greater depth. Up to now, 280 young professionals have attended this School.

12. The Agency also conducted knowledge management seminars at the Shanghai Nuclear Engineering Research and Design Institute (SNERDI), China; at the Karlsruhe Research Centre, Germany, in cooperation with the European Commission (EC); in Sevastopol, Ukraine; and in Gelendzhik, the Russian Federation. The seminars provided a forum for exchanging experiences and information on knowledge management activities, lessons learned and good practices in different countries and nuclear organizations.

13. The Agency worked with educational institutions to promote close cooperation between industry, academia and government to ensure a sufficient number of qualified graduates to meet future workforce demands. In order to develop a NKM course at the Master of Science level to be taught at universities, a pilot project was launched involving more than 10 universities and designed to 'Train the Trainers'. At the first course held at the Karlsruhe Institute of Technology (KIT), Germany, in November 2011, young teachers were trained to deliver the NKM course at their respective universities. Some have already delivered the course, feedback will be provided on it during 2012, and a further group of teachers from other universities will be trained.

14. Multimedia products continue to be developed: more than 300 copies of the multimedia course on nuclear reactor physics have been distributed to Member States since September 2010; the first part of the interactive course on NKM can be accessed via the NKM website (<http://www.iaea.org/nuclearenergy/nuclearknowledge/>), which was updated in May 2012, and the

second part will become available in December 2012; over the last two years, 120 desk simulator CDs for nuclear power plants were distributed.

C. Nuclear knowledge management services

15. The Agency assists Member States in formulating country-specific policies on human resource development, education, training and knowledge management in support of nuclear power programmes. NKM assist visits to help counterparts benefit from the application of best practice NKM techniques were undertaken to Bulgaria, Kazakhstan, Russian Federation, Ukraine, USA, and Vietnam over the past two years and funded by both the Regular Budget and the Technical Cooperation Fund.

16. In Bulgaria, assistance was provided to improve and implement knowledge mapping technologies, and to assess organizational workload and evaluate future staffing needs under a national TC project, 'Managing Workforce Flow and Risk of Nuclear Knowledge Loss' (BUL/0/009).

17. With the assistance of Agency experts, the Kazakhstan Atomic Energy Committee launched a pilot version of a nuclear knowledge management portal.

18. In the Russian Federation, two teams were organized to visit ROSATOM and the Institute of Environment Monitoring – Scientific Production Association Typhoon respectively, and provided advice based on their observations and discussion.

19. Under TC project, 'Strengthening Knowledge Management in Nuclear Industry' (UKR/0/010), the Agency provided support to Ukraine in the development of a document on nuclear knowledge management systems in nuclear power plants (NPPs), assistance in the design and implementation of a Knowledge Management Portal for nuclear utilities, and advice on technical specifications for an educational laboratory on NPP control and safety.

20. At the Nuclear Power Institute (NPI) at Texas A&M University, USA, a Knowledge Management Assist Mission (KMAM) on benchmarking nuclear education programmes took place on 10-15 October 2011 to assist in reviewing the educational programme and share experience and best practices.

21. In Vietnam under TC project 'Developing of Nuclear Power Infrastructure' (VIE/4/015) as part of on-going Agency efforts to support capacity building for countries introducing nuclear power, a master plan for education and training to support an NPP programme was developed.

D. Applying nuclear knowledge management to development

22. As human resource development and knowledge management are the main vehicles for the transfer of technology by the Agency, supporting capacity building efforts in Member States is an important focus of the TC Programme. In 2011, the Agency approved more than 20 national and regional projects for the current 2012-13 TC cycle that are directly related in the area of nuclear knowledge management. Furthermore, almost all TC projects include an explicit component on human resources development and capacity building to create, transfer and preserve nuclear knowledge in Member States.

23. Preparations for the 2012-2013 TC programme cycle were completed in 2011 and included workshops and training events to strengthen project design capacity in Member States, streamlining the language and approach used. A number of areas for improvement, both operational and strategic, were identified in a quality review process and taken into account in the next TC cycle. Lessons learned from the review process have been incorporated into the guidelines for the preparation of the 2014–2015 TC programme cycle.

24. Agency support, in the form of fellowship, scientific visits, training of scientists and technicians and mentorship by Agency experts and consultants, was provided through national and regional projects, including projects under the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA) and the Co-operative Agreement for Arab States in Asia for Research, Development and Training related to Nuclear Science and Technology (ARASIA).

25. The Regional Designated Centres (RDCs) recognized by RCA and ARASIA continued to play a very important role in these efforts, as well as in the dissemination of know-how and good practice. Particular attention was given to the new Member States (Bahrain, Cambodia, Nepal) and those countries in the region classified as Less Developed Countries (LDCs) which have a pressing need for human resource capacity building

26. Throughout 2011, some 250 technicians and scientists from ARASIA Member States were trained in the areas of human health, food and agriculture, marine environment, nuclear analytical techniques, quality assurance and quality control in nuclear analytical techniques, naturally occurring radioactive materials (NORM), and energy planning. Regional cooperation under the RCA continued to be effective, and the group conducted a review of its programme development mechanism in 2011 in an effort to further improve the RCA programme.

27. Technical cooperation among developing countries (TCDC), or south-south cooperation, has proved to be an effective mechanism for mutual support in the region. As was the case in 2010, most experts recruited under RCA projects in 2011 were from within the region. The 2012–2013 RCA Programme was developed through rigorous consultation among RCA members and is based on the RCA Strategic Priorities for 2012–2017.

28. A series of workshops were held in 2011 under a regional TC project RER/0/028 ‘Improving Educational and Training Capabilities in Nuclear Science and Applications’. Topics included establishing connections with end-users, outreach and promotion of nuclear physics, education curricula in medical physics, career opportunities for professionals in nuclear science, and approaching external sources of research activities funding (such as the European Union’s Horizon 2020 Framework Programme for Research and Innovation). In Tajikistan, under TC project TAD/0/003, ‘Establishing a National Educational and Training Centre on Radiation Protection’, Agency support focused on ensuring that the training materials complied with Agency standards, checking for consistency and translating into Russian.

29. Management skills and networking among nuclear research and development institutions were developed under another regional TC project RER/0/031, ‘Strengthening Sustainability of Nuclear Research and Development Institutes in the Modern Science and Technology Environment’. In cooperation with the World Intellectual Property Organization (WIPO), the project increased the sustainability of nuclear knowledge in the open market economies. Training activities were focused on two main areas: increasing capacities in writing competitive research project proposals, communicating with stakeholders and improving presentation skills; and building capacities in technology licensing negotiation and protection of intellectual property rights. Participants created concrete project proposals with one proposal winning an EU research grant of EUR one million.

30. Intellectual property rights were also the focus of two important training events held in China and the Philippines on ‘Innovation, Technology Transfer and Successful Technology Licensing in Research and Development Institutions’, organized jointly by the IAEA and WIPO. Both events were attended by a large audience of scientists and decision-makers, who debated the issue of intellectual property as a means for innovation, promotion and successful technology transfer of research results from R&D institutions. The events provided information and training on legal and organizational infrastructure issues, including institutional policies, explained licensing procedures and how to use licensing as a means for technology transfer, as well as providing participants with opportunities for networking with potential stakeholders.

31. In connection with human health, food, agriculture, physical chemistry and water hydrology, coordinated research projects helped create and share new knowledge, and technical cooperation projects helped implement activities and disseminate results and data to address Member States’ needs. Programme elements that relate to NKM in a general manner include training courses at the Seibersdorf Laboratories, the Monaco Marine Environment Laboratories and in Member States’ laboratories. Distance-learning modules, web-based documents, and information and communication technology based training materials are being developed and made available on CDs and through the internet.

E. Applying nuclear knowledge management to strengthen safety, security and safeguards

32. The Agency’s safety standards and security guidelines provide the basis for the major NKM activities in nuclear safety and security. The IAEA safety standards crystallize state-of-the-art safety knowledge through the open and transparent peer review process and strategic feedback from their application, thus representing international consensus and today’s good practices worldwide. Safety services such as the Operational Safety Review Team (OSART), Integrated Regulatory Review Service (IRRS) and Safety Evaluation of Fuel Cycle Facilities During Operation (SEDO) are based on these standards, which further enhance knowledge management, information sharing and feedback. Most nuclear safety and security implemented activities have contributed to fostering networking and exchange of information and sharing knowledge among the Member States.³

33. New training materials, video presentations, brochures and leaflets in support of sharing knowledge and experience in the application of the Agency’s safety standards were produced or updated, thereby improving accessibility of this knowledge and these training resources. Specific video lectures on the safety of research reactors and the nuclear fuel cycle were developed and widely disseminated. Tailored workshops and training events were conducted in several areas of nuclear and radiation safety and nuclear security. New standard training packages were produced for radiation protection in paediatric radiology as well as for digital radiology. Video presentations were posted on the Agency’s website and used for training events. New videos were produced on the basis of workshops covering safety culture during pre-operational phases.

34. The Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources has continued to provide a pool of future experts in radiation protection. Basic professional training on nuclear safety and regulatory control as well as specialized workshops on human resources

³ More detailed references on the topic can be found in the report entitled “Measures to strengthen international cooperation in nuclear, radiation, transport and waste safety” (GOV/2012/28-GC(56)/6).

at nuclear installations based on relevant Agency safety standards have been continuously implemented.

35. Regional and global knowledge networks support NKM in facilitating the exchange of information, education and training and promoting human resources development. The Global Nuclear Safety and Security Network (GNSSN) continued strengthening the Global Nuclear Safety and Security Framework (GNSSF). In addition, regional networks and forums are valuable in improving safety and security at the regional and international level. These regional networks and forums are the Asian Nuclear Safety Network (ANSN), Arab Network for Nuclear Regulators (ANNuR), European Nuclear Safety Regulators Group (ENSREG), European Technical Safety Organizations Network (ETSON), Forum for Nuclear Regulatory Bodies in Africa (FNRBA) and Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO), and other thematic networks, such as the International Regulatory Network (RegNet), Regulatory Cooperation Forum (RCF) and Technical and Scientific Support Organization Forum (TSOF). The Regulatory Cooperation Forum (RCF) connects embarking countries with countries with mature nuclear power programmes to provide the necessary assistance in capacity building efforts.

36. In addition to the NKM activities to support Member States in strengthening safety and security, the Secretariat has also enhanced its mechanisms and tools to capture and preserve the Secretariat's knowledge and organizational memory in nuclear safety and security. The nuclear safety and security knowledge management process has been updated and a series of activities aiming to preserve, capture and enhance the transfer of the Secretariat's knowledge in nuclear safety and security are under development.

37. The training of personnel from Member States in the application of safeguards continues to be an essential Agency NKM activity. Since September 2010, 14 national, regional and international training courses and workshops have been conducted to assist Member States in fulfilling their obligations under their safeguards agreements. The courses provide knowledge and enable participants to share experiences, capture lessons learned and build best practices. Additionally in this regard, 'Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols' (IAEA Services Series 21) was published in 2012, mainly for State and regional safeguards regulatory authorities and facility operators within the Member State.

38. To help individual Member States in establishing and strengthening their State systems of accounting for and control of nuclear material (SSACs) which are fundamental for efficient and effective safeguards implementation, the Agency conducted IAEA SSAC Advisory Service (ISSAS) missions in Kazakhstan and Mexico in 2011.

39. Education and training in radiation protection were strongly supported through postgraduate educational courses (PGECs) in radiation protection and the safety of radiation sources. The source syllabus consists of lectures and practical sessions followed by research work. These are important in developing human resources for effective radiation, transport and waste safety infrastructure in Member States considering or launching nuclear power programmes or other nuclear applications.

F. Strengthening nuclear knowledge sharing networks

40. The Agency's waste management networks, comprising the International Decommissioning Network (IDN), the International Low-Level Waste Disposal Network (DISPONET), the Underground Research Facilities Network (URF), and the Network of Environmental Management

and Remediation (ENVIRONET), were expanded in January 2011 with the launch of the International Network of Laboratories for Nuclear Waste Characterization (LABONET).

41. The networks continue to enhance delivery of Agency programmes in the different areas of radioactive waste management: 23 major events were carried out in 2011 including training courses, workshops and group scientific visits, and 17 are planned for 2012. In addition, each network holds an annual meeting to plan and align activities in accordance with Member States' needs.

42. All five networks will be linked together under the Agency's web-based platform Connecting the Network of Networks for Enhanced Communication and Training (CONNECT) with the release of Version 2.0 by the end of 2012. The platform has been launched in stages to limited network participants on a select number of topics only to gain feedback and to correct problems before general release. CONNECT will allow all network participants to communicate directly with one another via workspaces for 'Communities of Practice' and to share learning materials and information. Benefits to participants will include the efficient sharing of technical solutions to waste management challenges, the accelerated adoption of best practices and enhanced peer-to-peer contacts, especially between those with developed and less developed programmes.

43. The Agency continued to facilitate the regional networks for education and training in nuclear technology in Asia, Latin America and Africa. Their main objective is to promote, manage and preserve nuclear knowledge, to help ensure the continued availability of qualified nuclear personnel, and to enhance the quality of the human resources for the sustainability of nuclear technology, all of which are partially supported by the TC programme.

44. The Asian Network for Education in Nuclear Technology (ANENT) is a regional partnership established in 2004 to cooperate in capacity building and knowledge management in the Asia and the Pacific region. The ANENT web-portal has been developed to facilitate information exchange and education and e-training in nuclear technology over the Internet. ANENT continued to be very active during this period, incorporating new members.

45. The Latin-American Network for Education in Nuclear Technology (LANENT) was established in 2010. To date, 11 countries and 19 institutions from the region have permanent membership and two nuclear organizations from Spain and Europe are associate members.

46. The African Network for Education in Nuclear Science and Technology (AFRA-NEST) was established by the Africa Regional Cooperative Agreement for Research Development and Training related to Nuclear Science and Technology (AFRA) and launched in 2011 during the General Conference in order to implement AFRA strategy on human resource development (HRD) and NKM. The web-portal and terms of reference are currently being developed.

47. ANENT, LANENT and AFRA-NEST activities are supported by the Agency through seminars, workshops and training courses, organized either via regular budget or TC support, in the regions or at Agency headquarters. Over the last two years, special attention has been given to initiating collaboration at the interregional level, through special yearly meetings, a CONNECT workspace entitled 'Networking Nuclear Education', cross cutting activities to share best practices and through links to education networks in other regions such as European Nuclear Education Network (ENEN), Nuclear Technology Education Consortium (NTEC) and University Network of Excellence in Nuclear Engineering (UNENE) in Europe, the UK and Canada respectively.

48. In response to a General Conference request in 2010 to "further develop and utilize distance learning technologies and methods to make nuclear knowledge more broadly available in an efficient and effective manner", a new Cyber Learning Platform to support Nuclear Education and Training (CLP4NET) has been developed. A prototype was installed at KUSTAR in 2010 at the request of the

UAE, and regional hubs serving Asia, Africa and Latin America have been set up under agreements with Korean, Ghanaian and Argentine nuclear institutions respectively. CLP4NET has already been installed at the Korean Atomic Energy Research Institute (KAERI) in the Republic of Korea and in Vienna, Austria. Preliminary installation and testing of the CLP4NET prototype in Argentina and Ghana took place in summer 2012.

49. Four new Practical Arrangements (PAs) were concluded between the Agency and organizations in Member States in the area of nuclear education, training and outreach in 2011 and 2012. Five more are expected to be signed during the 56th General Conference: those with the National Atomic Energy Commission of Argentina (CNEA), the Ghana Atomic Energy Commission (GAEC) and the Ministry of Education and Training (MOET) of Vietnam are to support CLP4NET activities; the fourth, to be concluded with ROSATOM, includes cooperation on implementing joint regional initiatives on nuclear knowledge management and the fifth, with the National Research Nuclear University “MEPhI”, covers support for nuclear education and training, also including installation of CLP4NET.

50. The Agency concluded a PA with the University of Tokyo to enhance cooperation in the field of nuclear engineering and management research, education and training. The university served as one of the host organizations for the School of Nuclear Energy Management in Japan in 2012 and has agreed to cooperate in the creation of e-learning material on nuclear topics.

51. Arrangements with KUSTAR in UAE aim to facilitate the use of CLP4NET in support of national and regional needs for human resource development for operation of a first nuclear power plant.

52. Under the Arrangements signed between the Agency and the Nuclear Power Institute (NPI) at Texas A&M University, USA, an NKM assist visit was conducted (see paragraph 20) and a new joint School of Nuclear Energy Management will be held during 2013.

53. In line with the General Conference request that the Agency work with other intergovernmental organizations to further increase the level of awareness of efforts in the preservation and enhancement of nuclear knowledge, the Agency has continued work in this direction. It has supported the World Nuclear University (WNU) by providing lecturers for its courses and has participated in both European and Organisation for Economic Cooperation and Development efforts assessing the state of the nuclear work force which culminated in two important documents in 2012: ‘Putting into Perspective the Supply of and Demand for Nuclear Experts by 2020 within the EU-27 Nuclear Energy Sector’ published by the European Human Resource Observatory in the Nuclear Area (EHRO-N) and ‘Nuclear Education and Training: From Concern to Capability’ by OECD Nuclear Energy Agency (NEA 6979-OECD 2012). Estimates presented in these documents suggest that significant intervention will be required with implications for educational systems to maintain an adequately skilled and competent workforce, as well as to ensure the flow of new recruits needed for long-term sustainability.

G. Managing nuclear information

54. Demand for web-based products continues to grow. In response, the Agency, within the framework of the fast reactors knowledge preservation initiative, has developed a Knowledge Organization System (FR-KOS), which has been available to Member States upon request via the Agency’s official website since 2011. The same methodology and tools will be applied to preserve critical knowledge from other knowledge domains.

55. Preservation of knowledge related to construction, modernization and operation of WWER type reactors has been recognised as critically important. The Agency, in cooperation with the EC's Joint Research Centre, developed a 'Knowledge Package on WWER RPV Embrittlement' since embrittlement of pressure vessels has been identified as a critical knowledge domain. It includes video recordings of key experts and reviews of important documents, and preserves documents and conference materials. The package has been completed and will be shared among interested organizations in Member States.

56. The International Nuclear Information System (INIS) continued to play an important role in nuclear information management and knowledge preservation. It remains an important source for many Member States. INIS membership continued to increase. Benin, Chad, Mauritania and Gabon joined INIS over the last two years, bringing the total number of INIS members to 151 (127 countries and 24 international organizations).

57. The INIS Online Database was replaced by the Google-based INIS Collection Search web application, improving search performance and accuracy. In 2011, 109 914 bibliographic records were added to the INIS collection, making a total of 3 367 451 records available to the public. An additional 13 586 full text documents were prepared and uploaded, bringing the total of full text documents available to 439 314, of which 309 627 are available to the public.

58. The Agency issued a new version of the joint INIS/Energy Technology Data Exchange (ETDE) thesaurus containing 30 556 terms. Digital preservation of nuclear information continued. In close cooperation with Member States, over 630 000 pages from the INIS microfiche collection were digitized. Capacity building on all aspects of INIS activities and operation continued: 40 participants from Member States were trained, and representatives of 12 Member States, the ETDE and INIS participated in the 13th INIS/ETDE Joint Technical Committee Meeting in October 2011 and adopted guidelines for cooperation and direction over the next two years.

59. The IAEA Library continued its important role in managing nuclear information and providing Member States and the Secretariat with access to authoritative information in all areas of Agency activities. Currently, it ties together databases, customer services and capacity building. New members joined the International Nuclear Library Network (INLN), bringing INLN membership to 42 in 2012. The IAEA Library integrates various nuclear information resources, focusing on tailoring customer services to meet clients' needs. Almost 89 000 monographic publications, over 45 000 technical reports and more than 8 000 journal titles in print and online formats are currently available.

60. The Agency continues to play an active role in preserving, sharing and transferring knowledge. During the period covered by this report, 180 computer programme packages were provided to 21 Member States and 19 new computer packages received from Member States within the framework of INIS cooperation with the OECD/NEA Databank.

Agency Activities in the Development of Innovative Nuclear Technology

A. Background

1. In resolution GC(55)/RES/12.B.3, the General Conference (GC) noted the progress 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. It noted that the Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) provides a forum for technology users and technology holders to study national, regional and global scenarios and corresponding architectures and explore the innovations in the development and deployment of sustainable nuclear energy systems. The GC also emphasized the important role that the Agency can play in assisting interested Member States in building national long-term nuclear energy strategies and in long-term sustainable nuclear energy deployment decision making and encouraged the IAEA Secretariat and interested Member States to jointly consider innovations in developing sustainable nuclear energy systems.

2. The GC requested the Director General to report on the progress made in the implementation of this resolution to the Board of Governors and to the General Conference at its fifty-sixth (2012) regular session under an appropriate agenda item. This report responds to that request and summarizes Agency activities related to innovative nuclear technology, in particular those carried out under INPRO.

B. INPRO Activities

B.1. Overall project status

3. As of May 2012, INPRO had increased its membership by four countries (Egypt, Israel, Malaysia and Vietnam) and had 37 members: Algeria, Argentina, Armenia, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Egypt, France, Germany, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, Republic of Korea, Malaysia, Morocco, Netherlands, Pakistan, Poland, Russian Federation, Slovakia, South Africa, Spain, Switzerland, Turkey, Ukraine, United States of America, Vietnam and the European Commission (EC).

4. The INPRO Action Plan for 2010–2011 was implemented during 2010 and 2011. In November 2011, the INPRO Steering Committee approved the INPRO Action Plan for 2012–2013, in which the former six INPRO Projects were consolidated further into four main projects to increase effectiveness and transparency:

Project 1: National long range nuclear energy strategies

Project 2: Global nuclear energy scenarios

Project 3: Innovations

Project 4: Policy and the INPRO Dialogue Forum

Coordination with related activities throughout the Agency is included in the Action Plan, which defines interfaces for coordination and cooperation for all INPRO activities in all four projects.

5. In November 2011, the INPRO Steering Committee also endorsed the *INPRO 2017 Development Vision*, which guides the formulation and implementation of INPRO's activities through 2017 in line with the Agency's Medium Term Strategy for 2012–2017. The document specifies that INPRO takes a holistic and global view of nuclear energy systems and relevant innovations and that INPRO's activities are centred on global nuclear energy sustainability and the development of global, regional and national long-range nuclear energy strategies. The subsequent Steering Committee meeting in July 2012 took stock of progress in project implementation and initiated planning for the next biennium.

In 2012, INPRO continues to rely mainly on in-kind and extrabudgetary contributions from its members. Results obtained under INPRO are available to all Agency Member States. In April 2012, the Agency formally established the INPRO Group within the Division of Nuclear Power. As of May 2012, 12 cost-free experts worked in the INPRO Group, bringing the total since INPRO's establishment to 48.

6. GC(55)/RES/12.B.3 encouraged a review of the INPRO methodology in the light of the accident at the Fukushima Daichii nuclear power plant. The INPRO Action Plan for 2012–2013 includes updating the INPRO methodology to incorporate lessons from the accident and a new collaborative project, *Review of Innovative Reactor Concepts for Prevention of Severe Accidents and Mitigation of their Consequences* (RISC).

7. INPRO's communication activities continued to support cooperation with its stakeholders in Member States and provide them with current information on the project's activities and results. Highlights from INPRO projects were presented at a side event during the 55th Session of the IAEA General Conference in September 2011. In May 2012, the *2011 INPRO Progress Report* was published. It provides an overview of INPRO and summarizes progress and results achieved during 2011.

8. Coordination and cooperation with other international initiatives continued, including with the Generation IV International Forum (GIF) and the International Framework for Nuclear Energy Cooperation (IFNEC).

8.1.1. The 6th IAEA/INPRO/GIF coordination meeting took place in March 2012 in Vienna. Participants reviewed progress and updated the Joint IAEA/INPRO/GIF Action Plan. Special attention was given to trends in reactor safety assessments and the results of the topical meeting on safety aspects of sodium cooled fast reactors organized by GIF, INPRO and the IAEA Technical Working Group on Fast Reactors in November 2011.

8.1.2. A consultants meeting on options for cooperation with IFNEC was held in January 2012. It discussed possible modalities of cooperation and identified technical areas of mutual interest, including 'cradle to grave' comprehensive fuel services, soft coordination, infrastructure development, human resources development and a resource library.

B.2. National long range energy strategies

9. 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 long range nuclear energy deployment decision making through 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.

10. In 2011–2012, NESAs were on-going or initiated in Belarus, Indonesia, Kazakhstan and Ukraine.
 - 10.1.1. The final report of the Belarus NESA, which was initiated in 2009, was completed in March 2012, and an Agency publication summarizing results is under preparation. The report discusses the installation of two AES-2006 reactors of Russian design.
 - 10.1.2. The Indonesian NESA was initiated in October 2011 when 30 Indonesian experts were trained in the use of the INPRO methodology. In 2012 preparatory work continued on a work plan and identification of the nuclear energy system to be assessed.
 - 10.1.3. The Kazakhstan NESA was initiated in 2010. In 2011 24 national experts were trained in the use of the INPRO methodology and the Agency's energy planning tools.
 - 10.1.4. The Ukraine NESA, which was initiated in 2011, focuses on three areas of the INPRO methodology: economics, infrastructure and waste management. The first draft report was submitted to the Agency in November 2011, and a follow-up review and training workshop took place in May 2012.
11. The Agency provides NESA Support Packages for both countries introducing nuclear power and those with established programmes. Model packages of training material developed for Indonesia and Kazakhstan were made publicly available online. The packages include Power Point presentations and an e-learning course. The *Introduction to the Use of the INPRO Methodology in a NESA* (IAEA Nuclear Energy Series No. NP-T-1.12) and the booklet, *IAEA Tools and Methodologies for Energy System Planning and Nuclear Energy System Assessments*, were translated into Russian and Arabic in 2012.
12. Training courses on the Agency's energy planning tools, including the INPRO methodology, were held in August 2011 and July 2012 in the USA, attended by more than 50 participants from more than 15 Member States. A training course on the INPRO methodology specifically for university students was developed in 2011 and used in a nuclear power facility design and operation university course with 72 students in the Russian Federation. Complementary textbooks in English and Russian are being prepared.
13. In 2012, the Agency published *Revision 1 of Assessment of Nuclear Energy Systems Based on a Closed Nuclear Fuel Cycle with Fast Reactors* (originally IAEA-TECDOC-1639). The revision responded to requests from Member States to add a full text CD-ROM of the initial study on closed nuclear fuel cycles using the INPRO methodology, which was the basis for the publication.
14. In 2012, the Agency started to develop two new publications. One will be a system level, long term overview of the macroeconomic and socioeconomic implications of nuclear energy, taking into account anticipated technological and institutional innovations. The other will be a survey of existing national long range nuclear energy strategies, which can serve as a reference for Member States developing such long range strategies.
15. In 2012, a complete review and revision of the INPRO methodology was initiated to incorporate lessons learned from past NESAs, past INPRO projects and the Fukushima Daiichi accident and to make it more user-friendly. The review will also make it possible to use the INPRO methodology for comparative assessments and as a capacity building tool. The objectives, approach and content of the review were approved by the INPRO Steering Committee in July 2012.
16. The collaborative project *Proliferation Resistance and Safeguardability Assessment Tools* (PROSA) was initiated in the beginning of 2012. It builds on the collaborative project *Proliferation Resistance: Acquisition/Diversions Pathway Analysis* (PRADA), which was completed in December 2010, to develop a coordinated set of proliferation assessment tools to support a NESA systems

analysis. The tools allow different user groups to conduct assessments with different emphases, depths of analysis and different levels (i.e. state, nuclear energy system and facility).

17. The collaborative project *Environmental Impact Benchmarking Applicable for Nuclear Energy System under Normal Operation* (ENV) was completed in October 2011 and an Agency publication is being prepared. ENV concluded that while site specific meteorology does not significantly change the ranking of radionuclides in terms of health related impact on humans under normal operation, differences among countries in factors like food chains and consumption rates do change the ranking. This reflects the importance of the differing environmental behaviour of various radionuclides, including transfer in different media and accumulation in different food types. A follow-up collaborative project *Environmental Impact of Potential Accidental Releases from Nuclear Energy Systems* (ENV-PE) was included in the INPRO Action Plan for 2012–2013 to provide a framework for assessing radiation doses and related risks to human health caused by potential radioactive releases during an accident in a nuclear power plant.

B.3. Global nuclear energy scenarios

18. Under Project 2, *Global Nuclear Energy Scenarios*, INPRO seeks to develop global and regional nuclear energy scenarios, on the basis of a scientific-technical analysis, that will lead to a global vision on sustainable nuclear energy development in the 21st century.

19. The INPRO collaborative project GAINS (Global Architecture of Innovative Nuclear Energy Systems Based on Thermal and Fast Reactors Including a Closed Fuel Cycle) was concluded in 2011. It identified and quantified several scenarios for transitioning to a globally sustainable nuclear energy system based on thermal fast reactors and closed fuel cycles and highlighted their benefits. An Agency publication is being prepared. A follow-up project, Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability (SYNERGIES), was initiated in 2012. Its objective is to quantify the benefit of collaboration among countries during this transition and to identify drivers and impediments to such collaboration.

20. The collaborative project *Investigations of the ²³³U/Th Fuel Cycle* (ThFC) was concluded in 2011, and its final report was published in June 2012. It concluded that under certain conditions heavy water reactors could efficiently exploit Th-based fuel cycles for breeding and burning ²³³U in a once-through mode without recycling. The introduction of thorium fuel in an open fuel cycle using light water reactors would require significant modification of the fuel management strategy, e.g. a transition to very high burnups and the introduction of new material for fuel claddings. The report also estimated conditions for the possible competitiveness of Th reactors operating in a closed fuel cycle compared to uranium/plutonium reactors and highlighted differences in their proliferation resistance.

21. The collaborative project *Fuel Cycles for Innovative Nuclear Energy Systems based on Integrated Technologies* (FINITE) continued in 2011. It is developing guidance for assessing closed fuel cycles with regard to their sustainability, with a focus on advanced reprocessing technologies.

B.4. Technical and institutional innovations

22. Under Project 3, *Innovations*, INPRO seeks to investigate innovations in selected nuclear energy technologies and related R&D and in innovative institutional arrangements to be deployed in the 21st century and to support Member States in pursuing such innovations.

23. The final report of the collaborative project *Investigation of Technological Challenges Related to the Removal of Heat by Liquid Metal and Molten Salt Coolants from Reactor Cores Operating at High Temperatures* (COOL) was completed. An Agency publication is being prepared. The report presents the results of experiments and computational fluid dynamics studies on thermal hydraulics related to

liquid metal and molten salt coolants. It describes methods to improve the corrosion resistance of components, structural materials and instrumentation to heavy liquid metal coolants.

24. The collaborative project *Decay Heat Removal System for Liquid Metal Cooled Reactors* (DHR) was completed in 2011, and an Agency publication is being prepared. The project analysed pool hydraulics and heat transfer in heat exchangers and compared results from different modelling approaches and simulation tools. The results showed that primary temperatures were not changed significantly by delayed initiation of the decay heat removal system, replacement of intermediate sodium by sodium-potassium or decreased air inlet temperatures in the air-sodium heat exchanger.

25. The collaborative project *Advanced Water Cooled Reactors* (AWCR) was completed in December 2011, and an Agency publication is being prepared. The project reviewed case studies of improved passive safety systems in advanced water cooled reactor designs.

26. The collaborative project *Performance Assessment of Passive Gaseous Provisions* (PGAP) was completed at the end of 2011, and an Agency publication is being prepared. It analysed two reliability methods and their application to the decay heat removal system used in French gas cooled fast reactor designs.

27. The collaborative project *Implementation Issues for the Use of Nuclear Power in Small Grid Countries* (SMALL) was completed in 2011, and an Agency publication is being prepared. The project analysed the deployment of nuclear power in countries with small grids as well as their technical and economic options for managing spent nuclear fuel and radioactive waste.

28. The *INPRO study on Legal and Institutional Issues of Transportable Nuclear Power Plants* (TNPP) was completed in 2011. A report is under preparation.

29. In 2011 a new activity on *International R&D Cooperation on Innovative Nuclear Reactor Designs* was initiated to review options for cooperation on fast breeder technology through centres of excellence, including the Multipurpose Fast Research Reactor (MBIR) proposed by the Russian Federation.

B.5. INPRO Dialogue Forum

30. Under Project 4, which includes the *INPRO Dialogue Forum on Global Nuclear Energy Sustainability*, INPRO seeks to bring together technology holders and users to share information on long range nuclear energy system strategies, global nuclear energy scenarios and technical and institutional innovations. The INPRO Dialogue Forum is supported also by the TC programme, so that TC recipient countries can participate in and benefit from INPRO activities, which are otherwise funded mainly from extrabudgetary contributions.

31. The third INPRO Dialogue Forum was held in October 2011 and attended by 68 participants from 36 Member States and international organizations. It focused on common user considerations for small and medium sized nuclear power reactors (SMRs) in light of recent developments in SMR technologies. It built on a prior INPRO study of developing countries considering nuclear power programmes that had focused on large reactors.

32. The fourth INPRO Dialogue Forum, in July 2012, addressed “Drivers and Impediments for Regional Cooperation on the Way to Sustainable Nuclear Energy Systems”. Fifty participants attended from 35 Member States and exchanged views on the benefits of regional cooperation in building sustainable nuclear energy systems and the perspectives of the user and supplier countries regarding the driving forces and impediments for such a cooperation. The workshop also provided input to SYNERGIES.

33. The fifth INPRO Dialogue Forum on “Long Term Prospects for Nuclear Energy in the Post-Fukushima Era” was held in Seoul, Republic of Korea, in August 2012 and was attended by over 100 participants from 50 Member States and international organizations. It was co-organized with the Government of the Republic of Korea and was the first Dialogue Forum hosted by a Member State. It dealt with Member States’ visions and strategies for nuclear energy systems in the post-Fukushima era, safety issues, socio-political issues and public acceptance and explored ways to ensure the long range sustainability of nuclear energy on the national, regional and global levels, in the light of the lessons learned from Fukushima.

C. Other Agency Activities related to Innovative Nuclear Technology

34. The Agency continues to provide an international forum for information exchange and objective reviews and discussion of technology development and the design of selected innovative reactors and their fuel cycles. The framework is provided by Technical Working Groups on advanced water reactors, fast-spectrum and accelerator-driven systems (both critical and subcritical), gas cooled reactors, fuel cycle options and nuclear desalination. Activities are planned and implemented in close cooperation with other relevant international initiatives and organizations, such as the EC, GIF, International Centre for Theoretical Physics and OECD/NEA, to avoid duplication across programmes.

C.1. Innovations in reactor technology and applications

35. The Agency published *Construction Technologies for New Nuclear Power Plants* (IAEA Nuclear Energy Series No. NP-T-2.5) in December 2011. It incorporates global experience from a variety of recent large construction projects and includes comprehensive descriptions of all construction methods, including their advantages and disadvantages and a discussion of best practices and lessons learned. Associated workshops were organized in June 2011 in Shanghai, China, and in December in Paris, France.

36. In the area of light and heavy water reactors, the Agency held a technical meeting on Fuel Design and Licensing of Mixed Cores for Water Cooled Reactors in December 2011 to foster international information exchange and to prepare a report. Two new coordinated research projects (CRPs), Prediction of Axial and Radial Creep in Pressure Tubes and Application of Computational Fluid Dynamics (CFD) Codes for Nuclear Power Plant Design, were initiated in April 2012. The Agency published *Natural Circulation Phenomena and Modelling for Advanced Water Cooled Reactors* (IAEA-TECDOC-1677) in May 2012.

37. 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. A new CRP on safety tests conducted in the Experimental Breeder Reactor II (USA) begun in 2012. The final report of a CRP on Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects was completed in 2011 and will be published shortly. To help identify lessons learned from the Fukushima Daiichi accident the Agency held a technical meeting on the Impact of the Fukushima Event on Current and Future Fast Reactors Designs (Dresden, Germany, March 2012) and an international workshop on Prevention and Mitigation of Severe Accidents in Sodium-cooled Fast Reactors (Tsuruga, Japan, June 2012). The TWG-FR met in June 2012 to exchange information on the

status of national programmes and provide recommendations for the implementation of IAEA activities in 2012-2013. In 2012 the Agency published the proceedings of the International Conference on Fast Reactors and Related Fuel Cycles: Safe Technologies and Sustainable Scenarios (FR09), held in Kyoto in 2009. It is participating in the organization of the FR13 conference to be hosted by France in Paris in March 2013.

38. In the area of gas cooled reactors, a new CRP was started in 2012 on uncertainties in neutronics, thermal-hydraulics and depletion modelling of high temperature gas cooled reactors (HTGRs). In March 2012 a training course on Environmental Degradation of Components in Nuclear Power Plants was held in collaboration with the International Centre for Theoretical Physics (ICTP) in Trieste, Italy. It covered the degradation of nickel based alloys, stainless steels, reactor pressure vessel, core internals and piping steels, zircalloys, and other alloys in water environments relevant to reactor vessels and internals, steam generators, fuel cladding, irradiated components, fuel storage containers, and balance of plant components and systems. It also covered materials degradation issues for supercritical water cooled reactors and other Generation IV nuclear energy systems including both gas cooled and liquid metal cooled systems. In June 2012 the Agency published *Advances in High Temperature Gas Cooled Reactor Fuel Technology* (IAEA-TECDOC-1674), which presents the results of a CRP on the same subject and describes advances in the design and manufacturing of coated particle HTGR fuel, including its performance under normal and accident conditions. The report documents the results of round-robin tests on the characterization of different coated particle TRISO fuel designed and manufactured in the different Member States that participated in the CRP.

39. Non-electric applications of nuclear reactors include seawater desalination for industrial use and drinking water, hydrogen production, district heating and the production of process heat for industrial uses. The Agency held a workshop on non-electric applications of nuclear energy in Prague in October 2011. Meetings were held in December 2011 to begin developing reports on, first, nuclear power for cogeneration of electricity and desalinated seawater, hydrogen or heat and, second, nuclear power for industrial applications. The final research coordination meeting for a CRP on New Technologies for Seawater Desalination using Nuclear Energy was held in October 2011, and a new CRP on the Techno-economic Aspects of Hydrogen Production using Nuclear Energy and Benchmarking of HEEP was initiated in 2012. Technical reports on the *Status of Hydrogen Production Using Nuclear Energy* and *Advances in Nuclear Power for Process Heat Applications* were completed, and the Agency started development of a toolkit on nuclear hydrogen production.

40. In the field of small and medium sized reactors (SMR), activities focused on assisting Member States to develop a roadmap for technology development, assessment and implementation. In August 2011, the Agency held a technical meeting on Options to Incorporate Intrinsic Proliferation Resistance Features to Nuclear Power Plants with Innovative SMRs to foster information exchange and prepare a report, and in October it held a technical meeting in cooperation with the European Commission – Joint Research Centre (EC-JRC) on Options to Enhance Energy Supply Security using Nuclear Power Plants based on SMRs to investigate the viability of integrating SMRs with renewable energy resources to improve energy system cost-effectiveness and sustainability. In addition to the INPRO Dialogue Forum on Nuclear Energy Innovations: Common User Considerations for SMRs (see paragraph 31 above), a workshop on SMR Technology Assessment was held in December 2011 to help Member States identify SMR designs commercially available for near term deployment and to introduce the process of technology assessment towards informed decision making. The final research coordination meeting for a CRP on Development of Methodologies for the Assessment of Passive Safety System Performance of Advanced Reactors was held in April 2012, and as a supplement to its Advanced Reactors Information System (ARIS), the Agency published a booklet *Status of Small and Medium Sized Reactor Designs* in September 2011.

C.2. Innovations in fuels and fuel cycles

41. In September 2011, a meeting on uranium production from phosphates was held in Vienna, Austria. The meeting introduced the concept of 'comprehensive extraction' to optimize returns from mining and processing operations. In such an approach the objective is to extract all elements of current and potential future value, not just a single target commodity.

42. In cooperation with Indian Rare Earths Limited (IREL), the Agency organized an international meeting in India in October 2011 on world thorium resources. The meeting focused on resource estimates, exploration, production and the use of thorium in the nuclear fuel cycle, with an emphasis on environmental, health, safety, economic and social licensing aspects. The participants noted thorium's promise in extending the global deployment of nuclear power and concluded that the technology is sufficiently mature for initial commercial deployment, although no one has yet taken that step. It also addressed the co-production of thorium and rare earth elements, and the importance of conserving thorium and defining good practices to store co-produced thorium for future use.

43. A CRP is underway on near term and promising long term options for the deployment of thorium based energy. There is a need for a coordinated examination of how thorium fuels might be deployed and the current obstacles to such deployment. The CRP has therefore established a group of scientists to assess, report and advise on strategies to advance the deployment of thorium energy.

44. A meeting was held from 31 August to 2 September 2011 on Spent Fuel Treatment Options: Perspective of Users of Reprocessing Services in a Foreign Country. The meeting reviewed existing R&D programmes to develop innovative recycling technologies and innovative arrangements with reprocessing abroad without recycling in the customer country. It concluded, however, that the only current recycling option is still the reprocessing of spent fuel to recycle plutonium (as mixed uranium-plutonium oxide (MOX) fuel) and reprocessed uranium (RepU) in thermal reactors. Proceedings of the meeting will be published in 2013.

45. A CRP on Accelerator Simulation and Theoretical Modelling of Radiation Effects (SMoRE) was completed. The project integrated efforts of accelerator experimentalists and material scientists from 15 Member States to better understand high-dose irradiation phenomena and the nature of radiation damage. These issues are of particular importance for advanced fast neutron and future fusion systems that require extremely high radiation loads on structural materials. The final CRP report will be published later in 2012.

46. A new CRP on Demonstrating Performance of Spent Fuel and Related Storage System Components during Very Long Term Storage will investigate innovative non-intrusive techniques to verify the integrity of spent fuel and dry storage systems (metal casks and concrete shielded metal canisters) for periods extending beyond 100 years.

47. A meeting on Fuel and Fuel Cycle Options for Small and Medium Size Reactor (SMRs) was held in October 2011. The meeting reviewed the status of past and present SMRs in the world based on light water reactors (LWRs), pressurized heavy water reactor (PHWRs), high temperature reactors (HTRs) and fast reactors (FRs), highlighting the fuel and fuel cycle options. The meeting noted the need to develop innovative fuel and fuel cycles for SMRs that emphasize safety, economics and closing the fuel cycle. SMRs based on water cooled reactors with uranium oxide fuel and zirconium alloy cladding are being considered in most countries based on the satisfactory performance of these materials in conventional nuclear power reactors. However, for fixed bed pressurized water reactors, TRISO fuel, i.e. spherical uranium dioxide particles coated in silicon carbide (SiC) or a stainless steel matrix, is an innovative concept that requires further investigation. Other innovative concepts are modular and mobile gas cooled fast reactors with porous fuel pins containing uranium carbide fuel and SiC cladding.

48. In the waste technology area, a CRP was initiated on Processing Technologies for High Level Waste, Formulation of Matrices and Characterization of Waste Forms. In addition to high level waste from historical and current aqueous reprocessing, this CRP covers high level waste that would be generated from advanced aqueous processing and pyro-processing and is of interest for the development of innovative fuel cycles.

49. A CRP is underway on Treatment of Irradiated Graphite to Meet Acceptance Criteria for Waste Disposal. It will facilitate the exchange of information and technological experiences on new developments in the area and identify innovative technologies to be applied for conformity with modern safety and economic requirements. The first research coordination meeting was held in November 2011. The CRP covers not only accumulated graphite waste from shutdown reactors and waste from operating reactors yet to be decommissioned, but also the irradiated graphite resulting from high temperature gas cooled reactors such as China's high temperature reactor.

50. With respect to innovation related to research reactors, the Agency began a CRP in 2011 on the use of digital instrumentation and control (I&C) systems to optimize maintenance in research reactors. Other projects supported the continuing development of advanced high density LEU research reactor fuel, the development and demonstration of core designs that use LEU fuel for miniature neutron source reactors (MNSRs), the expansion of non-HEU molybdenum-99 (Mo-99) production technology and the conversion of large scale Mo-99 producers to LEU including for innovative high density uranium target.