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*Atoms for Peace and Development*

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**STRENGTHENING THE AGENCY'S  
ACTIVITIES RELATED TO  
NUCLEAR SCIENCE, TECHNOLOGY  
AND APPLICATIONS**

*Report by the Director General*



# Board of Governors General Conference

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Item 18 of the Conference's provisional agenda  
(GC(65)/1 and Add. 1)

# 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(64)/RES/12, GC(63)/RES/10 and GC(62)/RES/9, this document contains progress reports on:

- Part A: Non-Power Nuclear Applications
  - General (Annex 1)
  - Support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC) (Annex 2)
  - Renovation of the Agency's Nuclear Applications Laboratories at Seibersdorf (Annex 3)
  - Development of the Sterile Insect Technique Package for the Management of Disease-Transmitting Mosquitoes (Annex 4)
  - Strengthening the Support to Member States in Food and Agriculture (Annex 5)
  - Use of Isotope Hydrology for Water Resources Management (Annex 6)
  - Zoonotic Disease Integrated Action (ZODIAC) Project (Annex 7)
  - Plan for Producing Potable Water Economically Using small and Medium Sized Nuclear Reactors (Annex 8)
  
- Part B: Nuclear Power Applications
  - Introduction (Annex 9)
  - IAEA Communication, Cooperation with Other Agencies and Stakeholder Involvement (Annex 10)

- Nuclear Fuel Cycle and Waste Management (Annex 11)
  - Research Reactors (Annex 12)
  - Operating Nuclear Power Plants (Annex 13)
  - Agency Activities in the Development of Innovative Nuclear Power Technology (Annex 14)
  - Approaches to Supporting Nuclear Power Infrastructure Development (Annex 15)
  - Small and Medium Sized or Modular Reactors — Development and Deployment (Annex 16)
- Part C: Nuclear Knowledge Management
    - Nuclear Knowledge Management (Annex 17)

Further information on the Agency's activities related to nuclear science, technology and applications can be found in the *Nuclear Technology Review 2021* (document GC(65)/INF/2); the *IAEA Annual Report 2020* (GC(65)/5), in particular the section on nuclear technology; and the *Technical Cooperation Report for 2020* (GC(65)/INF/4).

#### **Recommended Action**

- It is recommended that the Board take note of Annexes 1-17 of this report and authorize the Director General to submit the report to the General Conference at its 65th regular session.

# General

## Non-power nuclear applications

### A. Background

1. In resolution GC(64)/RES/12.A.1, the General Conference requested the Director General, in conformity with the Statute, to continue to pursue, in consultation with Member States, the Agency's activities in the areas of nuclear science, technology, and applications, with special emphasis on supporting the development of nuclear applications in Member States with a view to strengthening infrastructures and fostering science, technology, and engineering for meeting sustainable growth and development needs of Member States in a safe manner.

2. The General Conference recommended that the Secretariat report to the Board of Governors and to the General Conference at its 65th regular session on the progress made in the areas of nuclear science, technology and applications. This report has been prepared in response to that recommendation.

### B. Progress since the 64th Regular Session of the General Conference

3. The Agency, as a member of the United Nations Crisis Management Team for COVID-19 and in coordination with the World Health Organization (WHO) continued providing assistance to Member States, in fighting COVID-19 through the provision of equipment and training.<sup>1</sup>

4. The Agency has responded to requests from 128 countries and territories for assistance during the COVID-19 pandemic. Besides supplying related equipment such as reverse transcription–polymerase chain reaction (RT–PCR) instruments, the Agency, through various webinars, assisted health care providers around the world to adjust their standard operating procedures to cope with the pandemic in order to continue delivering their services. COVID-19 support was provided to more than 300 medical and veterinary laboratories in 128 countries and territories. More than 1950 consignments of equipment and supplies for detecting and diagnosing COVID-19 have been delivered to 128 countries and territories. More than 100 webinars and virtual training events were conducted in the past year.

5. The Agency continued to validate the most promising COVID-19 detection kits in order to determine their sensitivity and specificity performance as they became available on the market. In

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<sup>1</sup> Please see GC(65)/INF/7 - IAEA Support to Member State Efforts in Addressing the COVID-19 Pandemic.

addition, the Agency continued to provide updated standard operating procedures and guidance as more diagnostic tests were validated and used together with individualized technical support and backstopping, in line with the massive scale-up of testing in Member States. COVID-19-related guidance and expert services were provided to 285 medical and veterinary laboratories, with direct, individualized backstopping provided to 87 veterinary laboratories.

6. A series of webinars entitled ‘COVID-19 Preparedness for Radiotherapy Departments’ were delivered to support health professionals in Member States to continue their essential services during the COVID-19 pandemic. More than 6000 professionals from 144 countries attended these webinars.

7. The Agency worked with the WHO to prepare technical specifications, including minimum requirements, for medical imaging devices necessary for diagnosing COVID-19-related complications. These specifications can serve as a guide for Member States when purchasing devices, including ultrasound, X ray and computed tomography systems. The Agency also developed together with the WHO, technical specifications of radiotherapy equipment for cancer treatment.

8. The Agency published more than 20 peer review publications with guidance on different applications of nuclear medicine and diagnostic imaging, including cardiology, cancer, health technology assessment, and COVID-19 and other infectious diseases.

9. The Agency continued to collaborate with designated Member State institutions to implement the Agency’s programmatic activities and promote the practical use of nuclear techniques. At the end of 2020, the Agency had 46 active Collaborating Centres (37 of which in fields related to non-power nuclear applications) in 33 Member States, representing an increase of three compared to the end of 2019.

10. The Agency continued its efforts to inform Member States about coordinated research activities and their results on a dedicated webpage. At the end of 2020, the Agency operated 1710 active research contracts and agreements in 113 Member States as part of 124 active coordinated research projects (CRPs), of which 81 were related to non-power nuclear applications.

11. The Agency continued to strengthen its relationship with the WHO through cooperation in areas such as the use of investigational radiopharmaceuticals. The Agency and the WHO developed dedicated guidance documents to address good manufacturing practices specific to investigational radiopharmaceuticals used in both early and late clinical trials.

12. Technetium-99m continues to be the most employed radioisotope for diagnosis in nuclear medicine. A comprehensive report on the status of the application of such radiopharmaceuticals resulted from the Technical Meeting on New Generation of Technetium-99m Kits for Oncology Applications, held virtually in May 2021 with 28 participants from 14 Member States.

13. The Agency has upgraded the Medical Isotope Browser with features to estimate the production of medical isotopes with accelerators. The nuclear data library, TALYS-based evaluated nuclear data library (TENDL), has been improved and a more descriptive graphical representation of the produced amounts of radioisotopes has been added.

14. The Isotope Browser App for smartphones was downloaded by more than 120000 users. The App has been extended with more nuclear structure information, such as the atomic mass excess.

15. The Agency issued two publications on the therapeutic use of radiopharmaceuticals: *Therapeutic Radiopharmaceuticals Labelled with Copper-67, Rhenium-186 and Scandium-47* (IAEA-TECDOC-1945) in February 2021 and *Production of Emerging Radionuclides towards Theranostic Applications: Copper-61, Scandium-43 and -44, and Yttrium-86* (IAEA-TECDOC-1955) in May 2021.

16. The Agency launched the updated Database on Industrial Irradiation Facilities, featuring an interactive map with information on nearly 300 gamma irradiators and electron accelerators from around the world.

17. A Workshop on Radiation Technology for Industry and Environment was held virtually in April 2021 to strengthen information and knowledge exchange on developments and advances in radiation technology in industrial and environmental applications, and to foster cooperation in radiation sciences and technologies. The event was attended by 153 participants from around the world.

18. To strengthen the Agency's activities in the area of fusion science and technology in view of the advances in nuclear fusion research at the International Thermonuclear Experimental Reactor (ITER), the Agency organized a Technical Meeting on the collisional-radiative properties of Tungsten and Hydrogen in the edge plasma of fusion devices, in March 2021, in collaboration with Forschungszentrum Jülich, to improve numerical databases for the interaction of the plasma with the first wall of ITER. The meeting was attended by 40 participants from 16 Member States.

19. The Agency held three consultancy meetings, on recycling of polymer wastes for novel materials, on recent achievements in radiation-processed products from natural polymers, and on the processing of cultural artefacts using radiation technology, in October 2020 and February 2021. The recommendations from those meetings will help defining future research and development activities and CRPs.

20. The Agency issued two IAEA Technical Documents (TECDOCs) on industrial applications of computed tomography and sealed radioactive sources in 2020: *An Introduction to Practical Industrial Tomography Techniques for Non-destructive Testing (NDT)* (IAEA-TECDOC-1931) and *Industrial Applications of Sealed Radioactive Sources* (IAEA-TECDOC-1925).

21. To assist Member States towards mitigating the impact of climate change, the Agency increased its focus on climate-smart agriculture, developing guidelines and technology to measure agricultural derived greenhouse gas emissions. An Agency-supported book entitled *Measuring Emission of Agricultural Greenhouse Gases and Developing Mitigation Options using Nuclear and Related Techniques* was published in early 2021, as a milestone in nuclear applications for climate-smart agriculture.

22. Research experiments at the Agency's Seibersdorf laboratories and in 11 Member States were carried out to investigate the efficacy of irradiated vaccines against animal diseases, and results are providing proof-of-concept for the use of irradiation to produce bacterial and viral vaccine antigens. The Agency supported these experiments by designing and producing irradiated vaccine antigens and evaluating vaccine response in animals using technologies developed in the Animal Production and Health Laboratory.

23. Through innovative research and readily transferable technology in food irradiation, and in authenticity and control of chemical hazards in food, the Agency continued to support food safety and quality control systems critical to protecting consumers and facilitating global trade among Member States. A field-deployable method for differentiating Arabica coffee from Robusta coffee, therefore helping combat food fraud, was developed.

24. The Agency continued to support capacity building, emergency interventions and South-South cooperation through scientific and technical networks coordinated by the Agency, such as the Veterinary Diagnostic Laboratory Network, a scientific and technical network of national veterinary laboratories from 46 African and 19 Asian countries, as well as recent initiated networks in Latin America and the Caribbean, and Eastern Europe.

25. Laboratory networks for food safety were further strengthened in Africa, Asia and the Pacific, and Latin America and the Caribbean by Agency support to over 150 food safety and control institutions. In addition, a mutation breeding network was established in the Asia and the Pacific region and another was formalized for Latin America.
26. The Agency, through its Ocean Acidification International Coordination Centre (OA-ICC), supported Member States in their work to address ocean acidification and marine pollution of all kinds, through activities fostering the quality of monitoring data for contaminants, such as trace metals including cadmium, lead and mercury, as well as persistent organic pollutants.
27. In collaboration with the Ocean Acidification Africa Network, the OA-ICC co-organized a regional meeting, entitled “Ocean Acidification Day of Action”, in Monrovia in January 2021 to highlight new science and capacity building efforts that are under way in West Africa.
28. The Agency continued to support regional marine programmes such as the United Nations Environment Programme (UNEP) Mediterranean Action Plan, the Convention for the Protection of the Marine Environment of the North-East Atlantic, the Convention on the Protection of the Marine Environment of the Baltic Sea Area, and international conventions such as the Minamata Convention on Mercury and the Stockholm Convention on Persistent Organic Pollutants by providing matrix certified reference materials of high quality through interlaboratory comparisons for the analysis of contaminants in marine matrices. The linkages between the Agency’s and the UNEP’s implementation of the Minamata Convention, specifically with regard to the evaluation of the effectiveness of regulations on the emission of mercury into the environment, have been intensified in the past two years. In addition, a formal agreement exists between the Agency and the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. This includes the provision of services to build and maintain quality assurance for contaminants monitoring in the Mediterranean Sea through extrabudgetary funding.
29. In a series of three webinars conducted in 2021, methodologies for gamma spectrometry techniques were delivered to more than 750 scientists in Member States. Over 260 participants registered for an advanced workshop on gamma spectrometry techniques, held in June 2021.
30. Three additional carbonate reference materials were established to support high-precision monitoring of the isotopic composition of atmospheric greenhouse gases. A report on water stable isotope materials was completed to enhance the capabilities of laboratories for reporting reliable monitoring data.
31. The Analytical Laboratories for the Measurement of Environmental Radioactivity network has grown to encompass 194 laboratories in 90 Member States, all endorsed by their national Governments to provide rapid assistance in radionuclide measurements in the environment in case of radiological or nuclear emergencies affecting the environment. Regular annual training activities for laboratories were performed, with around 100 laboratories participating in the last proficiency test to demonstrate their technical competence.
32. The Agency, through its Marine Radioactivity Information System (MARIS), continues to support marine research and monitoring initiatives in Member States through the provision of verified data and information on levels of radioactivity in the world’s oceans. MARIS is an open, web-based system providing environmental scientists, policy makers and the public with recent and historical marine radioactivity data sourced from laboratories around the world.
33. In addition to extrabudgetary contributions received from Member States, the Agency received from a private company a new advanced microscope-based imaging platform capable of identifying and quantifying radiation exposure in people. The imaging platform forms part of the Agency’s biological

dosimetry model laboratory, which will provide teaching, training, research, and services related to dosimetry to IAEA Member States.

34. The Agency published *Guidelines for the Certification of Clinically Qualified Medical Physicists* (Training Course Series No. 71) to promote the recognition of medical physicists as health care professionals. The guidelines were promoted at the Asia-Oceania Congress on Medical Physics and the 18th South East Asian Congress on Medical Physics in December 2020; virtual conference of the Middle East Federation of Organizations of Medical Physics in April 2021; and the European Congress of Medical Physics in June 2021.

35. The Agency held the International Conference on Molecular Imaging and Clinical PET–CT (IPET-2020) virtually in November 2020, attended by over 3000 participants from 126 Member States. Qualified participants were awarded 15 continuing medical education credits by the European Accreditation Council for Continuing Medical Education (EACCME). Over 40 speakers from 22 countries presented important clinical aspects and the appropriate use of medical imaging in the management of patients with cancer. Special sessions dedicated to COVID-19, education, ethics and leadership were also conducted, and a keynote lecture on the global burden of cancer was presented by a WHO representative. Ten global and regional professional organizations participated in the Conference.

36. The Agency held the International Conference on Advances in Radiation Oncology (ICARO-3) virtually in February 2021. ICARO-3 had over 3000 participants from 142 Member States and the involvement of 11 professional organizations. Qualified participants were awarded 15 continuing medical education credits by the EACCME. The scientific programme included ten refresher courses and three e-contouring workshops.

37. Guidance based on data generated from CRPs and regional technical cooperation projects on body composition in infants up to 24 months of age and breast milk intake was provided to the WHO to help inform two WHO expert groups on updating complementary feeding guidelines and updating the Food and Agriculture Organization of the United Nations–WHO nutrient requirements for infants and young children.

38. Agency–WHO cooperation is ongoing through the coordination of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories and dosimetry audit services, among others. The Agency is expanding dosimetry audit services to include the auditing of newly commissioned linear accelerator electron beams.

39. The Agency participated in the European Commission QuADRANT project workshop in December 2020, at which Quality Assurance Team for Radiation Oncology, Quality Management Audits in Nuclear Medicine Practices and Quality Assurance Audit for Diagnostic Radiology Improvement and Learning activities were presented. The QuADRANT project seeks to promote clinical audits in the Europe region.

40. The Agency published *Nuclear Medicine Resources Manual 2020 Edition* (IAEA Human Health Series No. 37). This edition addresses all of the elements that should be considered to establish and operate a nuclear medicine facility, including equipment requirements and quality control; clinical applications, both diagnostic and therapeutic; patient protection, including radiation safety; human resources; and continuing professional development.

41. The Agency launched the new Medical Imaging and Nuclear Medicine Global Resources Database (IMAGINE). IMAGINE is the first comprehensive global database on medical imaging and nuclear medicine. It contains detailed information from over 170 countries and territories on the availability of medical imaging and nuclear medicine equipment, and human resources for both

modalities. Using maps and graphs to display its findings, IMAGINE provides valuable information to support strategic planning in Member States to better address health needs through the appropriate use of radiology and nuclear medicine.

42. The Agency commemorated the 60-year anniversary of the Directory of Radiotherapy Centres (DIRAC) in 2020. DIRAC is the only global database containing information about radiotherapy equipment. Continuous improvement constantly adds new granularity to the data, including on particle therapy and advanced radiotherapy techniques, as well as new functionalities for uploading and updating information.

43. A report of the Lancet Oncology Commission on Imaging and Nuclear Medicine was published in March 2021. The Commission utilized data collated by the Agency on equipment, workforce, and procedures, with a focus on low- and middle-income countries, through the Agency's Nuclear Medicine Database and IMAGINE. The Commission report highlights dramatic inequalities in access to imaging resources and outlines a compelling health economics case for countries, illustrating that scaling up access to medical imaging for cancer patients would yield substantial health and economic benefits.

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

## A. Background

1. In resolution GC(64)/RES/12/A.2, the General Conference recognized that tsetse flies and the trypanosomosis problem which they cause constitute one of the greatest constraints on the African continent's socio-economic development, affecting the health of humans and of livestock, limiting sustainable rural development and thus causing poverty and food insecurity.
2. The General Conference requested the Agency and other partners to strengthen capacity building in Member States for informed decision-making regarding the choice of tsetse and trypanosomosis control strategies and the cost-effective integration of sterile insect technique (SIT) operations into area-wide integrated pest management (AW-IPM) campaigns. The General Conference also requested the Secretariat, in cooperation with Member States and other partners, to maintain funding through the Regular Budget and the Technical Cooperation Fund for consistent assistance to selected operational SIT field projects and to strengthen its support for research and development and technology transfer to African Member States to complement their efforts to create and subsequently expand tsetse-free zones.
3. The General Conference, in resolution GC(64)/RES/12.A.2, 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 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

### B.1. Strengthening Collaboration with AU-PATTEC

4. The Agency established virtual meetings with AU-PATTEC on the status of the activities of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture and the Agency's assistance provided under the technical cooperation (TC) programme in support of tsetse and trypanosomosis control. The Agency will also continue its close collaboration with AU-PATTEC on its goal to eliminate tsetse flies and trypanosomosis through the creation of sustainable tsetse and trypanosomosis free areas.

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

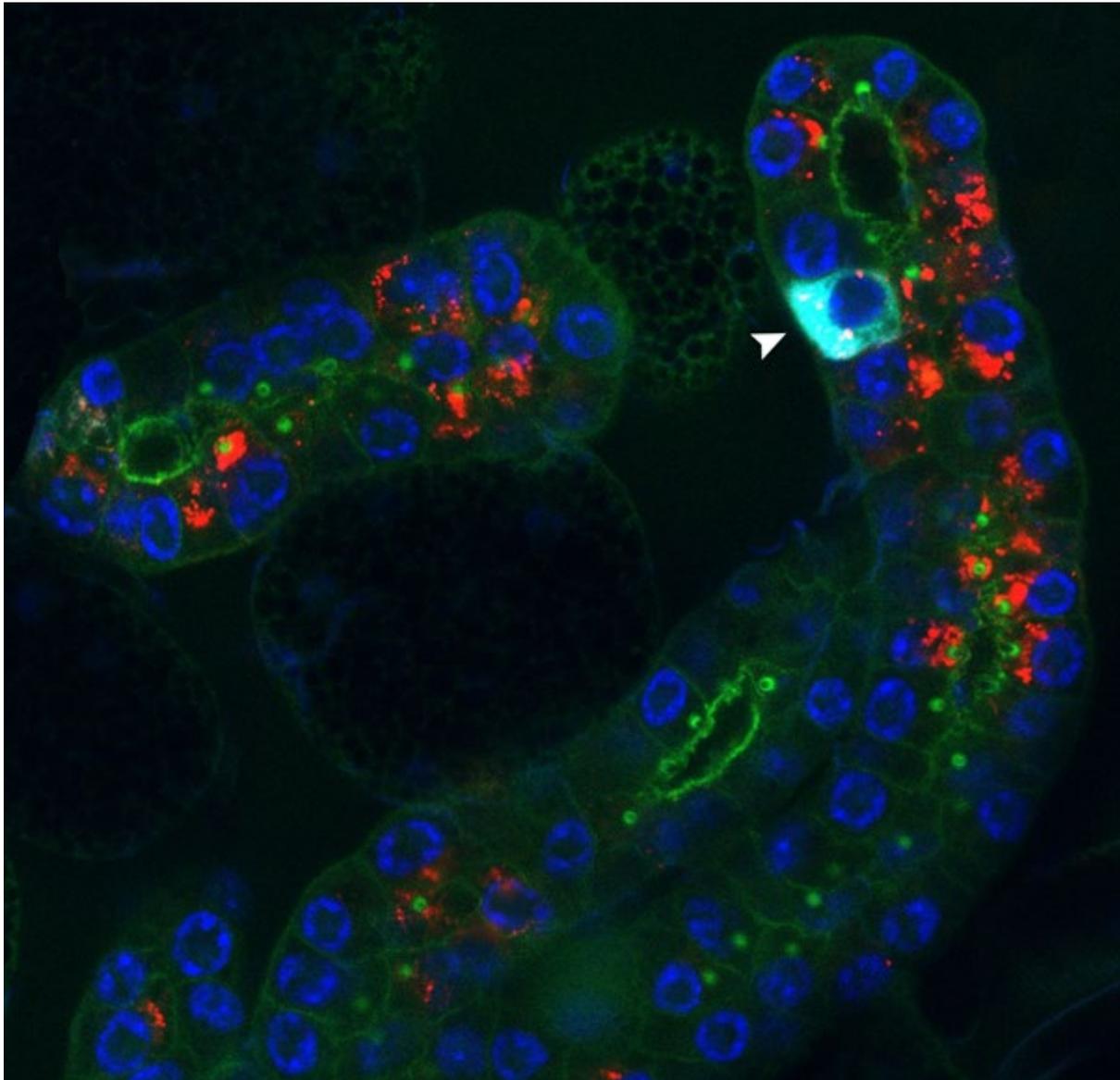
5. The Agency continued to respond to Member States' requests for support in incorporating SIT into AW-IPM to eliminate or control tsetse-transmitted trypanosomosis. The disease has been recognized as a major constraint on both livestock and agricultural crop production in sub-Saharan Africa. The support has included the provision of technical advice, procurement of equipment and

materials, training courses and workshops, fellowships and scientific visits through the relevant TC projects, and research that was conducted at the Insect Pest Control Laboratory (IPCL) at the FAO/IAEA Agriculture and Biotechnology Laboratories in Seibersdorf, Austria. In addition, experts from affected Member States continued to participate in the coordinated research project entitled “Improvement of Colony Management in Insect Mass-rearing for SIT Applications”, which includes a research group on tsetse flies.

6. The Agency’s support strengthened capacity in Member States, enabling them to obtain and analyse baseline data to support informed decision-making regarding the choice and feasibility of available tsetse and trypanosomosis suppression or eradication strategies, including the cost-effective integration of SIT operations into AW-IPM campaigns. In that context, the Agency continued providing support to Burkina Faso, Chad, Ethiopia, Mali, Senegal, South Africa, Uganda, the United Republic of Tanzania, Zambia and Zimbabwe.

7. Since September 2020, the Agency has supported eight fellowships (partially online, partially hands-on). The fellowships provided individual training at specialized institutions for a total duration of more than 700 days. The IPCL is currently hosting two PhD students, supported through the TC programme, working under the supervision of senior Agency scientists on research topics pertaining to the tsetse microbiome and pathogens, and the release of chilled tsetse flies.

8. Research activities at the IPCL continued to focus on improving the productivity and the performance of tsetse colonies by understanding the impact of pathogenic viruses and symbiotic bacteria.



*FIG. B.1. Iflavirus and negevirus infection in Glossina morsitans morsitans fatbodies at 40x magnification. Viruses were detected with Stellaris RNA fluorescence in situ hybridization probes. Blue: nucleus (stained with 4',6-diamidino-2-phenylindole), green: F-actin (stained with 488 phalloidin), red: iflavirus, cyan: negevirus. Arrow head shows colocalization between iflavirus and negevirus. (Source: IAEA)*

9. A Near Infrared Pupae Sex Sorter for the tsetse fly has also been developed and is currently in operation in two insectaries that produce tsetse pupae for the AW-IPM currently underway in the Niayes region, to the north-east of Dakar, Senegal. Units will also be provided to Burkina Faso and Ethiopia.

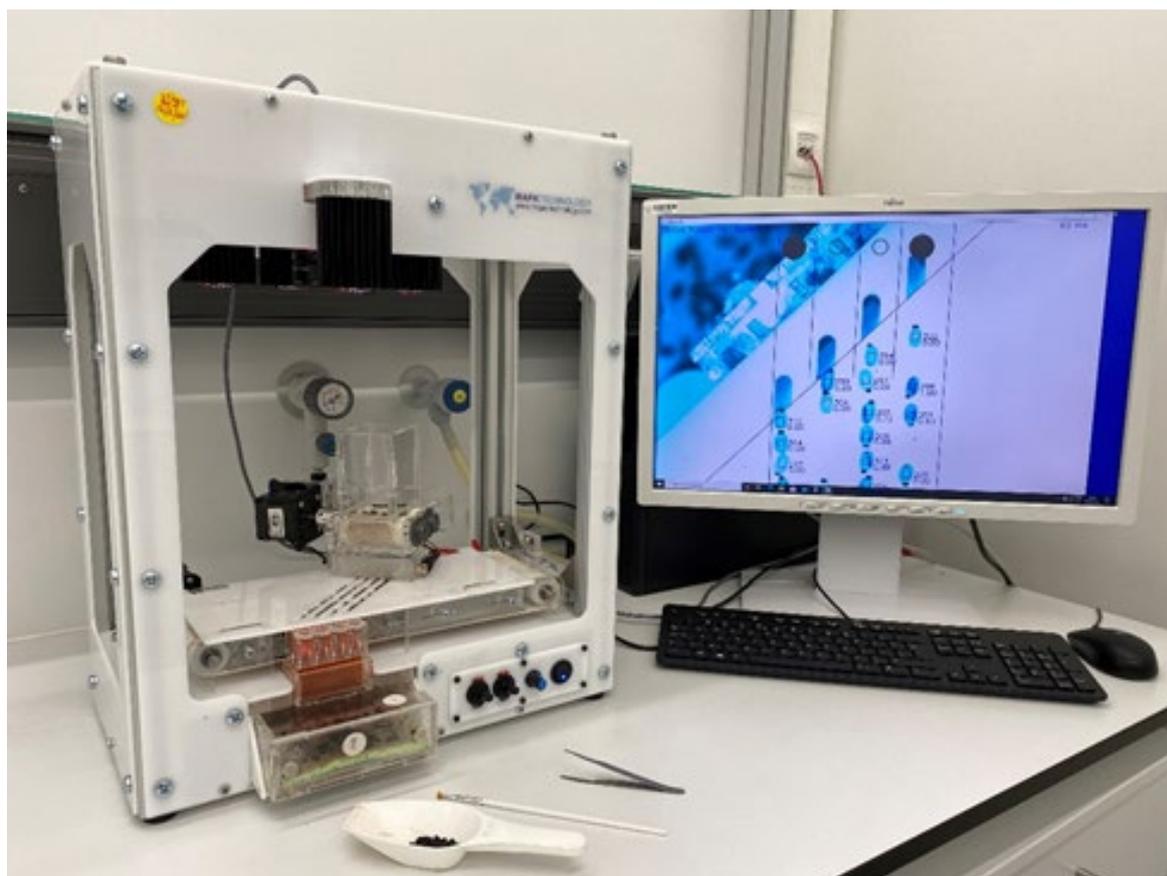


FIG. B.2. The Near Infrared Pupae Sex Sorter for the tsetse fly. (Source: IAEA)

10. Advances in knowledge and applicable technologies arising from the above-mentioned research activities are widely disseminated through publications in peer-reviewed scientific journals, as well as through conference presentations.

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

11. Under TC project RAF/5/080, the Agency continued to provide training in supporting area-wide tsetse and trypanosomosis management to improve livestock productivity and to supply equipment and consumables for field entomological surveillance activities and the operation of mass rearing insectaries and molecular biology laboratories in Burkina Faso, Ethiopia, Mali, Uganda, the United Republic of Tanzania, Zambia and Zimbabwe. The irradiation capacity at the tsetse insectaries of the United Republic of Tanzania and the International Centre of Research and Development for Livestock in Subhumid Zones was strengthened through the replacement of a non-functional irradiator. In addition, fellowships were implemented to support the progress in capacity building at the local level for drone operations targeting the releases of sterile flies in tsetse and trypanosomosis pilot projects in Ethiopia, Uganda, the United Republic of Tanzania, and Zimbabwe.

12. Through the TC programme, the Agency continued to provide technical support to Senegal in its efforts to eradicate the *Glossina palpalis gambiensis*, a species of tsetse fly, from the highly productive agricultural region of Niayes, to the north-east of Dakar, using an AW-IPM approach with an SIT component. Except for a few hot spot areas, the tsetse fly populations have been suppressed by approximately 97%. The prevalence of trypanosomosis is very low and Senegal continues to import more productive cattle into the area.



FIG. B.3. Healthy livestock in tsetse-cleared area. (Source: IAEA)

13. In Burkina Faso, capacity building activities on the use of molecular tools to identify tsetse fly and trypanosome species have been conducted and a fully equipped molecular biology laboratory has been established. Efforts to expand the *Glossina morsitans morsitans* colony and to establish a new colony of *Glossina tachinoides* from field-collected material have been initiated. A mobile freezer is routinely used to transport blood collected at the abattoir in Ouagadougou to feed the tsetse flies in the mass rearing insectary in Bobo-Dioulasso. Permission to use drones from the local authorities has been granted and procurement procedures for long-range drones and associated training to release the sterile males in the field have been initiated.

14. In Chad, preoperational activities have continued in the Mandoul area, one of the country's few remaining active foci of sleeping sickness. Genetic population studies have confirmed the isolation of the population of the vector tsetse fly *Glossina fuscipes fuscipes*. Suppression activities have continued with the deployment of very small targets, resulting in an extremely low density of tsetse flies and the lowest number of cases of sleeping sickness in this focus, which consists of areas for which historical records of disease transmission are available. The upscaling of the colony to produce sterile males has begun at a mass rearing facility operated by Scientica in Slovakia. Training activities on the maintenance of tsetse colonies and the long-distance shipment of sterile pupae have continued. A field insectarium that can process 10 000 pupae per week was established in Bodo. Procedures for the purchase of a long-range drone and training on its operation have been initiated with the aim of reducing the cost of the upcoming operational phase.

15. African trypanosomiasis affecting livestock continues to pose a significant constraint on development in much of sub-Saharan Africa, especially in the rural areas where poverty and lack of infrastructure are most acute. Where technically feasible, SIT, as a component of AW-IPM

interventions, can be a significant tool for alleviating this constraint. It provides an environmentally friendly option for eradicating tsetse fly vector populations, removing the risk not only of animal trypanosomosis, but also of human trypanosomosis (sleeping sickness) where it occurs. The benefits achieved, such as the improved ability to rear livestock for milk, meat and animal traction for ploughing to grow crops, will substantially improve the livelihoods of rural populations. The Agency continues to assist in building capacity in this area for the benefit of Member States in sub-Saharan Africa.

16. The constraints on successful and more widespread application of SIT in suitable areas continue to be the shortage of mass rearing capacity in Africa and the appropriate management and management structures for mass rearing and area-wide pest control operations.

# Renovation of the Agency's Nuclear Applications Laboratories at Seibersdorf

## A. Background

1. During the 56th regular session of the General Conference in September 2012, the Director General called for an initiative to modernize and renovate the eight laboratories of the Department of Nuclear Sciences and Applications in Seibersdorf, Austria, to enable them to meet the growing and evolving needs of Member States. The General Conference supported the initiative of the Director General in resolution GC(56)/RES/12.A.5, and the Renovation of the Nuclear Applications Laboratories (ReNuAL) project was officially launched on 1 January 2014. The strategy for the project was issued in May 2014 in documents GOV/INF/2014/11 and GOV/INF/2014/11/Corr.1.
2. ReNuAL Plus (ReNuAL+) was delineated in an addendum to the strategy that was issued in September 2014 (document GOV/INF/2014/11/Add.1) to provide for improvements required by the laboratories that could not be accommodated within scope of the ReNuAL project. In February 2017, the Secretariat issued document GOV/INF/2017/1, *Renovation of the Nuclear Applications Laboratories (ReNuAL) Project*, which updated Member States on the status of ReNuAL and ReNuAL+ and provided details on the implementation of ReNuAL, the scoping and costing of ReNuAL+, and efforts on resource mobilization.
3. The combined ReNuAL/ReNuAL+ initiative has delivered new laboratory buildings to house four of the eight nuclear applications laboratories in Seibersdorf and has provided a new linear accelerator facility for the Agency's Dosimetry Laboratory. It was expected that the four remaining laboratories would be expanded, and core infrastructure enhanced in the existing buildings once the other laboratories currently sharing those facilities moved into their new space. However, in early March 2020, an assessment by external experts concluded that the full renovation of the existing 60-year-old laboratory building, intended to make the laboratories 'fit for purpose' to support Member State requirements, would likely take longer, cost more and result in a lower-quality laboratory building than the construction of a new building to house three of the laboratories (the Terrestrial Environment Laboratory, the Plant Breeding and Genetics Laboratory, and the Nuclear Science and Instrumentation Laboratory). The ReNuAL project management team determined the conclusions of the experts to be appropriate and concurred that a new building was the most suitable option for enhancing the three laboratories.
4. In that context, the Director General announced during the March 2020 Board of Governors meeting plans to build a second new Flexible Modular Laboratory (FML-2) building, which will house the three above-mentioned laboratories. The Dosimetry Laboratory will be refurbished in its current location adjacent to its new linear accelerator facility. Ageing greenhouses, on which the work of three laboratories heavily depends, will also be replaced. The Director General provided information on resources required and further elaborated planning for this final phase of the project, informally called ReNuAL 2, during a technical briefing on 3 September 2020. The successful conclusion of this final project phase will enable the nuclear applications laboratories to respond to the growing and evolving needs of Member States and assist their efforts to achieve the Sustainable Development Goals.
5. The General Conference, in resolution GC(64)/RES/12.A.3, requested the Director General to report on the progress made in the implementation of this resolution to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

### B.1. Implementation Status

6. Steady progress has been made in the modernization of the laboratories since construction commenced in July 2016, and all new construction anticipated under the original project strategy and its addendum are now complete. The new Yukiya Amano Laboratories, which were officially opened by the Director General in June 2020, are now fully functional.

7. The new Energy Centre, which became operational in the second quarter of 2019, had a cogeneration feature incorporated into its operations to reduce energy consumption in the third quarter of 2020.

8. Concept design planning for the main elements of ReNuAL 2 (i.e., the FML-2 building, greenhouses, and Dosimetry Laboratory refurbishment) was concluded with the assistance of an external architectural firm in May 2021. It is expected that a contract for the construction of FML-2 will be offered for tender in the fourth quarter of 2021 in anticipation of a launch of construction in early 2022.



FIG. B.1. IAEA Seibersdorf Site Overview (Source: IAEA)

### B.2. Financial Status and Resource Mobilization

#### B.2.1. Financial Status

9. Over €39 million in extrabudgetary funds was raised for ReNuAL and ReNuAL+, with financial and in-kind contributions received from 42 Member States and additional financial and in-kind support received from non-traditional donors. The combined ReNuAL/ReNuAL+ project target budget of €57.8 million was exceeded by approximately €470 000. Approximately €9.7 million of this project budget remains available to address the requirements of the four remaining laboratories in the next project phase, which will include the construction of a new building (FML-2), construction of new greenhouses, refurbishment of the Dosimetry Laboratory, and additional infrastructure work.

10. Preliminary cost estimates totalling €34.5 million for the final phase of laboratory modernization were provided to Member States in the Director General's technical briefing on 3 September 2020. With €9.7 million to address the needs of these laboratories already available from the ReNuAL/ReNuAL+ budget, the Director General requested Member State support to raise the remaining €24.8 million. As of the June 2021 Board of Governors meeting, five Member States have announced extrabudgetary contributions for the ReNuAL 2 phase totalling approximately €8.1 million. If approved, a proposal for €3.1 million in funding for ReNuAL 2 from the Major Capital Investment Fund would leave a current outstanding requirement of €13.6 million, based on current estimates. More refined estimates will become available upon completion of detailed designs ahead of the 65th General Conference.

### **B.2.2. Funding Priorities**

11. The funding needed to complete all ongoing project activities has been mobilized. These activities include ongoing work with external experts to produce conceptual and detailed designs for the construction of the FML-2 building, the refurbishment of the Dosimetry Laboratory wing and the replacement of greenhouses. A Member State contribution to ReNuAL 2 announced during the 64th General Conference included funding for the refurbishment of the Dosimetry Laboratory. The current objective is to obtain approximately €8.9 million in additional funding urgently needed to procure and launch construction of the FML-2 building. Funding for the replacement of the greenhouses may be pursued separately or in tandem with funding for FML-2.

### **B.2.3. Resource Mobilization Strategy**

12. The Secretariat has pursued an element-specific resource mobilization strategy that seeks resources from Member States and non-traditional donors based on existing funding requirements. In support of this strategy, new and targeted resource mobilization products have been developed to highlight the importance of the timely completion of laboratory modernization and the relevance of individual project elements to meeting Member States' demands for training, applied research and services. Tailored donor packages include comprehensive information on the remaining elements of the project and their funding requirements. Resource mobilization products are continually updated to account for progress in completing specific project elements, any changes in expected costs, and expected resource requirements.

13. Laboratory tours remain invaluable to highlight the important work of the laboratories and play an essential role in fundraising efforts; however, lab visits were suspended for much of the period due to the global COVID-19 pandemic and resumed only on a very limited basis in the first half of 2021. In response, the Secretariat has developed and is expanding access to online resources, including virtual laboratory tours. Special events organized by the Secretariat, including side events at the General Conference and the March and June 2021 Board of Governors meetings provided valuable additional support to resource mobilization efforts. During the March 2021 side event, the Director General announced the concept for a new donor display on which new contributors to ReNuAL 2 would be recognized. During the June 2021 side event, representatives of the five Member States that had announced contributions to ReNuAL 2 since the 64th General Conference were invited to symbolically place their 'national plaque' on the new donor display, which will be permanently installed in the lobby of the new FML-2 building upon its completion.



*FIG. B.2. IAEA Director General Rafael Mariano Grossi delivers his remarks at the ReNuAL2: Building for Science, Designing for the Future, a side event at the June 1579th Board of Governors Meeting held at the IAEA headquarters in Vienna on 7 June 2021 (Source: IAEA)*

#### **B.2.4. Resource Mobilization Efforts with Member States**

14. The Secretariat continued to engage in bilateral discussions with a wide number of Member States to support fundraising, resulting in 42 Member States providing financial contributions towards the ReNuAL and ReNuAL+ phases of the initiative and five Member States announcing contributions to the ReNuAL 2 phase. The Friends of ReNuAL, an informal group open to all Member States and co-chaired by Germany and South Africa, continued to play an important role in resource mobilization. Participants in the Friends group, which meets on a regular basis, have been significant bilateral contributors to the ReNuAL initiative, and the group remains an important vehicle for maintaining and increasing awareness of the importance of laboratory modernization and for generating Member State support for these efforts.

#### **B.2.5. Resource Mobilization Efforts with Non-Traditional Donors**

15. A new announcement of the remaining equipment requirements for the nuclear applications laboratories was posted to the United Nations Global Marketplace in December 2020 to maximize the potential of generating private sector interest in partnering with the Secretariat.

## C. Next Steps

16. With all the new facilities previously under construction now complete and fully operational, project focus has now been on working with external experts to finalize conceptual and detailed designs for the main elements of the ReNuAL 2 project phase, including construction of the FML-2 building, refurbishment of the Dosimetry Laboratory wing and replacement of the greenhouses. The ongoing design phase will yield refined cost estimates that will further inform the project's resource mobilization strategy, including short-, medium- and longer-term funding targets.

17. Resource mobilization efforts will focus on raising, by the fourth quarter of 2021, the additional €8.9 million funding urgently needed to procure and launch construction of the FML-2 building in early 2022. Funding to refurbish the Dosimetry Laboratory wing of the existing lab building has already been mobilized. Mobilizing resources to replace existing greenhouses will be prioritized with the objective of obtaining full funding in 2022 and may be pursued separately or in tandem with funding for the FML-2 building.



# Development of the Sterile Insect Technique Package for the Management of Disease-Transmitting Mosquitoes

## A. Background

1. In resolution GC(62)/RES/9.A.2, the General Conference noted with concern that “about 3.2 billion people remain at risk of malaria, transmitted by mosquitoes, and that in 2016 alone there were an estimated 216 million new cases of malaria and 445 000 deaths, mainly in Africa, thus constituting a major obstacle to poverty eradication in Africa.” It noted that “the malaria parasite has continued to develop resistance to available drugs and that mosquitoes had continued to develop resistance to insecticides.”

2. The General Conference noted with serious concern that, in recent years, “mosquito-transmitted dengue, now the world’s most common mosquito-borne disease, has become a major international public health concern with an incidence growing more than 30-fold during the last 50 years”, and that “dengue is estimated to infect around 400 million people per year, and over half of the world’s population is at risk of the disease.”

3. The General Conference noted that “the suppression of disease-transmitting mosquitoes using the sterile insect technique (SIT) will be suitable mostly in urban areas, where aerial spraying with insecticides is prohibited or not recommended, and an area-wide approach is required, which represents a novel and potentially powerful supplement to existing community-based programmes.”

4. The General Conference requested the Agency to continue and strengthen “the research, both in the laboratory and in the field, required to be able to refine and validate the use of the SIT for the integrated management of malaria-, dengue-, Zika- and other disease-transmitting mosquitoes.” It requested the Agency to “increasingly involve developing Member States’ scientific and research institutes in the research programme in order to secure their participation, leading to ownership by the affected countries.” The General Conference also requested the Agency to “increase efforts to develop and transfer more efficient sex separation systems, including genetic sexing strains, that allow complete removal of the female mosquitoes in production facilities and to develop cost-effective methods to release and monitor sterile males in the field.”

5. The General Conference also requested the Agency to “strengthen capacity building and networking in Latin America, Asia and the Pacific, and Africa through regional technical cooperation (TC) projects and to support field projects against *Aedes* and *Anopheles* mosquitoes through national TC projects for assessing the potential of the SIT as an efficient control tactic for disease-transmitting mosquitoes.”

6. The General Conference noted with appreciation “the interest shown by some donors in and their support for research and development (R&D) on the SIT for combating malaria-, dengue-, Zika- and other disease-transmitting mosquitoes,” and requested the Agency to “allocate adequate resources and to attract extrabudgetary funds so as to continue the currently expanded mosquito research programme, laboratory/office space and staffing.”

7. The General Conference invited the Agency to “act upon the recommendation made by the experts of the Thematic Plan for the Development and Application of the Sterile Insect Technique (SIT) and Related Genetic and Biological Control Methods for Disease Transmitting Mosquitoes to invest in supporting the management of the mosquito vector species through continuous funding of the development of the SIT and related genetic and environment-friendly methods.”

8. The General Conference, in resolution GC(64)/RES/12.A.5, requested the Director General to report on the progress made in the implementation of resolution GC(62)/RES/9.A.2 to the General Conference at its 65th regular session.

## **B. Progress since the 62nd Regular Session of the General Conference**

9. In response to resolution GC(62)/RES/9.A.2, the Agency, through the Insect Pest Control Laboratory (IPCL) in Seibersdorf, Austria, continued to work on the development of the SIT package for disease-transmitting mosquitoes, i.e. *Anopheles arabiensis*, which is a vector of malaria, and *Aedes aegypti* and *Aedes albopictus*, which are the main vectors of dengue, Zika, chikungunya and yellow fever. The IPCL is currently maintaining mosquito strains from 16 countries, including strains with morphological and other markers, which are currently being evaluated for their potential use in SIT-based approaches.



FIG. B.1. Male mosquitoes are loaded into the chamber of a Gammacell 220 unit for sterilization.  
(Source: IAEA)

10. The Agency continued its efforts to develop robust and efficient methods for sex separation, including genetic sexing. Two *Ae. aegypti* genetic sexing strain (GSSs), one based on red eye colour and the other on white eye colour, were developed and validated under laboratory conditions. The *Ae. aegypti* red-eye GSS is robust; it has been introgressed into different genomic backgrounds and can be used for field testing within the framework of the TC programme. An irradiation-induced chromosomal inversion was integrated into the red-eye GSS to enhance its genetic stability. Additional mutations (mainly body and eye-colour mutations) have been isolated for *Ae. aegypti*, *Ae. albopictus* and *An. arabiensis* and are currently under evaluation as potential selectable markers for genetic sexing.



FIG. B.2. *Aedes aegypti* pupae: (a) black-eyed male, (b) red-eyed female and (c) white-eyed female. (Source: IAEA).

11. In terms of mosquito mass-rearing technology, the IPCL has developed and validated several tools, pieces of equipment and procedures with the aim of reducing production costs and increasing the quality of the biological material. For example, new cages for adult *Aedes* mosquitoes and larval racks have been validated for *Ae. Albopictus*, with a significant reduction in cost; an automated larval counter has been evaluated for three species; and a new larval diet based on inexpensive insect proteins (black soldier fly powder) has been developed for mass-rearing mosquito larval stages.

12. Recognizing the increasing challenges associated with using isotopic irradiators for the sterilization of mosquitoes and the anticipated expansion of mosquito suppression projects, the Agency assessed the relative efficiency of X rays and gamma rays to induce sterility in male pupae of *An. arabiensis*, *Ae. albopictus* and *Ae. Aegypti*. The Agency also assessed the major factors impacting the dose response curve and quality of insects, including the dose rate, chilling, atmospheric conditions, geographic origin, life stage and age of pupae. Furthermore, the potential for irradiating adult chilled mosquitoes on a small and large scale is being investigated. The Agency also initiated collaboration with the private sector for the development of X-ray irradiators adapted to the sterilization of mosquitoes.

13. A rapid quality control test that measures flight ability has been developed for *Ae. aegypti*, *Ae. albopictus* and *An. arabiensis* and transferred to Member States.

14. Molecular tools to diagnose mosquito-borne diseases and pathogens in mosquito colonies were developed in collaboration with 'Infravec 2', a research project funded by the European Commission. These molecular tools will prove crucial in maintaining pathogen-free colonies in SIT programmes.

15. Following the successful suppression of target populations of *Ae. albopictus* in Guangzhou, China, through a combination of SIT and the incompatible insect technique, similar results were obtained in Singapore against *Ae. Aegypti*, where the target population was significantly suppressed. In Cuba, an open field pilot trial using the SIT to suppress populations of *Ae. aegypti* resulted in a 90% reduction in egg hatching.



FIG. B.3. The first release of mosquitoes in Habana, Cuba was carried out at the local school.  
(Source: Institute of Tropical Medicine Pedro Kouri)

16. The Centro Agricultura Ambiente ‘Giorgio Nicoli’ in Italy and Moscamed in Brazil have been designated as Agency Collaborating Centres since September 2017 and March 2018, respectively. They have reported significant development of the SIT package application for *Ae. albopictus* in Italy and *Ae. aegypti* in Brazil. Additionally, Sun Yat-sen University in China was designated as an Agency Collaborating Centre in 2021 to assist in the implementation of activities in the field of developing the SIT for control of mosquitoes, over a period of four years.

17. The Agency continued to implement the coordinated research project (CRP) entitled ‘Mosquito Handling, Transport, Release and Male Trapping Methods’. The CRP resulted in novel protocols for monitoring, marking, handling, transport, and release of sterile males, targeting the control of *Aedes* species, which will be transferred to Member States and will benefit mosquito SIT pilot projects around the world. A new CRP entitled ‘Mosquito Irradiation, Sterilization and Quality Control’, was approved and began in July 2020.

18. In response to Member States’ needs for new sterile male mosquito release methods, the Agency, in collaboration with the European Research Council, is undertaking efforts to reduce the weight of a drone release system for sterile male mosquitoes to allow for the system’s use over urban areas. Field tests are ongoing in some Member States.

19. The Agency continued to provide Member States with support through five regional TC projects covering: the European region (project RER5022, entitled ‘Establishing Genetic Control Programmes for *Aedes* Invasive Mosquitoes’ and RER5026, entitled ‘Enhancing the Capacity to Integrate Sterile Insect Technique in the Effective Management of Invasive *Aedes* Mosquitoes’); the Asia-Pacific region (project RAS5082, entitled ‘Managing and Controlling *Aedes* Vector Populations Using the Sterile Insect Technique’); and the Latin America and the Caribbean region (project RLA5074, entitled ‘Strengthening Regional Capacity in Latin America and the Caribbean for Integrated Vector Management Approaches with a Sterile Insect Technique Component, to Control *Aedes* Mosquitoes as Vectors of Human Pathogens, particularly Zika Virus’ and RLA5083, entitled ‘Enhancing Capacity for

the Use of the Sterile Insect Technique as a Component of Mosquito Control Programs'). It also provided support through an interregional TC project (project INT5155, entitled 'Sharing Knowledge on the Sterile Insect and Related Techniques for the Integrated Area-Wide Management of Insect Pests and Human Disease Vectors'), which is a fundamental strategic platform for the exchange of knowledge and experiences worldwide.

20. The Agency continued to provide support to Member States through the TC programme in Brazil, Cuba, Mauritius, Mexico, the Philippines, South Africa, Sri Lanka, Sudan and Turkey. The Agency has also supported pilot trials for mosquito SIT application in Italy, Spain and the United States of America.

21. The Agency launched a phased conditional approach scheme, through which Member States can test and implement SIT for vector control where advancing to the next phase depends on completion of activities in the previous phase, with the objective to progress towards implementation of SIT field programmes.

22. As part of a Memorandum of Understanding between the Agency and the WHO, a *Guidance Framework for Testing the Sterile Insect Technique as a Vector Control Tool against Aedes-Borne Diseases* has been available to Agency Member States since April 2020. In addition, in August 2019, Agency and WHO experts assisted Bangladesh in assessing the country's dengue outbreak and developing a plan to test SIT to suppress the mosquitoes that spread the disease.

23. After a very successful reduction in the prevalence of malaria since the beginning of the 21st century, the number of cases has remained stable in the past five years. The Agency is seeking further resources for the development of the SIT package against malaria-transmitting mosquitoes, particularly as it relates to the R&D component of the full SIT package, including its testing and validation, and transfer to Member States.

24. The SIT is part of an area-wide integrated vector management approach. The Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture and the IPCL have continued with the development, validation, and optimization of the SIT package as a complementary tool for the management of mosquito populations. Good progress has been made in collaboration with Member States, including through the TC programme, on two of the main challenges: the development of efficient sex separation methods that would allow male-only releases, and the aerial release of mosquitoes. The current developments in sexing and drone release will allow for the testing of the SIT approach in pilot trials to demonstrate that it is a safe, bio-secure and responsible approach to managing mosquito populations.

# Strengthening the Support to Member States in Food and Agriculture

## A. Background

1. In resolution GC(62)/RES/9.A.5, the General Conference recognized the central role of agricultural development in accelerating progress towards several Sustainable Development Goals (SDGs), in particular to end hunger, achieve food security and improved nutrition, and promote sustainable agricultural development for the socio-economic benefits of all Member States. It consequently urged the Secretariat to further expand, in an integrated and holistic manner, its efforts to address, inter alia, food insecurity in Member States and to further increase its contribution to raising agricultural productivity and sustainability, reducing poverty and hunger, and improving farmers' incomes, through the development and integrated application of nuclear science and technology. It encouraged the Joint FAO/IAEA Division to continue responding to the major global trends framing agricultural development in order to ensure to the maximum extent possible an increased resilience of livelihoods to threats and crises in agriculture, including the adaptation to and mitigation of the effects of climate change.
2. The General Conference further recognized that the major global trends that will frame agricultural development over the medium term include rising food demand, lingering food insecurity, malnutrition, and the impact of climate change. It consequently urged the Secretariat to address the impacts of climate change on food and agriculture through the use of nuclear technologies, with priority on adaptation to and mitigation of the effects of climate change, including through the development of tools and technology packages. It invited the Secretariat to carry out activities for addressing climate change challenges under the thematic heading of 'climate-smart agriculture'.
3. The General Conference further invited the Secretariat, in view of the global trend in antimicrobial resistance (AMR) and its impact on human and animal health, to continue to follow international efforts to establish possible applications where nuclear/isotopic methods/tools may provide comparative advantages.
4. Welcoming the demand-driven research activities on the development of communication tools to improve decision-making in agricultural water management in Africa, and the new visualization platform for nuclear and radiological emergency preparedness and response for food and agriculture, the General Conference urged the Secretariat to further strengthen its effort to seek extrabudgetary funding for strengthening its research activities in the preparedness and response to nuclear and radiological emergencies affecting food and agriculture.
5. The General Conference, in resolution GC(64)/RES/12.A.7, requested the Director General to report on the progress made in the implementation of resolution GC(62)/RES/9.A.5 to the General Conference at its 65th regular session.

## **B. Progress since the 62nd Regular Session of the General Conference**

6. The Joint FAO/IAEA Division, now named the Joint FAO/IAEA Centre, currently oversees 35 coordinated research projects (CRPs) involving approximately 450 research institutions and experimental stations in Member States and is responsible for providing scientific and technical support to 328 national, regional and interregional technical cooperation (TC) projects. During the reporting period, 264 demand-driven workshops, seminars and training courses were held, with the participation of 6433 trainees from developing countries, mainly supported through the Agency's TC programme. In addition, the Joint Centre yielded 602 publications, including 124 technical documents, newsletters, guidelines, and books; 290 articles in peer-reviewed scientific journals; 141 conference papers; and six special editions in peer-reviewed scientific journals.

7. Demand-driven research and development activities continued at the FAO/IAEA Agriculture and Biotechnology Laboratories in Seibersdorf, Austria, in response to Member States' requests, including the use of nuclear techniques for climate-smart agriculture and measuring agricultural greenhouse gases for better mitigation options; the development of isotopic and analytical techniques for food traceability and authenticity, as well as contaminant and residue analysis; the investigation of irradiated animal vaccines; the development of radiation hybrid maps for animal breeding; the strengthening of animal disease diagnostic applications for early detection of animal and zoonotic diseases, including COVID-19; the development of climate-adapted and higher-yielding crops; and the control of plant and livestock insect pests.

8. The development and further enhancement of laboratory networks with the participation of multiple stakeholders continued to be a primary focus, in particular to strengthen support for the timely diagnosis, control and eradication of transboundary animal and zoonotic diseases (e.g. the Veterinary Diagnostic Laboratory (VETLAB) Network); to enhance capabilities in food safety and food control systems (e.g. the Latin American and Caribbean Analytical Network (RALACA), the African Food Safety Network (AFoSaN) and the Food Safety Asia (FSA) Network); to foster crop improvement and adoption of modern biotechnologies (the Plant Mutation Breeding Network (MBN) for the Asia and Pacific region and the Coffee Mutation Network); and to share knowledge on the sterile insect technique (SIT) for insect pest control (Tephritid Workers Database).



*FIG. B.1. VETLAB Network scientists learn how to use the multi-pathogen assay method.  
(Source: IAEA)*

9. The Agency continued to support the VETLAB Network, which has extended to 45 Member States in Africa and 19 Member States in Asia, through the provision of training, diagnostic kits, standard operating procedures, and equipment and material for the control and prevention of transboundary animal and zoonotic diseases.

10. The Agency supported Member States in their efforts to tackle COVID-19 (further details are provided in document GOV/INF/2021/4). The Joint FAO/IAEA Centre responded immediately with strong technical support, expert guidance, and laboratory backstopping. The Agency provided packages to 128 countries and territories, including detection equipment, namely real-time reverse transcription–polymerase chain reaction (RT–PCR) instruments and testing kits, together with reagents and laboratory consumables, as well as biosafety supplies for the safe handling and analysis of samples of COVID-19.

11. The Indonesian Research Center for Veterinary Sciences was the first to rapidly detect the African swine fever (ASF) virus. Since the emergence of ASF in Indonesia in September 2019, the institute has implemented diagnostic tests for disease confirmation and surveillance. These include ASF-specific and multiplex (haemorrhagic disease panel) RT–PCR and virus isolation in primary cell cultures.

12. Since 2019, several Asian countries have experienced the emergence of lumpy skin disease (LSD) virus, which spread rapidly during the summer of 2020 in Bangladesh, Bhutan, Indonesia, Myanmar, Nepal, Sri Lanka, Thailand, and Viet Nam. The Agency, through the VETLAB Network, supported these countries with laboratory material and molecular characterization of local LSD virus isolates, sequencing the full genome or targeted multiple genes for Bangladesh and Viet Nam, and is working with the other countries.

13. Senegal detected and notified rabbit haemorrhagic disease virus (RHDV2) for the first time in 2020. It soon spread to Burkina Faso and Nigeria, causing high mortality in domestic rabbits. The VETLAB Network has efficiently worked to support partner veterinary laboratories in West Africa.

14. Episodes of acute mortalities or severe diseases owing to apparent unknown reasons can occur in wild and domestic animals. In the last few months, episodes of large mortalities have been reported in Burkina Faso (in wild birds such as doves) as well as in Ethiopia and Kenya (in camels). The Joint FAO/IAEA Centre and the VETLAB Network are actively supporting laboratory investigations to assess whether known or unknown infectious agents are present and to reveal the reason for these episodes.

15. Novel irradiated prototype vaccines were tested to investigate their efficacy against animal diseases. Experiments were done in collaboration with the University of Veterinary Medicine Vienna, the Austrian Agency for Health and Food Safety (AGES) and the Experimental Zooprophyllactic Institute of Venice. In addition, the Joint FAO/IAEA Centre provided technical support to establish a flow cytometry facility at the University of Peradeniya in Sri Lanka, an indispensable tool for evaluating vaccine responses.

16. A whole genome sequencing technology, based on the Oxford Nanopore MinION platforms, was implemented in seven African veterinary laboratories in the Democratic Republic of the Congo, Ethiopia, Morocco, Namibia, the Niger and Senegal, with support through the TC programme. The technology will be used primarily in a metagenomic mode to enable detection of unknown pathogens in domestic and wildlife carriers.

17. In 2020, the Agency, in collaboration with the University of Veterinary Medicine Vienna and the International Camel Consortium for Genetic Improvement and Conservation, developed a multi-species camelid deoxyribonucleic acid (DNA) chip for selection and breeding of high producing camels. This chip contains around 200 000 markers and can be used for genetic evaluation of a variety of camel species, including dromedaries, Bactrian camels, alpacas, and lamas. The chip is currently under validation and field testing and will be rolled out in late 2021.

18. The Agency provided technical support to six countries — Argentina, Bangladesh, Peru, Serbia, Sri Lanka, and Uruguay — in performing genome-wide evaluation of their local cattle. A bovine 60K DNA chip is being used to genotype more than 1,900 cattle. The purpose of this evaluation was to perform genome-wide association of genotypes with milk production traits (Serbia); to estimate genetic admixture and assess the level of taurine inheritance in crossbred cattle (Bangladesh and Sri Lanka); to identify selection signatures related to high-altitude adaptation (Peru); and to assess genetic biodiversity in local cattle (Argentina and Uruguay).

19. RALACA has expanded to include 57 institutions in 21 countries, as well as coordinating workshops and interlaboratory trials and training. AfoSaN continued to grow to 102 laboratories, and research and food control organizations have been established in 39 participating countries, fostering technical networking and capacity building. The FSA Network is facilitating collaboration among its member institutions in improving laboratory testing capabilities (e.g. Pakistan supported Papua New Guinea in food hazard testing, Lebanon assisted Jordan in testing pesticide residues, and Thailand supported Cambodia and Myanmar in testing contaminants), contributing to laboratory excellence and accreditation.

20. The MBN for the Asia and Pacific region, formally established with 13 signatory Member States at its first workshop in July 2019, held a second meeting virtually in November 2020, at which three additional Member States participated and joined the Network. The MBN's key roles as identified in the 'Jingzhou Proposal' of July 2019 are: strengthening national and regional capacities; enhancing germplasm resources; enabling the use of speed-breeding technologies; establishing functional genomics platforms; establishing stress-screening locations; early detection of transboundary pests and diseases; conservation of mutant germplasm; and joint resource mobilization. Strong interest in plant mutation breeding is also growing in the Latin America region.

21. The Agency expanded its technical interactions with the AGES for the use of its biosafety level 3 laboratory to strengthen research and development capacities for diagnostics of transboundary animal and zoonotic diseases, for the evaluation and validation of COVID-19 detection kits and tests, and for the genetic characterization of highly pathogenic bacteria and viruses affecting livestock in Member States. The Agency stepped up its assistance to several Asian Member States to fight the outbreak of ASF, including by strengthening Member States' technical diagnostic capabilities and providing guidance and advice to affected countries.



*FIG. B.2. Sample processing for the diagnosis of transboundary animal diseases at the National Centre for Veterinary Diagnosis, Viet Nam. (Source: IAEA)*

22. The Agency developed, in close collaboration with the Food and Agriculture Organization of the United Nations (FAO), guidelines on the use of nuclear and isotopic techniques for tracing antimicrobial movement from agricultural areas to the environment. Work is under way to produce a detailed guidance document for testing the methodology in Member States.

23. An Agency publication entitled *Strategies and Practices in the Remediation of Radioactive Contamination in Agriculture* was issued in February 2020, with a view to enhancing the preparedness and response planning of international organizations and Member States for nuclear emergencies and radiological incidents in relation to food and agriculture.

24. Applied research in parallel with capacity building on methodology for food authentication and detection of adulterants led to enhanced capacities for food safety and quality control in more than 30 Member States. This included various food products, such as milk, honey, and tea in China; high-value edible bird's nests in Malaysia; vinegar in the Philippines; and imported pork and milk products in Singapore. A 'quality assured' mark was also developed for local milk and dairy products in Slovenia.

25. Agency support resulted in ISO 17025:2017 accreditation for Member State food safety laboratories in Botswana, Mongolia, Namibia, Nigeria, Pakistan, South Africa and Uganda. This increases reliability of testing and monitoring chemical residues and related contaminants in foods.

26. Nuclear and isotopic analytical techniques developed through CRPs were applied in national surveillance and monitoring programmes for multiple/mixed residues and contaminants for more than five foodstuffs in ten Member States. One example is the multi-residue analytical method for detection

of 132 compounds, including pesticides and mycotoxins, in quinoa to address the challenge of quinoa export rejections in Peru.

27. The Agency continued work relevant to AMR, including development of an isotopic multi-residue method for quantification and confirmation of antimicrobial residues and mycotoxins in animal waste. This built on earlier work (analytical method) on determination of Chlortetracycline antimicrobial residues, antimicrobial activity and presence of resistance genes in droppings of experimentally treated broiler chickens and is critical to global AMR efforts. The Agency also supported more than 30 Member States in their antimicrobial residue testing and monitoring, a critical component of AMR. Further work is ongoing, including targeted research technology transfer.



*FIG. B.3. Recently accredited drug residue analytical laboratory in Pakistan. (Source: IAEA)*

28. The Agency continued to support the Codex Alimentarius Commission and the establishment of food safety standards and guidelines through active participation in Codex Committees such as on veterinary drug residues, pesticide residues and contaminants in food, as well as on methods of analysis. Most importantly, capacity building and technology transfer capabilities are enabling several Member States in the implementation of Codex standards, guidelines, and codes of practices.

29. The Agency, through the FAO/IAEA Joint Centre, supported the establishment or strengthening of five food safety and environmental health laboratories in Eritrea and The Gambia, as well as developing a blueprint for antimicrobial residue monitoring in the Asia and the Pacific region (in collaboration with the FAO Regional Office for Asia and the Pacific), piloted in Singapore and Thailand. Within the framework of the African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology, two regional designated centres were recognized in Algeria and Nigeria to support food safety education and analytical services, with a view to contributing to the enhancement of Africa's public health and regional and international trade in foodstuff through laboratory networking.

30. The Agency provided support to a Mediterranean fruit fly control scheme in Ecuador, as a component of the National Fruit Fly Management Project. As a result of the Agency's support, fruit and vegetable quality and quantity were increased, and international trade facilitated, with farmers being able to start the export of golden berries, dragon fruit and tree tomatoes to markets in the United States of America, Latin America and Europe.



*FIG. B.4. With the help of the SIT, Ecuador's tree tomato is now being exported to markets in the United States of America, Latin America and the Caribbean, and the European Union. (Source: Agrocalidad)*

31. The Agency provided support to Argentina in plant insect pest control, which is now bearing fruit thanks to the successful application of the SIT against the Mediterranean fruit fly. In early 2020, China recognized the fruit fly free status of Patagonia and parts of Mendoza Province. As a result, cherries and other stone and pome fruits from these regions of Argentina can be exported to the world's largest fresh food markets.

32. The Agency provided support to the Plurinational State of Bolivia to build a state-of-the-art fly emergence and release facility to support SIT implementation. Three million sterile male Mediterranean fruit flies are being shipped weekly from a mass-rearing and sterilization facility located in Mendoza, Argentina. The sterile flies are released over 2000 hectares where the pest is present in Cochabamba, Plurinational State of Bolivia.

33. The Agency recently developed the SIT package for the spotted wing drosophila and European grapevine moth, pests of soft fruits and grapes, respectively. Pilot field trials for both species, in collaboration with Argentina and Chile, were initiated in 2020.

34. During the reporting period, the Agency published 28 standard operating procedures, manuals and guidelines on area-wide integrated pest management (AW-IPM) for the benefit of national plant protection and animal and human health organizations, covering fruit flies, mosquitoes and trypanosome species. An animated infographic entitled 'Fruit Fly Standards can Help Gain Market Access' was produced in collaboration with the International Plant Protection Convention. Two open-source textbooks with over 1000 pages were produced in 2021: the second edition of the book 'Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management' and 'Area-Wide Integrated Pest Management: Development and Field Application'.

35. The Agency continued to provide technical support to the Senegal in its efforts to create a tsetse-free zone in the highly productive agricultural region of Niayes in western Senegal, using an AW-IPM approach with an SIT component. The tsetse fly populations in the project area have been suppressed

by approximately 97%, resulting in a very low prevalence of tsetse-borne trypanosomosis, allowing Senegal to continue importing more productive cattle into the area.

36. The Agency continued to provide technical assistance in plant mutation breeding and associated biotechnologies to more than 70 Member States, and supported the development and release of 18 new and improved crop varieties during 2020 in six Member States, namely, Bulgaria, China, India, Indonesia, Malaysia and Pakistan. In addition, a total of seven advanced improved mutant lines developed by Senegal were distributed to farmers through informal seed systems.



*FIG. B.5. Mutant ginger plants under selection for resistance to soft rot at the Scientific Research Council of Jamaica, with technical support from the Agency on irradiation, tissue culture and screening procedures. (Source: IAEA)*

37. Two firsts in plant mutation breeding were achieved in 2020, one in the improvement of ginger and the other in the improvement of forest trees. Technical assistance provided by the Agency enabled Jamaica to identify mutant ginger variants resistant to soft rot using tissue culture and irradiation in combination with laboratory- and greenhouse-based selection protocols. Agency assistance also enabled Chile to initiate the application of irradiation to the improvement of productivity and adaptation to climate change in forest trees, along with the establishment of a molecular biology laboratory to facilitate faster and more precise selection.

38. In 2020, the Agency worked in close cooperation with the FAO Country Office in Sudan to ensure access of growers in the North Kordofan region to a drought-adapted mutant variety of groundnut, Tafra-1, released in 2018 with the technical support of the Agency. Approximately 2900 tonnes of high-quality seeds are currently in production, with the aim of reaching 4300 smallholder farmers in 2021.

39. The Agency worked with researchers from several Member States to fight Fusarium wilt tropical race 4 (TR4), which has been destroying banana plantations in Asia, Africa, and Latin America. The concerted effort has led to the development and release by partners in China of a new mutant variety of Cavendish, a type of banana commonly used for export, with resistance to TR4. Other Member States have identified putative mutants with possible resistance or tolerance to the disease.



*FIG. B.6. Chinese plant breeders at a banana plantation with the new Cavendish varieties grown in Guangdong, China. (Source: G. Yi)*

40. The Agency has been assisting Member States in tackling another major challenge to agriculture productivity and food security: Striga, a serious parasite for cereal and cowpea crops in sub-Saharan Africa. This parasitic weed causes yield reduction of staple crops such maize, millet, rice and sorghum, resulting in enormous economic losses. Through the Agency's technical support, Burkina Faso, Madagascar, and Sudan have developed maize, rice and sorghum mutant lines with resistance to Striga.



*FIG. B.7. A researcher from Burkina Faso's Institute for the Environment and Agricultural Research explains the results of the new sorghum lines resistant to Striga to fellow colleagues at the Agency's Plant Breeding and Genetics Laboratory in Seibersdorf, Austria.*

*(Source: IAEA)*

41. Technical guidance from the Agency to Pakistan over the past four years has enabled the development and increased seed dissemination of four new and improved mutant cotton varieties resulting in a continuously expanding cultivation area. During 2020, the area in which the four recent mutant cotton varieties are found rose to around 700 000 hectares, which constitutes over 40% of the total cotton area in the Panjab province, the major cotton-growing region in the country.

42. The Agency strengthened its cooperation with, and its support for, small island developing States in the area of crop improvement for food security. Through the TC programme, an interregional training course was held in October 2019 on mutation breeding and efficiency enhancing techniques for the benefit of 24 scientists from Fiji, the Marshall Islands, Palau, Papua New Guinea and Vanuatu, as well as from other small States in Africa and Latin America. Similar support in the area of food safety was provided to Fiji, the Marshall Islands, Papua New Guinea and Vanuatu.

43. The Agency continued its support to more than 75 African, Asian, European and Latin American Member States in the development of soil conservation strategies using fallout radionuclide techniques to ensure sustainable agricultural production and mitigate the impacts of climate change on soil erosion, especially in upland ecosystems.

44. The Agency has furthered the development of the online Decision Support System for Nuclear Emergencies Affecting Food and Agriculture. The system is being customized for Member States such as Belgium and China to provide tailor-made solutions for improving nuclear emergency preparedness and response in food and agriculture. It includes the collection, management, and visualization of appropriate data from affected areas to ensure timely dissemination and communication to stakeholders and the general public.

45. The Agency, through the TC programme, assisted Mali and Nigeria with drip irrigation and smart fertilization guided by nuclear technology-fostered subsistence agriculture. As a result, 500 rural smallholder farmers in Mali, mostly women, were able to turn low-yielding lands into fertile agricultural plots. The technology has also empowered 2500 Nigerians, also mostly women, to grow crops and make a living for themselves.



*FIG. B.8. Smallholder farmers harvesting tomatoes in the Sahel region of Segou in central Mali. (Source: D. Coulibaly)*

46. The Agency has also contributed to the use of digital agriculture as part of demand-driven research activities on communication tools to improve decision making in agricultural water management in Africa. It has developed real-time digital technology for mapping soil properties and monitoring landscape water availability, along with a new visualization platform for nuclear and radiological emergency preparedness and response in food and agriculture.

47. The Agency has coordinated international research and development activities using isotopic techniques to identify greenhouse gas emission pathways and, in turn, devise effective mitigation techniques. Among the achievements were the development of a novel instrument for real-time measurement and analysis of carbon dioxide in agriculture and the development of a low-cost and robust method for methane measurement, in collaboration with the Agrobiological Centre of the Brazilian Agricultural Research Corporation and the Agronomic Institute of Paraná.

## **C. Strengthening the FAO–Agency Partnership**

48. The Joint FAO/IAEA Centre has continuously adjusted its programmatic activities to address the evolving needs of Member States and to help them improve productivity and address threats to food and agriculture production, livelihoods and health, as well as to accelerate delivery of the SDGs.

49. The Director General of the Agency and the Director-General of the FAO signed a Revised Arrangement for the FAO–Agency partnership on 23 February 2021, upgrading the Joint FAO/IAEA

Division to the Joint FAO/IAEA Centre and expanding the horizons of their cooperative work. Both organizations have committed to strengthening the FAO–Agency strategic partnership for the benefit of millions of people.

50. The Revised Arrangement has expanded the areas of common interest to include the “improvement of monitoring and controlling of transboundary animal, zoonotic and plant diseases” as a key area. This change formally recognizes the collaboration that was previously taking place and will enable the integration of the Joint FAO/IAEA Centre laboratories’ capacities into FAO’s work on One Health. The strengthened partnership will contribute to the Agency’s Zoonotic Disease Integrated Action (ZODIAC) project.

51. The Joint Centre maintains effective coordination with the relevant FAO organizational units/centres through active participation in and contributions to FAO’s Strategic Framework for 2022–2031, continuous interactions on work planning and results reporting, consultation on the work planning for the biennium and briefings on activities in Member States. It also coordinates with FAO Regional and Country Offices during work planning, project implementation and reporting.

52. The Joint Centre participates actively in the biennial FAO regional conferences for Africa, Asia and the Pacific, Europe and Central Asia, and Latin America and the Caribbean. Information materials illustrating nuclear and nuclear-related technologies and selected impacts of these in each region have been well received by stakeholders during these conferences.

53. The Agency has enhanced its work with FAO on important global initiatives, such as the Global Strategy for the Control and Eradication of Peste des Petits Ruminants; the collection and preservation of genetic material of livestock available locally in Member States for the identification of DNA markers associated with high productivity and disease resistance; the Global Soil Laboratory Network, within the Global Soil Partnership; and the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture through demand-based innovations that focus on the improvement and use of plant genetic diversity.

# Use of Isotope Hydrology for Water Resources Management

## A. Background

1. At its 63rd regular session in September 2019, the General Conference, through resolution GC(63)/RES/10, requested the Secretariat, subject to the availability of resources, to further strengthen efforts to fully exploit the potential of isotope and nuclear techniques for water resources development and management in interested countries; to continue to help Member States obtain easy access to isotopic analysis by upgrading selected laboratories; to expand activities related to the IAEA Water Availability Enhancement (IWAVE) Project and to groundwater management; to provide easier access for Member States to new techniques for the use of noble gas isotopes in the age-dating of groundwater; to strengthen activities which contribute to the understanding of climate and its impact on the water cycle; to expand the use of geochemical and isotope tools to enhance hydrological models in mining areas; to expand the use of isotopes for pollution studies and to carry out international intercomparison exercises; to further strengthen efforts to enhance the temporal and spatial coverage of the Agency's global isotope monitoring programmes for precipitation and rivers; and to continue to develop human resources in isotope hydrology.

2. The General Conference, in resolution GC(63)/RES/10.A.3, requested the Director General to report on achievements in implementing this resolution to the Board of Governors and to the General Conference at its 65th regular session.

## B. Progress since the 63rd Regular Session of the General Conference

### B.1. Strengthening Isotope Hydrology Activities

#### B.1.1. Isotope Hydrology Laboratory

3. The development of a new state-of-the-art helium-3 mass spectrometer system for the analysis of tritium concentrations using the helium-3 ingrowth method and applicable to various forms of environmental samples was completed in the Agency's Isotope Hydrology Laboratory (IHL) in the first half of 2020. The mass spectrometer was procured using Peaceful Uses Initiative funds provided by Japan. The helium-3 ingrowth method is non-destructive and much more sensitive than other analytical techniques. A standard operating procedure was developed, and the system is now ready for wider applications through coordinated research projects (CRPs) and technical cooperation (TC) projects to better assess tritium levels in natural environmental materials.



*FIG. B.1. New method for tritium enrichment based on permeable electrolytic membrane technology.  
(Source: IAEA)*

4. Isotope fingerprinting of nitrate is critical in allowing isotope hydrologists to identify and distinguish sources of nitrate in aquatic systems and to quantify natural remediation processes like denitrification and nutrient assimilation in rivers. In 2020, the Agency published a new low-cost titanium (III) chloride reduction method for the rapid conversion of aqueous nitrate to nitrous oxide gas, which is required to undertake isotope measurements. The new method lowers the effort and cost of previous methods by 90% and has been adopted for routine use in the IHL in support of CRPs and TC projects related to the impacts of nutrient pollution on water quality.

5. The installation of a new ion chromatography (IC) system with capacity for simultaneous analysis of cations and anions was completed in 2021. The IC system allows for the measuring of major and trace cations and anions, including nitrate, nitrite and ammonium, and will assist programmatic activities pertaining to isotope monitoring in precipitation, groundwater pollution studies and the operation of global isotope monitoring networks, as well as the CRPs that support nitrogen pollution, water quality and climate change studies requiring the assessment of nitrogen oxides and sulphur oxides. The experience gained from operating the IC system will allow the Agency to provide advice and technical assistance to Member States supported through TC projects.

6. The Agency acquired an elemental analyzer isotope ratio mass spectrometer (EA-IRMS) system to measure sulphur stable isotopes (namely the ratio of sulphur-32 to sulphur-34) in ground and surface waters. Sulphur isotopes are used to assess acid mine drainage, seawater intrusion and other important water quality indicators. The EA-IRMS system is currently being installed and will be used to support several CRPs on water quality and the impacts of mining on the local water cycle.

7. The Agency continued to develop low cost, easy-to-operate tritium enrichment units (TEUs) based on permeable electrolytic membrane technologies. The TEUs are used to conduct simpler and

more precise tritium measurements in groundwater and precipitation samples. Expanded analytical facilities for tritium in natural waters are required for the assessment of groundwater replenishment rates and to facilitate groundwater vulnerability mapping for Member States.

8. A specialized laser spectrometer for the precise quantification of the rare oxygen-17 isotope in water samples is now fully operational at the Agency's IHL. Oxygen-17 is a new tracer in hydro-climatological applications that offers insights into important climatically driven hydrologic processes like evaporation or the distinguishing of stratospheric water sources. The new laser is currently being used to support the IAEA–WMO Global Network of Isotopes in Precipitation (GNIP) programme.

### **B.1.2. General**

9. Twenty-one isotope hydrology laboratories were equipped with, or upgraded, their laser spectrometry analysers in the period 2020–2021 through the Agency's TC programme. Since the laser technology for stable isotope analysis became available 12 years ago, a total of 105 laboratories in 69 Member States have benefited from the Agency's support to acquire and operate laser spectroscopy instruments used to measure stable oxygen and hydrogen isotopes in water samples. In addition, the Agency provided four TEUs designed and developed by the Agency to four Member States during the reporting period.

10. The Agency published the results of the Tritium Intercomparison in 2020. A record number of 78 laboratories worldwide participated in the test. The results showed that approximately 75% of the laboratories produced reliable isotope data suitable for use in water resource investigations; however, around 25% underperformed owing to systemic errors, mistakes and poorly performing instrumentation. Several strategies to improve and correct analytical problems were recommended, such as the use of new data evaluation strategies and screening runs for contamination, as well as the inclusion of additional control standards.

11. Results of the first proficiency test to assess the isotope ratio mass spectrometry and laser absorption spectroscopy measurements of 25 laboratories in Latin America and the Caribbean were published in 2020. Eighty-one percent of the laboratories had satisfactory performance for deuterium (hydrogen-2) but only 54% achieved similar scores for oxygen-18. The strict conditions of the proficiency test allowed identification of core challenges in laser absorption spectroscopy and the provision of recommendations to improve the performance of a number of laboratories reporting analytical problems.

12. The Water Isotope Interlaboratory Comparison (WICO) 2020 proficiency test for water stable isotopes (such as oxygen-18 and hydrogen-2) was conducted on five natural test waters, and for the first time included the rare oxygen-17 isotope, which has recently begun being used in climatic studies. A record number of 307 laboratories from 88 Member States, including a large influx of new participants from China, Latin America and the Caribbean, and the Russian Federation marked a 75% increase in participation over the past decade. Despite delays and laboratory closures due to the COVID-19 pandemic, 281 laboratories still completed the proficiency test on time. Results showed that 85% of laboratories were able to produce accurate results, with the remaining 15% showing less adequate results. The quality of the latter group's results may be attributed to reasons such as inexperience, poor handling of reference materials, and general instrumental performance issues. The Agency will work with these laboratories to assist them in improving their results. The results of the oxygen-17 intercomparison highlighted the substantial challenges in attaining the desired precision and accuracy required to incorporate this rare isotope into climate studies. The Agency will continue to provide assistance to laboratories working with this isotope to overcome the identified challenges.

13. The Fukushima Prefecture Initiative Project aimed at the development of simple and rapid analysis methods for radionuclides was completed in 2021. The Agency actively supported Fukushima

Prefecture in setting up their own analytical facility in their prefectural laboratory over the last four years. The project resulted in Fukushima Prefecture being able to analyse tritium and strontium-90 in environmental samples precisely and accurately according to the system and analysis protocols developed and validated jointly with the Agency.

14. The CRP entitled “Use of Isotope Hydrology to Characterize Groundwater Systems in the Vicinity of Nuclear Power Plants” was completed in 2020. Ten teams from Argentina, Brazil, China, Italy, Japan, Lithuania, Morocco, Pakistan, Ukraine and Viet Nam used stable and radioactive isotopes to characterize groundwater flow systems around several nuclear power plants in a comprehensive manner to plan and implement countermeasures in the event of a radioactive leak or accident. Several scientific papers describing the results and recommendations of the studies carried out in the CRP were published in 2020.

15. The CRP entitled “Isotopes to Study Nitrogen Pollution and Eutrophication of Rivers and Lakes” has improved the capabilities of scientists across the world to utilize the nitrogen-15 and oxygen-18 isotopes found in nitrates and has succeeded in conducting the first measurements of nitrate isotopes in river waters in seven Member States (Argentina, Chile, Cuba, Ghana, India, Malaysia, and Sri Lanka). Three new laboratories in China, Cuba and India were set up for nitrate isotope analysis of water samples during the project and several more Member States are receiving assistance to establish similar facilities.

## **B.2. The IWAVE Approach**

16. The introduction of the IWAVE process in the last two TC cycles has shown the relevance of IWAVE consultations and workshops in the design, as well as the various stages of implementation, of TC projects dealing with the use of isotope hydrology tools. The IWAVE approach is now considered an essential tool to efficiently coordinate the Agency’s and Member States’ efforts in the planning and formulation of TC projects to ensure that key hydrological gaps are properly addressed and that relevant stakeholders actively participate in these projects from the early stages. IWAVE particularly helps to develop a long-term strategy for technical collaboration, resulting in more successful project outcomes with greater impact and sustainability.

17. Over the last biennium, IWAVE workshops and expert missions were carried out in the context of regional and national TC projects in Africa (Benin, Cameroon, Eswatini, Ghana, Kenya, Mali, Niger, Nigeria, Senegal and Togo) and the Latin America and Caribbean region (the Plurinational State of Bolivia, Colombia, Mexico and Paraguay). Groundwater resource assessments were conducted in five transboundary aquifers in the arid and semiarid regions of the Sahel, the Guarani aquifer in South America, the Dry Corridor in Central America, and deep aquifers in Mexico. In addition, the information gathered as part of the IWAVE approach helped to better assist Member States in strengthening their technical capabilities and, in particular, their laboratory infrastructures. IWAVE has fostered closer interaction between various water sector stakeholders, including hydrologists, modellers, managers and policy makers, contributing to more confident water resources assessments.

## **B.3. Water Quality**

18. The CRP entitled ‘Isotopes to Study Nitrogen Pollution and Eutrophication of Rivers and Lakes’ was concluded in February 2020. The project included 18 countries from five continents, facilitated a better understanding of nitrogen dynamics in water resources and improved expertise in utilizing nitrate isotopes (nitrogen-15 and oxygen-18) to evaluate the origin of nitrate pollution and assess related analytical methods and interpretations. Around 500 water samples from 13 participating Member States were analysed for nitrate isotopes at the Agency’s IHL. More than 20 new case studies related to the application of nitrate isotopes in surface waters and groundwaters have been published so far.

19. A global database on nitrate isotopes (nitrogen-15 and oxygen-18) composed of more than 5000 entries from 45 countries covering the last 25 years was compiled and made available on the Agency's website. Analysis of the database revealed that shallow aquifers suffer from higher nitrate concentration levels than rivers, originating mostly from fertilizers, and urban and animal waste. The analysis also showed that regardless of the source of nitrogen pollution, environmental factors such as temperature, climate and season strongly affect the processes that nitrogen species undergo from the moment they are introduced into aquatic systems. These findings thus have serious implications for the management of pollution in waterways.



*FIG. B.2. Radon-222 sampling at the Los Gigantes uranium mine, Argentina. (Source: IAEA)*

#### **B.4. Climate and Water Resources**

20. Re-analysis of the 60-year record of oxygen-18 in precipitation across the globe revealed complex temporal and spatial climatic isotope responses (e.g. warming and cooling in both directions over time). Advanced supervised machine learning tools were applied to detect trends and patterns over decades. Large decadal scale cyclical events, like the Atlantic Multidecadal and Pacific Decadal Oscillations, were found to be the biggest drivers of oxygen-18 variation and climate on the Earth's continents. In contrast, oceanic islands seem to be better positioned as indicators of long-term climatic isotope responses as they experience fewer interfering impacts from the oscillations than the continents. These results have been published and made available to Member States together with recommendations on the relevance of GNIP and isotope measurements in precipitation to climate change studies.

21. As part of ongoing efforts to better characterize and map present and future water availability and quality in the Sahel region, a dedicated isotope database containing isotope and hydrochemical data was compiled by the Agency. This unique database contains isotope and water quality data obtained as part of TC projects in 13 Member States from the late 1960s until today. Besides data used to map water quality in the region, this resource contains stable isotope data, carbon-14 data and more than 3000 tritium records. This naturally occurring radioactive isotope of hydrogen is being used to date groundwater to as far back as 100 years ago. This critical piece of information is being used to develop

hydrological maps at various spatial scales showing areas containing groundwater being replenished under current semiarid conditions, and those where fossil groundwater is the most common source of water. Situated in a critically sensitive climatic zone, and with a huge demand for additional water resources, the Sahel region and its future rely on precise information on the renewal rate of these valuable water resources.

22. A global database of isotope data for lakes was compiled to estimate lake vulnerability to evaporation, a vulnerability that can be intensified by flow regulation and over-exploitation particularly in response to climate change. The dataset comprises 7415 stable isotope measurements from 1256 lakes of all sizes across the world spanning diverse geographical and climatic zones: tropical, arid, temperate, continental and polar. Each lake was evaluated and modelled for its evaporation losses using an array of potential drivers of lake-catchment evaporation obtained from global geospatial datasets. The database will be open access for Member States and can be used to characterize hydrological cycles and better predict the responses of lakes to climatic variability and changes to the ecosystem.

### **B.5. Isotope Monitoring Networks**

23. During the reporting period, through collaboration with Member States' institutions, GNIP expanded, with the establishment of additional 50 sampling stations in 23 Member States. Twelve of these institutions (though not necessarily their Member States) are new to the GNIP programme. Seven additional Member States participated in GNIP. The total number of GNIP stations is currently 419. The GNIP database surpassed 140 000 records during the reporting period.

24. The Global Network of Isotopes in Rivers (GNIR) currently comprises 71 stations in 25 Member States, of which nine were developed during the reporting period. These include five pilot sites incorporating sampling for nitrogen-15 in dissolved nitrate ion. Six additional Member States now contribute to GNIR.



*FIG. B.3. Sampling lake water in Chad. (Source: Ministry of Water and Sanitation, N'Djamena)*

### **B.6. Capacity Development**

25. Generic and specialized training courses, technical workshops and development of e-learning materials were offered to build Member States' capacities and expertise in isotope hydrology. Teaching modules on isotope hydrology tools and methods were updated and made available on the Agency's website to provide basic knowledge on integrating isotope hydrology tools into water resources

assessments. These modules will be incorporated into university curricula in participating Member States, including at three AFRA designated centres in Egypt, Morocco and Tunisia.

26. The onset of the COVID-19 pandemic significantly stalled in-person trainings for participants of the Agency's TC programme. In response, substantial support (training material, teaching programmes and agendas, and scientific oversight) was developed for the organization of online training courses. These efforts resulted in a number of comprehensive virtual training events in the TC programme, including regional training courses for Latin America and the Caribbean, Europe and Central Asia, dedicated teaching material in the Russian language, and remote training on isotope analyses with laser spectroscopy.



# Zoonotic Disease Integrated Action (ZODIAC) Project

## A. Background

1. In resolution GC(64)/RES/12.A.4., the General Conference welcomed the Director General's proposal to establish the Zoonotic Disease Integrated Action (ZODIAC) project at the Board of Governors meeting on 15 June 2020.
2. The General Conference recognized that the Agency has a longstanding practice of cooperation with other relevant international organizations and specialized agencies; and further recognized the importance of complementing the respective mandates of such organizations, as well as longstanding protocols that guide cooperation such as Taking a Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries (the Tripartite Zoonoses Guide), which addresses collaborative efforts to address health risks at the human–animal–environment interface.
3. The General Conference noted that zoonotic diseases such as COVID-19, including vector-borne diseases such as malaria, yellow fever, chikungunya virus, and dengue fever, have significant and long-term implications on human health and the socio-economic development of Member States.
4. The General Conference recognized the importance of nuclear science, technology and applications to detect, trace and control emerging pathogens that could develop into diseases and pandemics and further recognized the importance of making these technologies available to all Member States.
5. The General Conference noted that ZODIAC could support Member States and enhance their preparedness to address emerging and re-emerging zoonotic diseases, through the use of molecular biology nuclear and nuclear-derived methods, by enhancing capacity in Member States to detect, trace and respond to emerging pathogens that could develop into zoonotic diseases and pandemics.
6. The General Conference welcomed that ZODIAC would build upon existing, relevant Agency nuclear science and technology applications and structures, such as the VETLAB Network, and other delivery mechanisms of the technical cooperation programme.
7. The General Conference welcomed the reaffirmation by the Directors General of the IAEA and FAO of their commitment to the longstanding partnership between the two organizations, including in strengthening global capacity to detect, trace and respond to zoonotic diseases, through the use of nuclear and nuclear-derived techniques at all phases of disease development.
8. The General Conference recognized that ZODIAC is also intended, through the use of nuclear and nuclear-derived techniques, to form part of the Agency's support to Member States in combatting zoonotic diseases and preventing future pandemics, in collaboration and coordination with existing networks of laboratories, such as VETLAB.
9. 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 65th regular session.

## **B. Progress since the 64th Regular Session of the General Conference**

10. The Agency continued to respond to the needs and priorities of Member States by implementing all of its programmatic activities related to zoonotic diseases. A total of 24 webinars on the use of the reverse transcription–polymerase chain reaction (RT–PCR) technique took place and 19 videos on the use of RT–PCR and serology were released in Arabic, English, French, Russian and Spanish. Technical support continued to be provided for the procurement of equipment, reagents and personal protective equipment sent to 257 laboratories, and 16 mobile X ray units were sent to Member States through technical cooperation project INT0098.

11. The Agency, through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, continued pursuing its adaptive research and development (R&D) in the field of animal health in its own laboratory in Seibersdorf, as well as through the coordination of the VETLAB Network and through the implementation of six coordinated research projects, including two new projects entitled “Novel Test Approaches to Determine Efficacy and Potency of Irradiated and Other Vaccines” and “Application of Advanced Molecular Characterization Technologies Through the Veterinary Diagnostic Laboratory Network (VETLAB Network)” initiated in 2021.

12. Building upon document GOV/INF/2020/13, a detailed ZODIAC project document was prepared by the Secretariat and presented to the Board of Governors meeting in November 2020. The ZODIAC project document contains elements such as a needs analysis, a detailed workplan, a timeframe and the financial aspects of the project. The ZODIAC project document builds upon, among others, the past experience of the Agency in providing support to Member States on detection and monitoring of transboundary animal and zoonotic diseases, such as Highly Pathogenic Avian Influenza (2003-to date), severe acute respiratory syndrome (2003), Middle East respiratory syndrome (2016), Ebola (2014, 2018), Zika (2016), and the lessons learned from the Agency’s response to COVID-19 (2019-onwards). At its November 2020 meeting, the Board of Governors approved the proposed off-cycle interregional technical cooperation project INT5157, “Supporting National and Regional Capacity in Integrated Action for Control of Zoonotic Diseases” (contained in document GOV/2020/37) that will serve for the technology transfer and capacity building needs of ZODIAC.

13. Responding to the needs for information on ZODIAC objectives, implementation and technologies, the Secretariat held, at the request of interested Member States, over thirty bilateral meetings with Vienna-based Permanent Missions as well as groups of designated national experts on zoonotic diseases and technical briefings.

14. The implementation of ZODIAC strongly relies on maximizing the use of existing Agency mechanisms. Following responses from 143 Member States to the call for nomination of ZODIAC National Coordinators<sup>2</sup>, the Agency, through its relevant Divisions of the Department of Technical Cooperation and the Department of Nuclear Sciences and Applications, organized, between 25 February and 26 March 2021 four regional meetings to brief the designated ZODIAC National Coordinators about ZODIAC, their expected roles and responsibilities, and further actions to be taken by the participating Member States in the context of ZODIAC. The participation of the National Liaison Officers in the meeting as observers was facilitated to enable better national coordination for ZODIAC implementation.

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<sup>2</sup> A total of 143 individuals were nominated as ZODIAC National Coordinators or alternates (Africa: 41; Asia-Pacific: 33; Europe: 42; Americas: 27).



*FIG. B.1. IAEA Director General Rafael Mariano Grossi addresses the first ZODIAC National Coordinators Meeting for the Africa Region joined by IAEA DDG-NA Najat Mokhtar and IAEA DDG-TC Hua Liu on 25 February 2021. (Source: IAEA)*

15. On 23 February 2021, the Director General of the Agency and the Director-General of the Food and Agriculture Organization of the United Nations (FAO) signed a Revised Arrangement that aimed, among others, at expanding the areas of common interest between the two organizations especially with regard to the monitoring and control of transboundary animal, zoonotic and plant diseases. The Joint FAO/IAEA laboratories' R&D capacities in Seibersdorf will continue to complement the FAO's work on the One Health initiative. Discussions continue at senior management and technical levels with the World Organisation for Animal Health and the World Health Organization, to define areas of specific cooperation in the context of ZODIAC thus ensuring complementarity of the work implemented in the context of zoonotic diseases.



*FIG. B.2. IAEA Director General Rafael Mariano Grossi signed a Revised Arrangement with FAO Director General Qu Dongyu, during a virtual meeting on 23 February 2021. (Source: IAEA)*

16. ZODIAC National Laboratories (ZNLs) will be at the centre of coordinated R&D activities, as well as capacity building and technology transfer and networking. The ZNLs will actively contribute to the development of innovative and novel methodologies for the mining, detection, characterization, tracing, and monitoring of zoonotic diseases in animals. Responding to the call for nominations by the Secretariat, 110 nominations for ZNLs were received<sup>3</sup> from the 143 Member States who nominated a ZODIAC National Coordinator. In May 2021, an online survey was developed by the Secretariat with 111 responses received from designated ZNLs. The results of the survey were an initial basis to determine the level of technical support needed by the laboratories to acquire the capacity for using nuclear and nuclear-derived techniques in the context of zoonotic diseases.

17. With the support of the Member States leading the initiatives, the Secretariat developed contacts and held bilateral meetings with other ongoing initiatives such as the Preventing Zoonotic Disease Emergence (PREZODE) initiative, the US Agency for International Development's PREDICT project, the Eklipse project and the One Health High-Level Expert Panel, with a view to develop partnerships and cooperation while ensuring complementarity of the activities, avoiding duplication of efforts and increasing the visibility of ZODIAC.

18. The use of the coordinated research project mechanism is pivotal for building national R&D capacities involving ZNLs, needed to efficiently and sustainably detect and monitor zoonotic diseases using nuclear and nuclear-derived techniques. In animal health, two consultancy meetings were organized in February and June 2021 involving 43 senior animal health experts to advise on strengthening applied research to develop and validate the laboratory tools required in Member States at the animal-human interface, and on development of tools for the mining, monitoring and tracing of zoonotic pathogens in Africa, respectively. The first meeting identified five major areas of research: tracing the origin of the pathogen; identifying wildlife/livestock-animal reservoirs and hosts; monitoring pathogen mutations and new strains; better understanding pathogen circulation and the animal-human interface; and developing timely and reliable diagnostic techniques. Based on this meeting, four ZODIAC coordinated research projects were developed, one for each region based on regional priorities and regional challenges. The second meeting provided guidance on how to explore the priority disease pathogens and the tools needed for their mining, monitoring, tracing and characterization in order to perform comprehensive field validation of the assays through multiple competent laboratories and prepare standardized operating procedures adapted to the region. The IAEA will coordinate the research projects involving relevant ZNLs including ZODIAC Affiliated Laboratories to develop the necessary tools and procedures that would become available for all ZNLs to enable them to carry out independent R&D activities. In human health, two consultancy meetings involving 25 senior experts took place on radiomics and artificial intelligence, and on radiobiology and molecular biology in March and May 2021, respectively, to review the global needs in those fields related to the management of existing and emerging zoonotic diseases with a view to defining coordinated research projects.

19. Timely resource mobilization is a critical aspect of ZODIAC, which has been designed to be entirely funded through extrabudgetary resources. Besides the traditional and trusted partners, the Secretariat initiated its efforts in mobilizing resources from non-traditional donors, with a primary focus on private companies and funds. While these efforts will continue, to date contributions and pledges have been received from ten Member States totalling €9 million.<sup>4</sup>

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<sup>3</sup> As of 14 July 2021.

<sup>4</sup> As of 14 July 2021.

# Plan for Producing Potable Water Economically Using Small and Medium Sized Nuclear Reactors

## A. Background

1. In resolution GC(62)/RES/9.A.4, the General Conference requested the Director General to continue consultations and strengthen interactions with interested Member States, the competent organizations of the United Nations system, regional development bodies and other relevant intergovernmental and non-governmental organizations in activities relating to seawater desalination using nuclear energy.
2. The General Conference also stressed the need for continued strengthening of international cooperation in the planning and implementation of nuclear desalination demonstration programmes through national and regional projects open for the participation of any interested country. It also requested the Director General, subject to the availability of resources, to continue to increase the Secretariat's activities in capacity building (including training and education) on nuclear desalination projects to bridge the gap among users/vendors/operators/regulators.
3. In resolution GC(64)/RES/12.A.6, the General Conference requested the Director General to report on progress made in the implementation of resolution GC(62)/RES/9 to the Board of Governors and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

4. The Agency is initiating a coordinated research project (CRP) on assessing the role of nuclear desalination within the context of climate change mitigation, covering the techno-economics of the available technologies and aspects related to the deployment. An Agency meeting organized in 2020, and attended by eight experts from six Member States, discussed the benefits, objectives and expected outcomes of the planned CRP and recommended expanding its scope to assess the potential for cogeneration to mitigate climate change including through water recycling, hydrogen production and reducing reliance on fossil fuels for major heat applications. The CRP also plans to examine the applicability of small modular reactors for remote and micro-grid cogeneration applications and the value of such systems towards reducing carbon emissions.
5. The Agency is drafting a publication on vendor and user responsibilities in nuclear cogeneration projects to promote a better understanding of the requirements and constraints of users and vendors as a prerequisite to facilitating the implementation of nuclear cogeneration projects. Several meetings were held to draft the publication, including one in October 2020, attended by four experts, covering perspectives from user/vendors on the main technical issues for the deployment of nuclear cogeneration

projects, best practices for user/vendor involvement and lessons learned from previous or ongoing nuclear cogeneration projects.

6. The Technical Meeting on Potential Schemes for Licensing Nuclear Cogeneration Plants, held virtually in March 2021, was attended by 32 participants from 16 Member States. The meeting tackled various aspects of licensing approaches for nuclear cogeneration facilities, delivering valuable insights on different countries' experiences. The main recommendations from the meeting included the need to consider cogeneration projects in the frame of the Agency's Milestones approach and to prepare a guideline document for licensing of nuclear cogeneration projects for proven technology (e.g. desalination, heating, and hydrogen production through conventional electrolysis).

# Introduction

## A. Background

1. In resolution GC(64)/RES/12.B.1, the General Conference affirmed the importance of the role of the Agency in facilitating the development and use of nuclear energy for peaceful purposes, in fostering international cooperation among interested Member States, and in disseminating well-balanced information on nuclear energy to the public. It also encouraged the Agency to continue its support to interested Member States, including through peer review and advisory services, in building their national capacities in the operation of nuclear power plants and their nuclear power infrastructure when embarking on new nuclear power programmes.

2. The General Conference also encouraged Member States that are considering developing nuclear power to voluntarily use the support provided by the Agency to Member States on energy planning and assessment of energy systems in relation to environment, climate and economic factors and requested the Agency to continue its services to help interested Member States in this regard. It commended the Secretariat's efforts in providing comprehensive information on nuclear energy's potential as a low carbon energy source and its potential to contribute to mitigating climate change and encouraged the Secretariat to work directly with Member States upon request and to continue to extend its activities in these areas, including the Paris Agreement.

3. The General Conference also stressed the importance, when planning, deploying, or decommissioning nuclear energy facilities, including nuclear power plants and related fuel cycle activities, of ensuring the highest standards of safety and emergency preparedness and response, security, non-proliferation, and environmental protection, of being informed of the best available technologies and practices, of continuously exchanging information on R&D addressing safety issues, of strengthening long-term research programmes to learn about severe accidents and related decommissioning activities, and of enabling continuous improvement in this regard; and valued the role of the Agency in fostering exchange of expertise and discussions within the international nuclear community on such issues.

4. The General Conference, in resolution GC(64)/RES12.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

5. To promote gender equality and diversity and to encourage Member States to establish an inclusive workforce within their nuclear industry, the Director General launched the *IAEA Marie Skłodowska-Curie Fellowship Programme (MSCFP)* in March 2020, which aims to inspire and encourage women to pursue a career in nuclear science and technology, nuclear safety and security, or

non-proliferation, by providing scholarships for masters programmes in nuclear related fields and an opportunity to pursue internships facilitated by the Agency relating to their field of study. Since its launch, the project governance framework for the MSCFP has been established, and the Technical Selection Committee and Project Management Team have become fully operational. The application call for the 2020 MSCFP cycle closed on 11 October 2020 with 557 applications received from more than 90 countries. In December 2020, the first 100 students of 71 nationalities were selected to study in universities spread across 40 countries. Preparations are ongoing for the second MSCFP cycle, the application period for which will run from 15 July to 30 September 2021, with the review and selection of applications concluding by mid-December 2021.

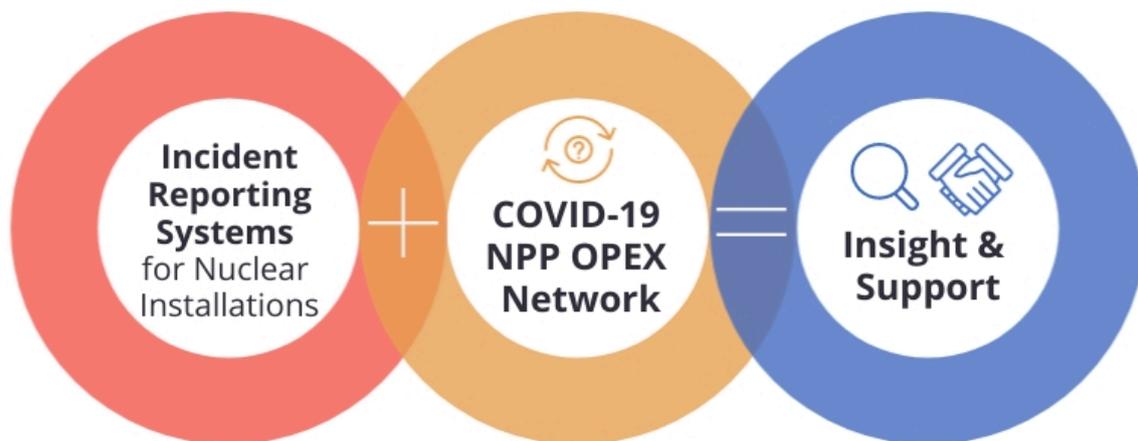


FIG. B.1. Quotes by MSCFP participants

6. Preparations for the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) were initiated in 2020, and continued into 2021 when COP26 was postponed to November 2021. The Agency Secretariat set up an internal coordination group with the Department of Nuclear Energy taking the lead on the role of nuclear power to mitigate

climate change, and the Departments of Nuclear Sciences and Applications and of Technical Cooperation taking the lead on the role of nuclear technologies in climate change monitoring and adaptation. The Agency elaborated the key messages pertaining to nuclear power in the Agency's climate change communication campaign. A booklet entitled *Nuclear Energy's Contribution to a Net Zero World* is being developed for COP26, with input from Member States on topics such as the role of nuclear power in moving away from coal; the role of nuclear power, renewables and hydrogen in driving energy systems to net zero emissions; the contribution of nuclear power to the resilience of energy systems; and the importance of investments in nuclear power programmes to drive the economic recovery and the clean energy transition. Proposals for events were made to the United Kingdom as the COP26 host, and the Agency is also looking at partnering with other Member States to highlight the importance of including nuclear energy in the climate debate. The Agency was also active in participating at events on the road to COP26, with the Director General being invited to a series of events such as the International Energy Agency's Net Zero Summit in March 2021, the World Nuclear Fuel Cycle forum in April 2021, and the Nuclear Innovation: Clean Energy Future event taking place at the 12th Clean Energy Ministerial meeting in June 2021.

## IAEA Support for Nuclear Facility Operators during COVID-19 Crisis



7. The COVID-19 Nuclear Power Plant Operating Experience Network platform remained operational and currently has 27 reports from 10 Member States and 5 international organizations to support information and experience sharing between operating organizations, technical support organizations, relevant international organizations and other stakeholders.

8. Annual publications based on the Power Reactor Information System and Country Nuclear Power Profiles were issued. These include the 40th edition of *Nuclear Power Reactors in the World* (Reference Data Series No. 2), the 52nd edition of *Operating Experience with Nuclear Power Stations in Member States* and the 2021 edition of *Country Nuclear Power Profiles*.

9. As part of efforts to maintain and strengthen the assistance and peer review and advisory services provided to Member States embarking on a nuclear power programme or expanding such programmes, and in support of Finland's nuclear power expansion programme, Fennovoima completed a self-

assessment of construction readiness consistent with guidance provided in *CORR Guidelines: Preparing and Conducting Review Missions of Construction Project Readiness for Nuclear Power Plants* (IAEA Services Series No. 24). Fennovoima also publicly announced plans for an Agency Construction Readiness Review (CORR) mission.

10. On the basis of a recommendation by the Standing Advisory Group on Nuclear Energy, the Director General approved the Terms of Reference of an Agency-wide platform on small and medium sized or modular reactors and their applications. The platform comprises a high-level Steering Committee and an implementation team, both chaired by the Department of Nuclear Energy. The Steering Committee is responsible for developing a medium-term strategy for Agency-wide support to Member States for the development and early deployment of SMRs. It will also review all requests and recommendations received from Member States, international organizations and advisory groups in the areas of SMRs and related applications.

11. The 18th INPRO Dialogue Forum on partnerships for nuclear development and deployment was organized virtually in May 2021 with representation from 33 countries and five international organizations. Participants of the event noted that synergies in supporting national research and development (R&D) programmes, technical cooperation aimed at enhanced fuel cycle operations and waste management, and joint use of tools for economic assessment of electricity generation technologies will help to ensure that nuclear power remains a viable option in future clean energy systems. The 19th INPRO Dialogue Forum on Public Communications in Nuclear Activities is planned for December 2021.

12. The International Conference on Fast Reactors and Related Fuel Cycles: Sustainable Clean Energy for the Future (FR21), originally scheduled for May 2021 in Beijing, was postponed to April 2022 and became FR22. In preparation for FR22, the Agency developed a series of webinars dedicated to fast reactor technology. The first webinar entitled “Fast Reactors and Related Fuel Cycles: Status, Prospects and What’s Next?” was conducted in June 2021 and was attended by 155 participants, (31 women), from 31 Member States.

13. The Agency continued to maintain and strengthen its assistance and advisory services to Member States embarking on or expanding a nuclear power programme through self-evaluation support and Integrated Nuclear Infrastructure Review (INIR) missions to assess the status of nuclear power infrastructure development. A Phase 2 mission to Uzbekistan (May/June 2021, rescheduled from 2020), a Phase 1 follow-up mission to Kenya (June 2021, rescheduled from 2020) were conducted as well as an INIR Phase 1 mission to Sri Lanka planned for August 2021. Self-evaluation support missions and pre-INIR missions were conducted virtually, including for Uganda in May 2021. The Agency also continued to offer support to embarking countries through around 30 technical cooperation projects directly related to nuclear power infrastructure development. The implementation of the appropriate activities is coordinated between Member States and the Agency through the development and regular update of the national Integrated Work Plan and Country Nuclear Infrastructure Profile. Additionally, Member States received assistance and training through participation in interregional training courses related to nuclear power infrastructure development through the INT2021 technical cooperation project. The Agency continues to support Member States in developing enabling nuclear infrastructure for the emerging SMR technologies and support Member States for SMRs deployment.



*FIG. B.2. Department of Nuclear Energy representative during an Integrated Nuclear Infrastructure Review Phase 2 mission to Uzbekistan in June 2021. (Source: IAEA)*

14. The IAEA LEU Bank in Kazakhstan has operated securely and safely throughout the past twelve months and the Project and Financial Plan have been revised following the update of the Plan of Activities for Operation. In September 2020, the Agency concluded a transport contract with the China Nuclear Energy Industry Corporation, which was approved by the China Atomic Energy Authority and became effective on 14 December 2020, thus providing a possible route for the transport of low enriched uranium (LEU) and/or equipment through the territory of China.

15. In April 2021 at the request of the Government of Japan, an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) mission on the long-term policy of the Japan Atomic Energy Agency (JAEA) on decommissioning of its installations and processing and disposal of associated radioactive waste was undertaken in hybrid format. The review team included nine international experts from eight Member States and provided the JAEA with a number of observations, recommendations and suggestions.

## International Conference on Management of NORM in Industry

**668** participants from **105** Member States

16. The International Conference on the Management of Naturally Occurring Radioactive Materials (NORM) in Industry was organized in October 2020 as a fully virtual event, comprising ten plenary sessions and eight side events over ten days. With 668 participants from 105 Member States and active involvement and participation of the industries concerned (oil and gas, metallurgy, phosphates) as well as governmental bodies and the research community, the Conference provided for further identification of Agency priorities based on Member States' needs.

17. The Nuclear Back End Webinar Series was delivered from October 2020 to July 2021, comprising 12 webinars covering topics related to spent fuel and radioactive waste management, decommissioning and environmental remediation. Presentations were delivered by both staff members and experts from 23 Member States. There were between 85 and 433 registered participants for the webinars from a total of 61 Member States.

18. In order to foster regional and international efforts in ensuring wide access to existing multi-purpose research reactors, and to increase research reactor operations and utilization, the Agency re-designated the French Alternative Energies and Atomic Energy Commission (CEA), in partnership with the Institute for Radiological Protection and Nuclear Safety, as an International Centre Based on Research Reactors (ICERR) for 2020–2025. There are now six ICERRs in six Member States.

19. Two Internet Reactor Laboratories (IRLs) were launched in 2021, hosted by the Czech Republic in Europe and the Republic of Korea in Asia. Uzbekistan joined the IRL project in June 2021. A kick-off meeting for IRL hosted by Morocco is planned in the third quarter of 2021. New five-year agreements for IRLs in Latin America with Argentina, Colombia, Cuba and Ecuador were prepared and are planned to be signed in 2021.



20. The Agency delivered eleven virtual Knowledge Management Assist Visit (KMAV) missions to Member States to support their infrastructure development and expansion. Nine National Expert Level 1 KMAV workshops were held in, Brazil, Chile, Indonesia, Jordan, Mexico, Romania, Sudan, Uzbekistan and Vietnam, and two National Expert Level 2 KMAV workshops were held in Armenia and Hungary.

21. The International Ministerial Conference on Nuclear Power in the 21st Century is organized on a regular basis in cooperation with a hosting Member State to provide a high level forum to discuss the role of nuclear power in meeting future energy demand, contributing to sustainable development and

mitigating climate change. Preparations are ongoing for the organization of the fifth such Ministerial Conference, which has been postponed to October 2022, in Washington D.C.

22. The 28th IAEA Fusion Energy Conference (FEC2020) was held virtually in May 2021, in cooperation with the CEA and the ITER Organization. The event was opened by the Director General and benefited from record high participation with over 4200 registrations and more than 2700 virtual connections to the 134 oral and 544 poster presentations. Three side events were organized, including one on “Women in Fusion”. On the occasion of the Conference, the Agency also published an *IAEA Bulletin* edition on fusion energy, updated the brochure entitled *Fusion Energy*, and upgraded the Fusion Device Information System which resulted in over 5000 individual visits during the Conference week.



*FIG. B.3. Rafael Mariano Grossi, IAEA Director General opened the 28th IAEA Fusion Energy Conference (FEC2020) held in May 2021. (Source: IAEA)*

# IAEA Communication, Cooperation with Other Agencies and Stakeholder Involvement

## A. Background

1. In resolution GC(64)/RES/12.B.2, the General Conference encouraged the Secretariat to continuously assist Member States in enhancing public awareness and understanding of peaceful uses of nuclear energy, including by publishing reports on stakeholder involvement and public information as well as organizing conferences, technical meetings and workshops, among other mechanisms.
2. The General Conference also requested the Secretariat to continue cooperation with international initiatives such as UN-Energy; encouraged strengthening mutual cooperation between Member States by exchanging information through international organizations such as the IAEA, OECD Nuclear Energy Agency (NEA), the International Framework for Nuclear Energy Cooperation (IFNEC), the World Nuclear Association (WNA) and the World Association of Nuclear Operators (WANO); encouraged the Secretariat to cooperate with national and international industrial organizations for standardization; and recommended that the Secretariat continue to explore opportunities for synergy between the Agency's activities and those pursued under other international initiatives such as the Generation IV International Forum (GIF), IFNEC, the European Sustainable Nuclear Industrial Initiative (ESNII) and the International Thermonuclear Experimental Reactor (ITER).
3. Furthermore, the General Conference welcomed the revision of the Nuclear Energy Series structure, encouraged the Secretariat to continue to develop Nuclear Energy Series documents as a more integrated, comprehensive and clearly organized set of publications to be maintained up-to-date and further encouraged the Secretariat to continue consolidating the drafting and review of Nuclear Energy Series publications to establish a single, systematic, and transparent process.
4. The General Conference, in resolution GC(64)/RES12.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

5. The IAEA and the International Energy Agency (IEA) signed a memorandum of understanding on 30 November 2020 to formalize and reinforce the cooperation between the two agencies on nuclear energy. The cooperation at working level covers statistical data collection and data exchange, participation of the IEA in the Agency's work on nuclear capacity projections to 2050, and peer review of publications in areas of common interest. The cooperation included the invitation to the IEA Executive Director for the 2020 Scientific Forum on Nuclear Power and the Clean Energy Transition, and the invitation to the IAEA's Director General for the IEA's Clean Energy Transition Summit in July 2020 and the Net Zero Summit in March 2021.



*FIG. B.1. Rafael Mariano Grossi, IAEA Director General, delivers his remarks at the Ministerial Panel 2: Catalysing Near-Term Implementation at the virtual event of the IEA – COP26 Net Zero Summit. IAEA, Vienna, Austria. 31 March 2021. (Source: IAEA)*

6. The Agency and WANO continued cooperating through the regular IAEA–WANO interface meetings. WANO participated in the virtual Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure in March 2021 and in the virtual meeting of the Technical Working Group on Nuclear Power Infrastructure in November 2020. Additionally, the Agency and WANO’s New Unit Assistance Working Group (NUAWG) cooperated on the development of a publication entitled *Roadmap to Operational Readiness*, which was published in 2020. A representative of NUAWG participated as speaker in the third webinar of the Webinar Series on the Role of Government and Key Organizations in Nuclear Power Programme Development, entitled “Responsibilities and Capabilities of Owners and Operators”. The Agency also participated as an observer in WANO’s review mission of the integrated management systems of Turkey’s Electricity Generation Company EÜAŞ. Agency participation in WANO Operational Readiness Assistance (ORA) missions, including the virtual ORA mission for the United Arab Emirates’ Barakah NPP unit 3 in June 2021, is part of the collaboration.

7. IFNEC regularly participates in Agency meetings. In addition to having a presence in IFNEC’s Steering Group, the Agency cooperates with IFNEC via its two Working Groups — the Infrastructure Development Working Group and the Reliable Nuclear Fuel Services Working Group. Representatives from IFNEC regularly participate in the Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure, held annually in Vienna, most recently in March 2021.

8. The IAEA, OECD/NEA and the European Commission are collaborating in the development of a standard taxonomy for decommissioning, with the aim of fostering interoperability of knowledge management systems containing lessons from ongoing decommissioning projects. This initiative is scheduled for completion by the end of 2021, with the report being published in 2022.

9. The IAEA participated in various subgroups of the Working Party on International Nuclear Data Evaluation Co-operation of the OECD/NEA in May 2021 and contributed to the OECD/NEA Joint Evaluated Fission and Fusion (JEFF) library project with nuclear data evaluations for various nuclides

at the JEFF meeting of April 2021. Furthermore, the Agency held an annual coordination meeting with the OECD/NEA in June 2021. The topics included preparations for COP26, recent major developments in the framework of the COVID-19 pandemic, risk communication, nuclear development and economics, updates on the Red Book, gender balance in the nuclear industry, update on the OECD/NEA Framework for Irradiation Experiments, and cooperation in international conferences.

10. The Agency continued to cooperate with national and international industrial standardization organizations, such as the International Organization for Standardization (ISO) through ISO/TC 85 and 46. An event was organized in June 2021 to mark the 40th anniversary of concluding formal cooperation with the ISO through a memorandum of understanding.

11. The Agency continued cooperation with international initiatives by actively following the activities of UN-Energy and participating at the Youth for Vienna Energy Forum event.

12. Collaboration of the Agency with GIF, IFNEC, ESNII and ITER with regard to innovative and advanced nuclear energy systems continued over the reporting period. Currently INPRO participates in the GIF Proliferation Resistance and Physical Protection Working Group (PRPPWG) as an observer. Several members of the GIF PRPPWG are contributing to the update of the INPRO Methodology Manual on proliferation resistance in consultancies running from 2019 to 2021.

13. The Agency continued to underline stakeholder involvement, including public communication, as one of the key issues in the Milestones approach. The Agency will initiate the development of a Nuclear Energy Series publication on stakeholder engagement in new nuclear power programmes to support the Milestones approach and complement the recently completed overarching publication *Stakeholder Engagement in Nuclear Programmes* (IAEA Nuclear Energy Series No. NG-G-5.1). The annual Technical Meeting on Stakeholder Involvement was postponed from 2020 to December 2021 due to the outbreak of COVID-19.

14. In an effort to ensure continued engagement with Member States and other stakeholders during the COVID-19 pandemic, the Agency launched the Webinar Series on the Role of Government and Key Organizations in Nuclear Power Programme Development. A total of 1292 participants from around 60 Member States followed the four live webinars held in 2020 and 2021. The recordings are available online for further access. Three webinars were organized jointly with the African Commission on Nuclear Energy under the framework of the Practical Arrangements.

15. A webinar entitled “Stakeholder Involvement in New Nuclear Power: Engagement in the Nuclear Newcomer Field” was held on 1 June 2021 with 221 registered participants from 55 Member States, providing examples of activities relevant to nuclear infrastructure development.

16. The Agency also continued active outreach to young generation networks in the area of nuclear energy. In particular, a “DDG Talk” was held by the Deputy Director General, Head of the Department of Nuclear Energy Mikhail Chudakov with members of the United Nations-Nuclear Young Generation. The Agency also extended Practical Arrangements with the International Youth Nuclear Congress in the Area of Nuclear Science and Technology.



# Nuclear Fuel Cycle and Waste Management

## A. Background

1. In resolution GC(64)/RES/12.B.3, the General Conference recognized the importance of assisting Member States interested in uranium production to develop and maintain sustainable activities through appropriate technology, infrastructure and stakeholder involvement and the development of skilled human resources, encouraged the Agency to develop a guidance document with a step by step approach for countries considering or initiating a uranium production programme, and encouraged interested Member States to use the Uranium Production Site Appraisal Team (UPSAT) missions which support Member States in this field.
2. The General Conference also encouraged the Secretariat to assist interested Member States in analysing the technical challenges that may hinder the sustainable operation of nuclear fuel cycle facilities, such as ageing management issues.
3. Furthermore, the General Conference requested the Secretariat to continue and strengthen its efforts relating to the fuel cycle, spent fuel, and radioactive waste management, and to assist Member States to develop and implement adequate programmes, in accordance with relevant safety standards and security guidance. It also encouraged the Secretariat to promote information sharing to better integrate approaches to the back end of the fuel cycle that impact processing, transport, storage, and recycling of spent fuel and waste management, and to provide more information on all stages of waste management, including waste pre-disposal management and disposal, and thereby assisting Member States, including those embarking on nuclear power programmes, to develop and implement adequate disposal programmes, in accordance with relevant safety standards and security guidance.
4. In the same resolution, the General Conference requested the Agency to formulate guidance documents on decommissioning and action plans to support decommissioning, with a view to promoting the safe, secure, efficient, and sustainable execution of these activities, and to facilitate the systematic review of these guidance documents based on recent developments, as appropriate. It also encouraged the Agency to further strengthen its activities in the area of environmental remediation, and supported Member States in the adoption of best practices for managing naturally occurring radioactive materials (NORM) residue/wastes and to remediate NORM contaminated sites.
5. The General Conference also encouraged the Agency to further strengthen its activities in support of the effective management of disused sealed radioactive sources (DSRS) through, inter alia, the development of Qualified Technical Centres for DSRS management and cooperative efforts to strengthen supporting information on the borehole disposal of DSRS, with a view to enhancing safety and security of DSRS in the long term.
6. The General Conference, in resolution GC(64)/RES12.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

7. In November 2020, the Agency published *Geochemical and Mineralogical Characterization of Uranium and Thorium Deposits* (IAEA-TECDOC-1929) as the final report on the related coordinated research project (CRP) and, in December 2020, *Uranium Raw Material for the Nuclear Fuel Cycle: Exploration, Mining, Production, Supply and Demand, Economics and Environmental Issues* (URAM-2018) containing the proceedings of an international symposium held in Vienna, 25–29 June 2018.



FIG. B.1. Overview of world distribution of uranium deposits map. (Source: IAEA)

8. In December 2020, an upgraded version of the World Distribution of Uranium Deposits (UDEPO) database went live on the Agency’s website, with improved graphic interface functionalities for users and more than 5000 uranium deposits registered.

9. Also, in December 2020, the joint IAEA and OECD Nuclear Energy Agency (NEA) “Red Book” publication *Uranium 2020: Resources, Production and Demand* was issued. The 2020 edition of the Red Book presents the most recent review of uranium market fundamentals, based in large part on official government information, and offers a statistical profile of the global uranium industry.

10. In January 2021, the Agency published *World Distribution of Uranium Provinces* and *World Distribution of Thorium Deposits*. At a scale of 1:35 000 000, the uranium map shows the broad distribution of uranium provinces and related resource statistics worldwide, whilst the thorium map displays the thorium deposit-type classification system and deposit size ranges and includes interactive querying and layer capability in Adobe PDF.

11. In April 2021, the Agency published *A Preliminary Inventory and Assessment of Uranium Resources in Mine Wastes* (IAEA-TECDOC-1952), intended to not only provide a preliminary inventory of uranium contained in mine wastes, including the desirable goal of comprehensive extraction in the uranium mining industry, but also to provide an initial framework to integrate this aim with those of environmental and remediation considerations in achieving zero waste.

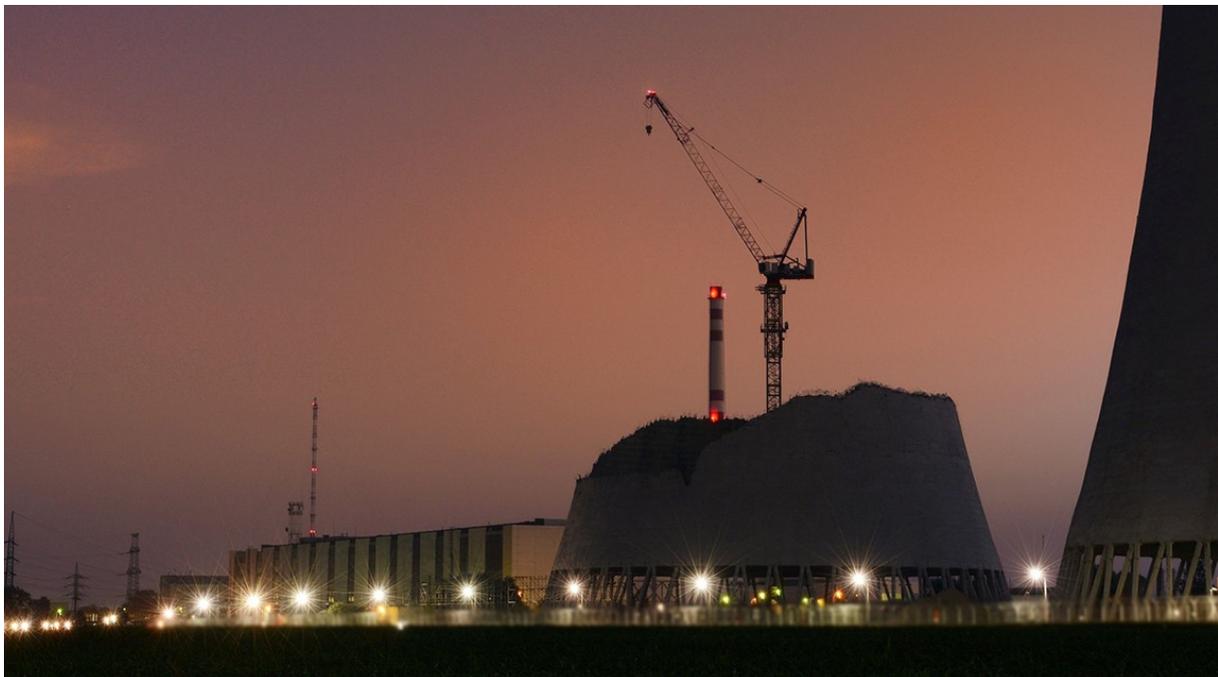
12. The Agency published in July 2020 Analysis of Options and Experimental Examination of Fuels for Water Cooled Reactors with Increased Accident Tolerance (ACTOF) (IAEA-TECDOC-1921) as the final report on the related CRP.
13. A webinar on accident tolerant fuels and their impact on spent fuel management was held in December 2020 and was attended by over 120 participants. The webinar focused on evolutionary accident tolerant fuel designs and their impact on the different fuel management steps after discharge from the reactor core: storage, transportation, recycling and disposal.
14. In April 2021, the Agency published Phenomenology, Simulation and Modelling of Accidents in Spent Fuel Pools (IAEA-TECDOC-1949), containing the proceedings of a Technical Meeting, that summarizes the discussions held among experts on the analysis, simulation and modelling of severe accident progression in spent fuel pools.
15. In the efforts to assist interested Member States in analysing the technical challenges that may hinder the sustainable operation of nuclear fuel cycle facilities, such as ageing management issues, the Third Research Coordination Meeting on Ageing Management Programmes for Spent Fuel Dry Storage Systems was held virtually in April 2021. It was attended by 21 experts (9 Chief Scientific Investigators (CSIs) and 12 observers) from 10 Member States. The CSIs presented the progress of the work done during the second phase of the CRP and discussed and agreed on the content of the final report of the CRP.
16. E-learning modules on the uranium production cycle are under development and an e-learning course on spent fuel storage is being translated into Japanese before being posted on the Cyber Learning Platform for Network Education and Training and other Agency network websites by the end of 2021.
17. A Technical Meeting on Fuel Failure in Normal Operation of Water Reactors: Experience, Causes and Mitigation was held virtually in December 2020 and was attended by 41 experts, from 15 countries and one international organization (OECD/NEA), who exchanged information on national experience and R&D progress. The presented papers will be compiled in a TECDOC that is currently being drafted.
18. The Second Research Coordination Meeting on Fuel Materials for Fast Reactors (FMFR) was held virtually in February 2021. It was attended by twelve experts from five countries and two international organizations (the European Commission's Joint Research Centre and the OECD/NEA). The eight CSIs presented the progress of the work done during the first phase of the CRP and discussed and agreed on individual and joint actions and the work-plan for the second phase of the CRP.
19. In June 2021, the Agency published Progress on Pellet–Cladding Interaction and Stress Corrosion Cracking: Experimentation, Modelling and Methodologies Applied to Support the Flexible Operation of Nuclear Power Plants (IAEA-TECDOC-1960), which provides a review of the studies carried out worldwide since the early 2000s on the subject, as an output of a Technical Meeting held in Aix-en-Provence, France in October 2019.
20. In February 2021, the Agency published Coolant Chemistry Control and Effects on Fuel Reliability in Pressurized Heavy Water Reactors (IAEA-TECDOC-1942) containing the report of a Technical Meeting, that presents up to date knowledge on the topic, including corrosion phenomena observed in the primary heat transport system and consequent effects on fuel reliability in pressurized heavy water reactors.
21. The First Research Coordination Meeting on Testing, Modelling and Simulations for Accident Tolerant and Advanced Technology Fuels was held in August 2021 to discuss and assess the relevance of research plans proposed by individual participants to the overall objectives of the CRP on the topic, and to foster interaction between CRP participants to achieve the project's goals.

22. The Agency published *Data Analysis and Collection for Costing of Research Reactor Decommissioning* (IAEA Nuclear Energy Series No. NW-T-2.12) in the third quarter of 2021. The publication aims to improve the general capability to prepare cost estimates for research reactor decommissioning, to determine the implications of different characterization strategies on cost and on designation of waste classes to assist the development of optimal approaches, and to understand the level of uncertainty of the cost estimates and the source of this uncertainty.

23. Two virtual Technical Meetings were conducted — in October 2020 with 51 participants from 23 Member States and the European Commission and OECD/NEA Secretariats, and in July 2021 with 57 participants from 29 Member States and three international organizations — to advance the Nuclear Energy Series draft publication on global status of decommissioning, covering status, trends and main issues and challenges of decommissioning nuclear power reactors, research reactors and nuclear fuel cycle facilities.

24. In December 2020, the virtual Technical Meeting on Advancing Collaboration on Competence Building and Knowledge Management for Decommissioning was held with 46 participants from 20 Member States and 3 international organizations, providing a forum to discuss relevant needs and opportunities. At the meeting, the two established Agency Collaborating Centres on decommissioning and a few organizations on their way to become such Collaborating Centres presented their capacities to support Agency activities in competence building and knowledge management for decommissioning.

25. In order to further formulate recommendations on practical enablers of end-state definition, controls and long-term stewardship for decommissioning and contaminated sites, in December 2020, the Agency held a Technical Meeting on the Use of Controls for Radioactively Contaminated Land with 48 participants from 29 Member States to discuss good practices and experience in applying controls both before and after implementation of environmental remediation measures.



*FIG. B.2. Demolition of V1 Nuclear Power Plant cooling towers in Slovakia. (Photo: JAVYS, a.s.)*

26. Slovakia's Nuclear and Decommissioning Company JAVYS became an Agency Collaborating Centre on decommissioning in March 2021. The establishment of Électricité de France's Directorate for Decommissioning and Waste Management Projects and the Japan Atomic Energy Agency as Agency Collaborating Centres on decommissioning is in progress. Thus, the number of organizations working

with the Agency within the Collaborating Centres scheme on knowledge management and capacity building for decommissioning will reach five and more have expressed their interest in such kind of a partnership.

27. To enhance its efforts in supporting Member States in the field of environmental remediation and NORM management, the Network on Environmental Management and Remediation (ENVIRONET) has made operational four Regional Working Groups aimed at capturing specific needs from Member States in Africa, Asia, Europe, and Latin America and the Caribbean) and consequently implementing activities and projects that can meet the identified needs. Events (e.g. webinars) were promoted in languages relevant to each region or sub-region in order to enhance the outreach and impact of exchanging experience, sharing of good practices and capacity building. Between October 2020 and August 2021, monthly webinars were held on different issues of environmental remediation, including regional webinars reflecting specific regional needs and challenges. The webinars were conducted in cooperation between the Department of Nuclear Energy and the Department of Nuclear Safety and Security with presenters from 14 Member States and between 51 and 512 registered participants per webinar from a total of 49 Member States.

28. The Agency continued its commitment to provide timely information and analysis related to the status and trends of radioactive waste and spent fuel management in Member States by embarking on the third cycle of its Status and Trends in Spent Fuel and Radioactive Waste Management project in cooperation with the OECD/NEA and the European Commission. The finalized report from the second cycle of the project is in publication with a predicted release date in the fourth quarter of 2021. The first third-cycle consultancy meeting convened virtually over the period January–June 2021, involving nine participants from five countries and representatives from the European Commission, OECD/NEA and World Nuclear Association, who agreed the terms of reference and identified the key themes which will be the focus of the next iteration of the document. The data analysed in the third cycle will be based on the inventories reported in the Spent Fuel and Radioactive Waste Information System and will be aligned with the latest reporting cycle of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

29. The Agency further strengthened its activities in support of the effective management of DSRS by developing the concept of Qualified Technical Centres (QTC) for DSRS management to build and expand the reach of existing capabilities in Member States. Over the past 12 months, the QTC framework was developed to include the assessment criteria and methodology whereby an organization is designated as a QTC. Plans are under way to test this methodology on a volunteer organization with the goal to be ready to seek formal nominations for QTC status by the end of 2021. In December 2020, the First Research Coordination Meeting on Developing a Framework for the Effective Implementation of a Borehole Disposal System was held virtually involving 26 participants from 14 Member States. The objective of the CRP is to foster cooperative efforts to further strengthen supporting information on the borehole disposal of DSRS, with a view to enhancing the safety and security of DSRS in the long term. The Agency continues to further enhance safety and security by supporting the removal of high activity sources in Member States, including, during 2020, source retrievals in Cyprus and Tunisia.



# Research Reactors

## A. Background

1. In resolution GC(64)/RES/12.B.4, the General Conference encouraged the Secretariat to continue to foster regional and international collaboration and networking that expands access to research reactors, such as international user communities. It also encouraged the Secretariat to inform Member States considering the development or installation of their first research reactor of the issues related to utilization, cost-effectiveness, environmental protection, safety and security, nuclear liability, proliferation resistance, including the application of comprehensive safeguards, and waste management associated with such reactors, and, on request, to assist Member States in pursuing new reactor projects following the Agency-developed Specific Considerations and Milestones for a Research Reactor Project systematically and on the basis of a robust, utilization-based strategic plan.
2. The General Conference also urged the Secretariat to continue to provide guidance on all aspects of the research reactor life cycle, including the development of ageing management programmes at both new and older research reactors, to ensure continuous improvements in safety and reliability, sustainable long-term operation, the sustainability of fuel supply, exploration of efficient and effective disposition options for spent fuel and waste management, and the development of a knowledgeable customer capability in Member States decommissioning research reactors.
3. Furthermore, the General Conference encouraged the Secretariat to further strengthen its efforts to support capacity building based on research reactors, including with the IAEA Internet Reactor Laboratory project which could be expanded in the Asia-Pacific, Europe and Africa regions.
4. Finally, the General Conference called on the Secretariat to continue to support international programmes working to minimize the civilian use of HEU where such minimization is technically and economically feasible.
5. The General Conference requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

6. A Training Workshop on Optimization of Performance and Processes in Neutron Activation Analysis, originally planned to be held in the Czech Republic, was held virtually in November and December 2020, with 57 participants from 28 Member States. Methods for optimizing performance in neutron activation analysis were critically analysed, focusing on improvement of throughput and of turnaround time, quality assurance and quality control, and opportunities for development and application of innovative processes. A draft Technical Reports Series publication entitled *Practical*

*Guide to Quality Assurance and Quality Control in Neutron Activation Analysis* is currently undergoing editing in preparation for publishing.

7. *Neutron Scattering with Low and Medium Flux Neutron Sources: Processes, Detection and Applications* (IAEA-TECDOC-1961) was published in June 2021. It serves as an authoritative reference on the application of neutron scattering at low and medium flux neutron sources, of interest to neutron scattering experts, research reactor and accelerator personnel and those considering R&D or education and training programmes based on this technique.

8. The Agency scheduled a virtual Technical Meeting on Advances in Neutron Detectors for Neutron Scattering and Imaging Applications, to be held from 30 August to 3 September 2021, to review the developments in neutron detectors for neutron scattering and neutron imaging applications.

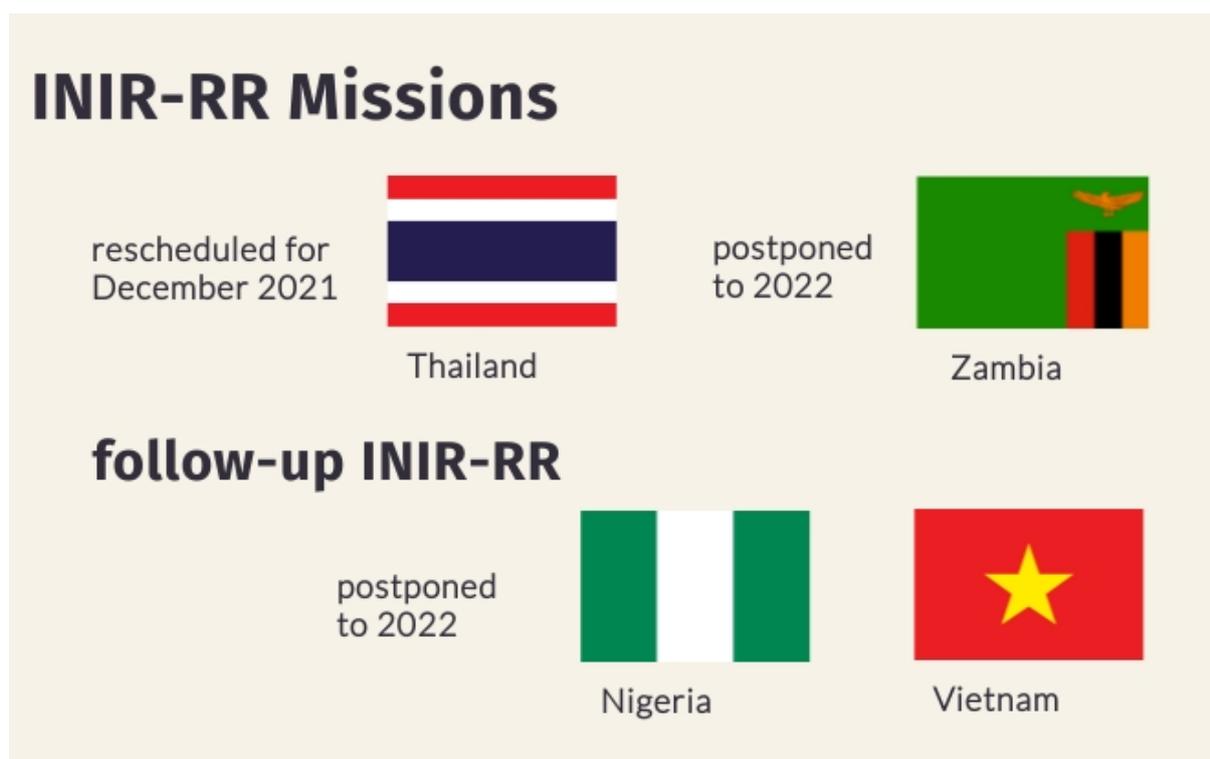
9. The Agency produced an e-learning course on neutron imaging and made it available to Member States in October 2020. The e-learning course on nuclear analytical techniques for forensic science was expanded with new modules introducing the use of X-ray diffraction and of X-ray fluorescence in forensic sciences, as well as sample preparation considerations for ion beam analysis.

10. A worldwide proficiency testing exercise for neutron activation analysis laboratories was held, providing a mechanism for laboratories to demonstrate their analytical performance and identify areas for improvement. The exercise included the participation of nuclear related techniques, leveraging synergies with the Nuclear Science and Instrumentation Laboratory at Seibersdorf. 70 laboratories from 44 Member States participated in total, including 42 neutron activation analysis laboratories.

11. Two Integrated Research Reactor Utilization Review missions, scheduled in 2020, had to be postponed owing to the COVID-19 pandemic. A third request was received, and the mission is tentatively scheduled for November 2021.

12. The Agency conducted a Training Workshop on the Assessment of the National Nuclear Infrastructure to Support a New Research Reactor Project in December 2020. The workshop provided practical guidance on the application of *Specific Considerations and Milestones for a Research Reactor Project* (IAEA Nuclear Energy Series No. NP-T-5.1), the establishment of infrastructure for a new research reactor, relevant Agency safety standards and other related Agency publications. The workshop also provided a forum at which participants shared and discussed experiences, challenges and lessons learned in the development and implementation of new research reactor projects.

13. In June 2021, the Agency issued *Specific Considerations in the Assessment of the Status of the National Nuclear Infrastructure for a New Research Reactor Programme* (IAEA Nuclear Energy Series No. NR-T-5.9). The publication provides guidance for the assessment of progress in the development of national nuclear infrastructure to support a new research reactor programme, based on the Milestones approach. It can be used either by a Member State wishing to evaluate its own progress or as the basis for Integrated Nuclear Infrastructure Review for Research Reactors (INIR-RR) missions that, upon a Member State's request, the Agency may perform to independently assess the status of the infrastructure or the progress made in developing it. The Agency also continued development of a publication on project management in construction of research reactors.



14. Due to COVID-19, the INIR-RR mission to Thailand, originally scheduled for 2020, was rescheduled for December 2021, and the INIR-RR mission to Zambia and follow-up INIR-RR missions to Nigeria and Viet Nam were postponed to 2022.

15. A Training Workshop on the Preparation of a Feasibility Study for a New Research Reactor Project was held in May 2021. The workshop was attended by 57 participants representing 17 Member States. The participants were provided with practical information and knowledge on the preparation of a feasibility study for a new research reactor project, taking into account potential utilization, safety requirements, and future operation. The workshop also served as a forum to share and discuss experiences, challenges and lessons learned.

16. In efforts to continue to provide guidance on all aspects of the research reactor life cycle, a Technical Meeting on Research Reactor Ageing Management, Refurbishment and Modernization was held in May–June 2021. It provided a forum to exchange experiences and information on the management of research reactor ageing, and experience from completed and ongoing projects on the modernization and refurbishment of research reactors. The participants also reviewed the draft guidelines for an ageing management, modernization and refurbishment programme for a research reactor developed by the Agency.

17. In June 2021, the Agency conducted a Training Workshop on Integrated Management Systems for Research Reactors that provided the participating Member States with practical information and a possibility to exchange experience on the establishment, implementation and continuous improvement of management systems for research reactors.

18. In April 2021, the Agency issued *Digital Instrumentation and Control Systems for New and Existing Research Reactors* (IAEA Nuclear Energy Series No. NR-G-5.1). The publication provides engineering guidance on the design, and operational aspects of digital instrumentation and control systems for the refurbishment of existing facilities and for new research reactors to enhance their reliability and availability.

19. In November 2020, the Agency released *Guidelines for the Operation and Maintenance Assessment for Research Reactors (OMARR)* (IAEA Services Series No. 44), which provides information on the preparation, implementation and reporting of OMARR missions, including pre-OMARR and follow-up missions to assist Member States to reach high operational standards and performance of their research reactors.
20. OMARR missions requested by Chile, the Democratic Republic of the Congo, the Islamic Republic of Iran, Poland and Thailand were rescheduled to the fourth quarter of 2021 and to 2022 due to the COVID-19 pandemic.
21. Similarly, a review mission to designate Morocco's National Centre for Nuclear Energy, Science and Technology (CNESTEN) as an International Centre Based on Research Reactors planned for late 2020 was postponed.
22. The 16th Research Reactor Group Fellowship Training Course originally planned in cooperation with the Eastern European Research Reactor Initiative in 2020, was postponed to October 2021 and a Research Reactor School in the Russian Federation originally planned in 2020 was postponed to 2022 due to the pandemic.
23. In April 2021, the Agency issued *Impact of Fuel Density on Performance and Economy of Research Reactors* (IAEA Nuclear Energy Series No. NF-T-2.7). The publication offers a preliminary evaluation of the performance and cost impacts of using high density fuel in a research reactor. It summarizes the major considerations of the impact of increased fuel density on reactor performance and fuel consumption and offers a simple evaluation of cost savings from using high density fuel, based on comparative fuel consumption.
24. To provide practical guidance on the consideration of decommissioning aspects to designers and operators of research reactors, the Agency started drafting a publication on considerations for decommissioning in the design and operation of research reactors.
25. The Agency continued supporting two highly enriched uranium (HEU) minimization projects in Kazakhstan. Preparations were conducted for the return of spent HEU fuel from the IVG.1M research reactor to the Russian Federation and down-blending of the irradiated HEU graphite fuel unloaded from the IGR research reactor through a series of virtual consultancy meetings, engagement of experts and contractual arrangements.
26. A Technical Meeting on Global Capabilities for the Production and Manufacture of Non-High Enriched Uranium Molybdenum-99 Targets was held in October 2020. Fifty participants from 15 Member States and the European Commission discussed the existing and upcoming techniques and capabilities for the manufacture of targets used in the production of molybdenum-99 and shared insights into progress made in the production of this important medical radioisotope without the use of HEU.
27. The Agency continued cooperation with Argonne National Laboratory for the organization of the annual International Meeting on Reduced Enrichment for Research and Test Reactors, held virtually in April 2021. Over 200 participants from 35 countries discussed various aspects of research reactor conversion from HEU to LEU fuel, development and qualification of high-density fuels, proliferation resistance of new research reactor designs, and ensuring continuity of the supply of high-assay LEU.
28. The Agency completed the upgrade of the Research Reactor Database with enhancement of its functionality and migration to a new IT platform. This publicly accessible database provides technical and administrative information on more than 840 research reactors, including critical and sub-critical assemblies, currently operating, under construction, planned, shut down, under decommissioning, or decommissioned in 70 countries.



*FIG. B.1. Internet Reactor Laboratory: transmission of the experiment from VR-1 research reactor in Czech Technical University, February 2021. For more information on Internet Reactor Laboratory, see Annex 9. (Source: IAEA)*



# Operating Nuclear Power Plants

## A. Background

1. In resolution GC(64)/RES/12.B.5, the General Conference requested the Secretariat to promote collaboration among interested Member States for strengthening excellence for the safe, secure, efficient, and sustainable operation of nuclear power plants, and to continue its support to interested Member States, in particular through strengthening their knowledge, experience, and capacity in management of ageing and plant life management.
2. The General Conference also encouraged the Secretariat to identify best practices and lessons learned with respect to procurement, supply chain, engineering, and related issues in the delivery of large, capital-intensive nuclear engineering projects and to promote and disseminate them through publications and web-based tools with respect to supply chain management.
3. Furthermore, the General Conference recognized the need to enhance further the support for grid and nuclear power plant interfaces, grid reliability, and cooling water usage, and recommended that the Secretariat collaborate on these matters with Member States that have operating nuclear power plants.
4. The General Conference, in resolution GC(64)/RES/12.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

5. The second Global Forum on innovation to improve technical drivers that improve economic sustainability of operating nuclear power plants was planned to be held in October 2020. Due to the global pandemic the international steering committee decided to postpone the event until 2022. In the meantime, the Agency launched the Global Forum for Nuclear Innovation Network on the IAEA CONNECT platform. This network was used to gather and highlight examples of deployed innovations during a side event at the 2020 session of the General Conference.
6. In efforts to promote collaboration among interested Member States for strengthening excellence for the safe, secure, efficient, and sustainable operation of nuclear power plants, the Technical Working Group on Managing Human Resources in the Field of Nuclear Energy was held as a virtual meeting in October 2020 and attended by more than 25 participants representing 15 Member States. It highlighted examples of deployed measures to counter the effects of the COVID-19 pandemic and provided a broad updated perspective on human resources, training and leadership topics relevant to operating Member States.
7. The Agency delivered a virtual Training Course on the Assessment of Behavioural Competencies for Safe, Secure and Effective Performance in Nuclear Organizations to 38 participants from 15 Member

States. The first part of the course was held in November 2020, and the second part took place in June 2021.

8. The Technical Meeting on Leadership and its Development in Nuclear Organizations, held in May 2021, was attended by more than 88 participants representing 37 Member States and two international organizations. It established the basis of the future work on the topic and elicited additional needs expressed by the participant Member States.

9. The Agency issued *Systematic Approach to Training for Nuclear Facility Personnel: Processes, Methodology and Practices* (IAEA Nuclear Energy Series No. NG-T-2.8) in April 2021. The publication provides a basis for establishing and sustaining the quality and reliability of training and qualification for all main categories of nuclear facility personnel and presents the systematic approach to training methodology updated with lessons learned and good practices.

10. The Agency also issued *Asset Management for Sustainable Nuclear Power Plant Operation* (IAEA Nuclear Energy Series No. NR-T-3.33) in March 2021. The publication contains experience and advice gathered from diverse international experts in the area of asset management. Asset management is a holistic approach to operation and maintenance which aims to ensure the sustained reliability of systems, structures and components via a balanced consideration of cost, opportunities and risk. The publication provides support to decision makers seeking the optimization of financial performance, operational performance and risk exposure.

11. In April 2021, the Agency published *Nuclear Power Plant Life Management* containing the proceedings of an international conference held in Lyon, France, 23–26 October 2017. Plant life management is a topic of increasing relevance as operating reactor licences continue to be extended, with numerous plants now being approved for operation of up to 80 years.

12. The Agency issued *Fire Protection in Nuclear Power Plants* (IAEA-TECDOC-1944) in February 2021. The publication contains experience and advice gathered from diverse international experts in the area of fire protection. Stakeholders in interested Member States can apply the information contained in the publication to improve the management of fire protection and minimize related risks at operating nuclear power plants worldwide.

13. *Management of Nuclear Power Plant Projects* (IAEA Nuclear Energy Series No. NG-T-1.6) was issued in October 2020. The publication contains experience and good practices gathered from international experts in the area of nuclear power plant project management. As an increasing number of Member States consider expanding or introducing nuclear power programmes, this practical publication on what to consider for a successful nuclear project and related support will become increasingly relevant.

14. In efforts to seek efficiencies in the development and management of digital information systems, and to ensure and improve long term accessibility and public access to these tools and databases, a major overhaul of the data acquisition, validation and acceptance module of the Power Reactor Information System (PRIS) database was deployed during the first semester of 2021. The project adapted the software to a new platform as the former platform was no longer supported by the software provider. The Agency took advantage of this opportunity to implement enhancements based on user feedback to improve efficiency and the overall user experience.

15. A major project was launched in June 2021 to update the PRIS statistics module. This update aims to improve the utility and user experience of the database through, for example, enhanced intuitiveness and also by adding new analytical features. In December 2020, the decommissioned reactor and decommissioning plan PRIS modules were updated to collect, evaluate and disseminate information on the current status and future prospects of NPP decommissioning in the world.

16. In order to provide further support to interested Member States by sharing best practices and strategies used in the justification of commercial industrial instrumentation and control equipment for nuclear power plant applications, the Agency issued *Application of Wireless Technologies in Nuclear Power Plant Instrumentation and Control Systems* (IAEA Nuclear Energy Series No. NR-T-3.29) in December 2020. The publication outlines various applications of wireless, digital technologies at operating nuclear power plants, in particular in instrumentation and control systems utilized to monitor and control plant operation.

17. *Computer Security Aspects of Design for Instrumentation and Control Systems at Nuclear Power Plants* (IAEA Nuclear Energy Series No. NR-T-3.30) was published in December 2020. This publication details IT security considerations for instrumentation and control systems at nuclear power plants. The publication is particularly timely as the industry, consistent with other industries worldwide, transitions toward digital applications.

18. The Agency also published *Challenges and Approaches for Selecting, Assessing and Qualifying Commercial Industrial Digital Instrumentation and Control Equipment for Use in Nuclear Power Plant Applications* (IAEA Nuclear Energy Series No. NR-T-3.31) in September 2020. Increasing the qualification and utilization of commercial industrial grade equipment can relieve challenges linked to strained supply chains and help ensure operating nuclear power plants remain economically viable.

19. Workshops related to electric grids were conducted to support nuclear power programme development. Thirty participants were trained via a virtual, national workshop for Saudi Arabia conducted in November 2020 on the nuclear power plant–grid interface, grid requirements and loss of power. Fifteen participants were trained at a virtual, national workshop for Uzbekistan conducted in June 2021 on electric grid reliability and interface with nuclear power plants.

20. In order to facilitate sharing experience and knowledge among Member States related to methods and strategies for the implementation of post-Fukushima actions at nuclear power plants, the Agency issued *Implementation and Effectiveness of Actions Taken at Nuclear Power Plants following the Fukushima Daiichi Accident* (IAEA-TECDOC-1930) in October 2020. The report summarizes the actions taken in Member States to implement the lessons learned following the 2011 accident at the Fukushima Daiichi nuclear power plant, as well as the effectiveness of those actions.

21. As part of continued support to interested Member States in building their national capacities in the operation of nuclear power plants, the Agency issued *Decontamination Approaches During Outage in Nuclear Power Plants — Experiences and Lessons Learned* (IAEA-TECDOC-1946) in March 2021. The publication contains experience and advice gathered from diverse international experts in the area of radiological decontamination and nuclear power plant outage planning and management. Stakeholders in interested Member States can apply the information contained in the publication to improve planning and implementation of nuclear power plant shutdowns. These improvements help operators ensure the economic sustainability of operating plants.



# Agency Activities in the Development of Innovative Nuclear Power Technology

## A. Background

1. In resolution GC(64)/RES/12.B.6, the General Conference requested the Secretariat to promote collaboration among interested Member States in developing innovative, globally sustainable nuclear energy systems and to support the establishment of effective collaboration mechanisms to exchange information on relevant experiences and good practices. It also encouraged the Secretariat to consider further opportunities to develop and coordinate the services it provides in building long-term national nuclear energy strategies and in long-term sustainable nuclear energy deployment decision-making using, inter alia, the analytical approaches and tools developed by INPRO.

2. The General Conference also encouraged the Secretariat to study cooperative approaches to the back end of the nuclear fuel cycle to ensure effective cooperation among countries towards the long-term sustainable use of nuclear energy and requested the Secretariat to facilitate discussion among developers of advanced reactors (e.g. SMRs, Generation IV reactors) on the challenges and technologies related to decommissioning and radioactive waste management at the earliest stage of their design thinking.

3. Furthermore, the General Conference encouraged the Secretariat to further its efforts on distance learning/training on development and evaluation of innovative nuclear technology for students and staff of universities and research centres, and to further develop tools supporting this activity that supports efficient delivery of services to Member States.

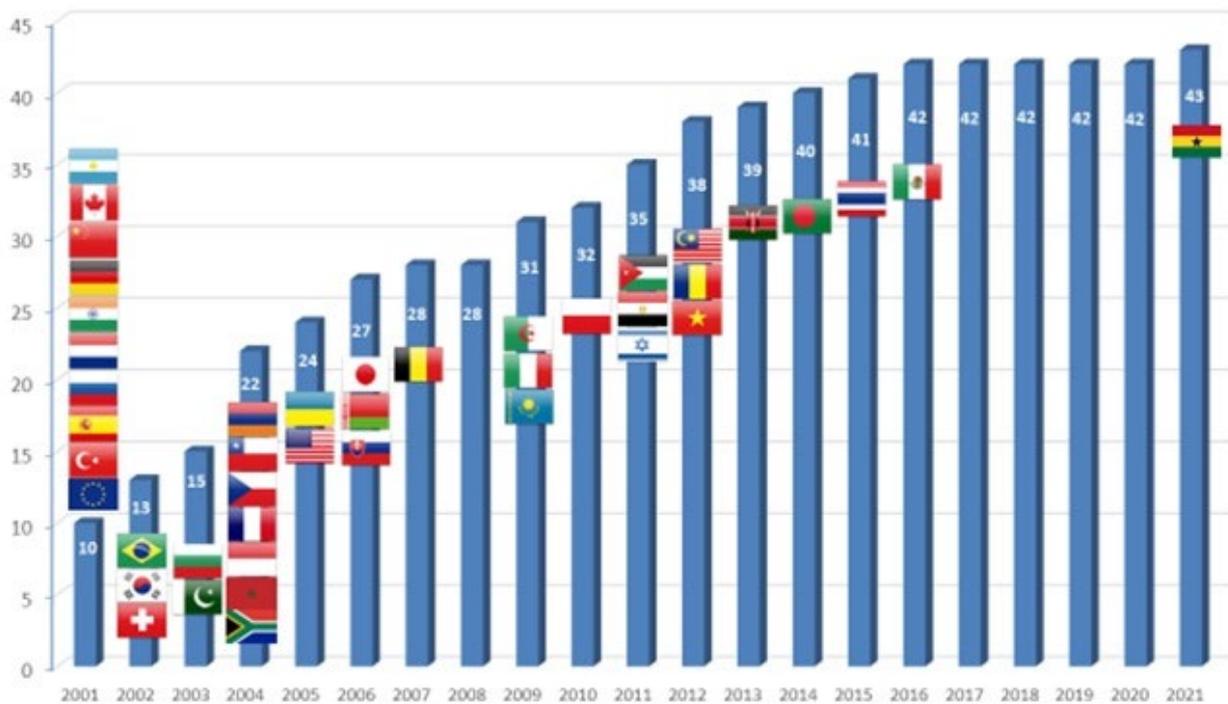
4. The General Conference, in resolution GC(64)/RES/12.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

5. INPRO increased its membership by one Member State in 2021 with the addition of Ghana and currently comprises 42 Member States and the European Union. Over the past years, INPRO developed a series of tools and services and as well as collaborative projects for collective action among its members. During the reporting period, the Agency has further promoted the use of these tools in university curricula working with Russian universities through the Regional Network for Education and Training in Nuclear Technology (STAR-NET) and held the IAEA-STAR-NET Regional School to Train the Trainers on Nuclear Energy System Modelling and Assessment Using the INPRO Methodology virtually in April 2021 in Russian. INPRO also has new engagements with the Nuclear Engineering Department Heads Organization and the Canadian University Network of Excellence in

Nuclear Engineering for a Regional School to Train the Trainers on Nuclear Energy System Modelling and Assessment Using the INPRO Methodology to be held virtually in September 2021. In efforts to develop the Agency's multilingual outreach, INPRO has developed an e-learning course on Analysis Support for Enhanced Nuclear Energy Sustainability (ASENES) in English, Russian and Spanish.

### INPRO Members 2001 - 2021



6. The Agency also started a new collaborative project called “Sustainable deployment scenarios for small modular reactors” (the ASENES SMR project) to involve new participants and to expand the scope of case studies performed with the use of methods and tools belonging to ASENES. The project has Armenia, Belarus, China, Indonesia, Romania, the Russian Federation, Thailand, and Ukraine as participants and Bulgaria, Egypt, Germany, Israel and Morocco as observers. Several other INPRO members are considering joining the ASENES SMR project.

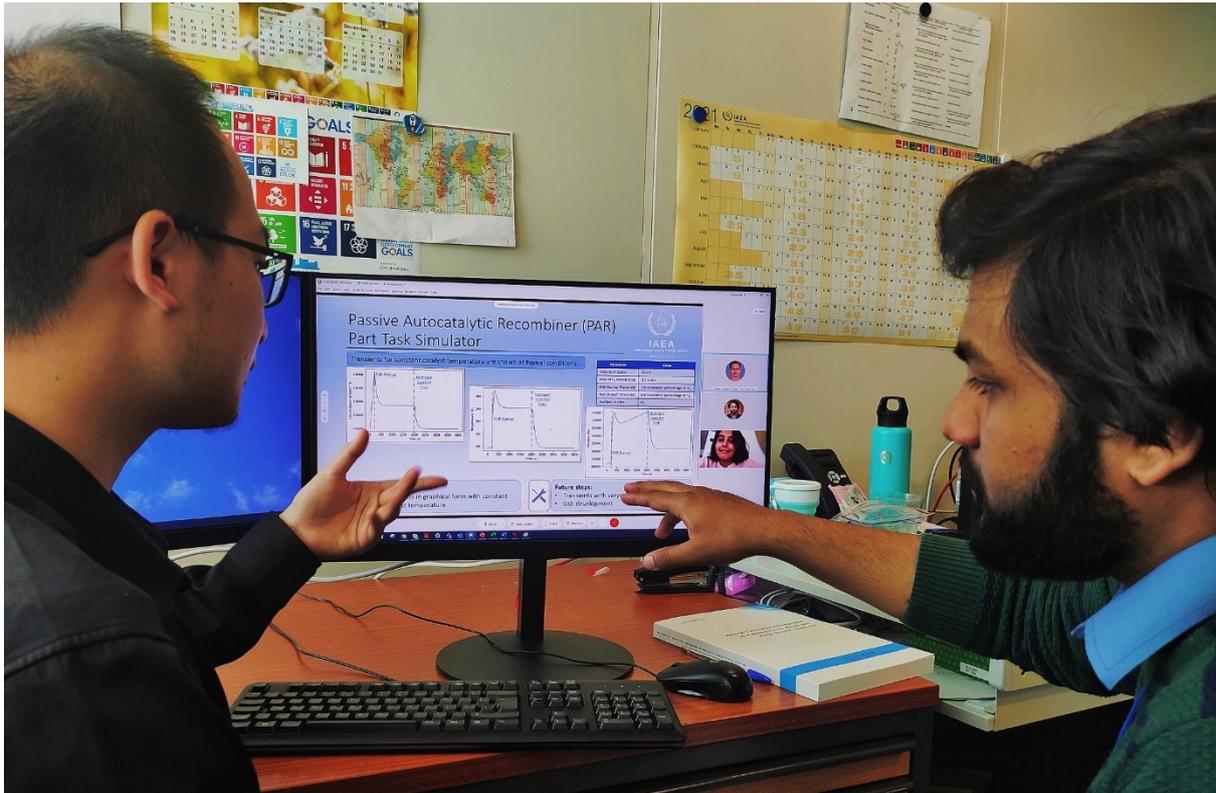
7. INPRO developed the Framework for Modelling Electricity Systems (FRAMES) to develop adequate capabilities within the Agency to provide Member States with quantitative and defensible analyses on the potential of nuclear power to address climate change and on the role that nuclear energy can play in present and future electricity systems. Additionally, this new capability can provide justifiable support for technical analyses involving the optimal grid integration of advanced nuclear technologies, such as SMRs, microreactors and fast reactors, as well as non-electric application of nuclear energy (hybrid energy systems, hydrogen production, co-generation, etc.). This capability will enable INPRO to play a critical role in supporting the needs of Member States in this area. URENCO and the Agency have an agreement to work together on making the voice of nuclear heard at COP26 especially in the decarbonized production of hydrogen. Hence, FRAMES analysis will support the key messages for the Agency's discussion on nuclear energy's role in these decarbonization strategies by showing the powerful role of nuclear working with renewable energy sources (wind, solar, hydro) to produce hydrogen.

8. INPRO uses a roadmapping strategy to encourage enhanced nuclear energy sustainability by presenting the status, prospects, benefits, and risks associated with a variety of options for a national nuclear energy system configuration to grow and evolve. INPRO roadmapping strives to save time, effort and resources required for improving the sustainability of a national nuclear energy system through collaboration and nuclear trade with other countries. This analysis uses the ROADMAPS Excel Tool from the INPRO toolbox to assist in Nuclear Energy System Assessment (NESA). In this regard, INPRO has started working with Argentina, the Republic of Korea, the Russian Federation and the USA in performing NESAs on planned designs to assess SMR design sustainability under the INPRO methodology and capturing gaps for evaluation by the design team to improve robustness and sustainability of design for deployment.

9. In order to promote collaboration among interested Member States in developing innovative, globally sustainable nuclear energy systems and to support the establishment of effective collaboration mechanisms to exchange information on relevant experiences and good practices, the Agency announced a new CRP on Technical Evaluation and Optimization of Nuclear–Renewable Hybrid Energy Systems in May 2021 to be launched early 2022.

10. A new project to modernize the Advanced Reactor Information System database was initiated in January 2021 to be completed by the fourth quarter of 2021. Also, a new project for the modernization of the Thermo-Physical Materials Properties (THERPRO) Database was initiated in May 2021 to be completed in 2022.

11. The Agency also published *Developments in the Analysis and Management of Combustible Gases in Severe Accidents in Water Cooled Reactors following the Fukushima Daiichi Accident* (IAEA-TECDOC-1939) in December 2020. This publication provides a comprehensive review of the current state of technology regarding safety issues related to combustible gases in water cooled nuclear reactors with a specific focus on developments following the Fukushima Daiichi accident. Recent results obtained in experimental and analytical research on hydrogen/combustible gas behaviour are discussed. The knowledge base developed is useful for the validation and assessment of combustible gas modelling in existing safety analysis tools, as well as for possible improvements to severe accident management guidelines.



*FIG. B.1. Under a new IAEA coordinated research project, a comprehensive graduate (MS and PhD) training programmes on thermal-hydraulics phenomena modelling and predictions applicable to the prototype designs of SCWRs will be developed and implemented for students from countries embarking on nuclear power programmes. (Source: IAEA)*

12. The Agency announced a new CRP on Advancing Thermal-Hydraulic Models and Predictive Tools for Design and Operation of SCWR Prototypes in May 2021. The CRP, which will be launched in 2022, will support Member States in thermal-hydraulic modelling, tools development and experimental studies applicable to the design of supercritical water cooled reactors (SCWRs).

13. As part of efforts to facilitate the exchange of knowledge and experience in the area of innovative, globally-sustainable nuclear energy systems, the Agency conducted a virtual Technical Meeting on Innovative Seismic Design Options for Advanced Water Cooled Reactors and Small Modular Reactors in May 2021, with 75 participants from 28 Member States and two international organizations.

14. In July 2020, the Agency published *Light Water Reactor Fuel Enrichment beyond the Five Per Cent Limit: Perspectives and Challenges* (IAEA-TECDOC-1918), that details technological options and corresponding issues regarding high assay low enriched uranium fuel and core design, safety analysis and assessments relevant to manufacturing, handling, transportation, storage, irradiation, and performance in normal and accident conditions.

15. A Technical Meeting on Advances in Post-Irradiation Examination Techniques for Power Reactor Irradiated Fuels and Innovative Fuels was held virtually in July 2021 to exchange information on recent experience and ongoing and future improvements in the field of post-irradiation examination techniques for power reactor irradiated fuels and innovative fuels.

16. In July 2021, the Agency announced a new CRP on Benchmark of Transition from Forced to Natural Circulation Experiment with Heavy Liquid Metal Loop. The overall objective of the CRP is to

improve the Member States' analytical capabilities in the field of simulation of fast reactors cooled by heavy liquid metals.

17. In March 2021, the Agency conducted the Ninth Joint IAEA–GIF Workshop on the Safety of Liquid Metal Cooled Fast Reactors attended by 28 experts from 12 Member States and two international organizations.

18. To support fast neutron systems, the Agency has started developing several publications on this technology including TECDOCs on benefits and challenges of SMR fast reactors, structural materials for heavy liquid metal cooled reactors, and a sodium coolant textbook on thermal-hydraulic correlations.

19. In order to further its efforts on distance learning/training on development and evaluation of innovative nuclear technology for students and staff of universities and research centres, the Agency published new e-learning modules via its the Cyber Learning Platform for Network Education and Training on an overview of water cooled reactors; an introduction to the history, advanced designs and global deployment of boiling water reactors; and hybrid energy systems.

20. Following the conclusion in 2020 of the CRP on Accelerator-Driven System (ADS) Applications and Use of Low-Enriched Uranium in ADSs, the Agency started the preparation of a publication on its results. The publication will cover the experiments and analyses related to LEU-fuelled ADS facilities that propose or confirm expansion of applications using ADSs, as well as the development and refinement of analytical tools for ADSs.

21. The IAEA also started developing a Nuclear Energy Series publication on synergies in technology development between nuclear fission and fusion for energy production. The publication will demonstrate possible synergies between nuclear fission and fusion in terms of technology development, transfer of knowledge and know-how and common infrastructure.

22. In September 2020, the Agency launched a new Fusion Device Information System (FusDIS), the first interactive database offering information about 120 public and private experimental fusion research devices which are currently in operation, under construction, closed, or being planned. FusDIS was further enhanced and updated in May 2021, by adding more technical data, country statistics and research outputs relevant to individual experimental facilities.

23. At the annual meeting of the International Fusion Research Council (IFRC), held in October 2020, the experts reviewed the latest achievements of fusion research all over the world, and discussed opportunities for international cooperation in some new areas, including support for starting new CRPs on the regulatory framework for fusion and on machine learning and artificial intelligence for fusion.

24. During the Joint IAEA–ITER Technical Meeting on Safety and Radiation Protection for Fusion Reactors, held virtually in November 2020, discussions and information exchanged focused on safety and radiation protection issues relevant to experimental fusion facilities, with a focus on ITER. The event was attended by 46 participants from 16 Member States and 2 intergovernmental organizations.

25. In December 2020, the Agency published an article entitled *Considerations for commercialization strategies for fusion energy* as a chapter of the Institute of Physics publication *Commercialising Fusion Energy: How Small Businesses are Transforming Big Science*.

26. The First Research Coordination Meeting on Development and Application of Ion Beam Techniques for Materials Irradiation and Characterization relevant to Fusion Technology was held in February 2021 and attended by 33 scientists from 11 Member States.

27. The fourth Nuclear Fusion Coordination Committee meeting took place in March 2021. The meeting focused on safety and regulatory aspects of fusion facilities.



# Approaches to Supporting Nuclear Power Infrastructure Development

## A. Background

1. In resolution GC(64)/RES/12.B.7, the General Conference encouraged the Nuclear Infrastructure Development Section to pursue its activities integrating the Agency's assistance provided to Member States embarking on or expanding nuclear power programmes, and encouraged Member States interested in or embarking on new or expanded nuclear power programmes to make use of Agency services related to nuclear infrastructure development.
2. The General Conference also requested the Secretariat to continue to incorporate lessons learned from INIR missions and to enhance the effectiveness of such INIR activities, urged Member States to develop and keep updated action plans to address the recommendations and suggestions provided by the INIR missions, and encouraged them to participate in the development of their Member State-specific Integrated Work Plans (IWPs).
3. The General Conference also encouraged the Secretariat to facilitate, where possible, international coordination to improve efficiency of multilateral and bilateral assistance to these Member States, and encouraged the strengthening of activities undertaken by Member States, both individually and collectively, to cooperate on a voluntary basis in nuclear infrastructure development.
4. The General Conference, in resolution GC(64)/RES/12.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

5. The Secretariat continued its efforts to provide integrated Agency assistance to Member States embarking on or expanding nuclear power programmes based on the Agency's Milestones approach (outlined in IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1)) through the inter-Departmental Nuclear Power Support Group and the Infrastructure Coordination Group, as well as through the enhanced accountability of the Member State specific 'core teams' including representatives from all relevant Secretariat Departments and the Office of Legal Affairs. The core teams participated in bilateral meetings with the respective Member States to develop or update their national IWPs and Country Nuclear Infrastructure Profiles (CNIPs) to plan and tailor Agency assistance to the current needs of each Member State and to monitor the progress of national infrastructure development following an INIR mission. In discussions with the respective Member States, four IWPs and CNIPs (Bangladesh in February 2021, Belarus in September 2020, Egypt in August 2021, and Sudan in April 2021,) were updated by the core teams to support the national action plans to address the results of INIR missions.

Additionally, IWP mid-term review meetings were held virtually with eight Member States (Egypt, Jordan, Kenya, Poland and Saudi Arabia in December 2020; Morocco and Nigeria in January 2021; and Ghana in February 2021) to ensure continued Agency support to embarking Member States and prioritize/identify activities for near-term support.



*FIG. B.1. Collins Juma, CEO, NuPEA; Eric Mathet, INIR team leader; IAEA, Zachary Ayieko, Chief Administrative Secretary, Ministry of Energy; Ezra Odondi Odhiambo, Chairman, NuPEA (from left to right) during the closing session of the INIR follow up mission to Kenya. (Source: IAEA)*

6. The Agency continued to underline the importance of an appropriate legal framework as well as an effective and independent regulatory body in nuclear power programme development. The regulatory framework is one of 19 infrastructure issues in the Milestones approach. In this regard, *Experiences of Member States in Building a Regulatory Framework for the Oversight of New Nuclear Power Plants: Country Case Studies* (IAEA-TECDOC-1948) was published in March 2021.

7. Additionally, a registry containing all recommendations and suggestions made during previous INIR missions is maintained and updated regularly. Lessons learned are further incorporated into revisions of existing and the development of new publications related to nuclear infrastructure development, in particular *Integrated Nuclear Infrastructure Review (INIR): Ten Years of Lessons Learned* (IAEA-TECDOC-1947), which was published in April 2021.

8. The Secretariat continued to perform INIR missions, where appropriate, in a mixture of English and one of the other United Nations official languages to facilitate the highest level of information exchange. Whereas self-evaluation reports are expected to be submitted in English, supporting documents can be provided in other United Nations official languages. The main INIR mission report is published in English. Additionally, in response to growing recognition and use of the Milestones approach, the Milestones publication (IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1)) was translated and published in Arabic, Chinese, French and Russian; the Spanish translation is in the process of being published.

9. The continued sustainability of the INIR service and the availability of a broad pool of experts are being ensured through regular training of external experts and staff members from relevant Departments, most recently in November 2020. The Secretariat continued to ensure that the use of external experts for INIR missions did not constitute a conflict of interest or provide a commercial advantage.

10. The 15th annual Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure, held as a virtual meeting in March 2021, was attended by more than 100 participants representing 35 Member States and international organizations. The meeting continued to be the main forum for newcomer and experienced Member States to share good practices and lessons learned in establishing the infrastructure required for a safe and successful nuclear power programme and prioritizing and sequencing the activities needed.

11. To enable the Agency to continue delivering its mandate following the restrictions stemming from the outbreak of COVID-19, an alternative solution was adopted to the implementation of interregional nuclear infrastructure training courses to increase awareness and understanding of the Milestones approach, namely a two-step approach. The first step comprises virtual presentations and panel discussions, while the second step comprises face to face training once feasible with additional focused presentations, group activities and site visits. Based on this alternative, training was provided to around 128 participants from 30 Member States during six interregional training courses partly implemented in September–December 2020 and May 2021 (virtual part). Eighteen other activities were postponed to 2021 and the two-step approach has been extended to seven more activities. All face to face activities will then take place starting in the fourth quarter of 2021, subject to the end of travel restrictions.

## Role of Government and Key Organizations in Nuclear Power Programme Development



**1** Milestones Approach and Key Organizations Involved in Nuclear Power Programme Development



**2** Responsibilities and Functions of a Nuclear Energy Programme Implementing Organization



**3** Responsibilities and Capabilities of Owners and Operators



**4** Experiences of Member States in Building Regulatory Framework for the Oversight of New Nuclear Power Plants

## Governing New Nuclear Programmes: Newcomer Success Stories



**1** Newcomers Success Stories: UAE

12. During the COVID-19 lockdown, the Agency encouraged newcomer Member States to continue to use the interactive e-learning material to support understanding of the Milestones approach and various aspects of nuclear power infrastructure, to broaden awareness, and as an introduction to the ongoing Webinar Series on the Role of Government and Key Organizations in Nuclear Power Programme Development. 432 participants from 49 Member States attended the last two webinars of the four-part series, which were held in October 2020 and February 2021. Additionally, the Agency developed a new webinar series on Governing New Nuclear Programmes: Newcomer Success Stories, with the first webinar on the experience and lessons learned of the United Arab Emirates, held in April 2021 with 529 live participants from 72 Member States.

13. A Technical Meeting on Alternative Contracting Options for New Nuclear Power Plants was organized as a virtual meeting in October 2020, with 51 participants from 18 Member States, to discuss current approaches and trends on contracting, gather Member States' experience on the challenges in implementing their contractual and ownership approaches, and present the structure for a revised draft publication on the subject.

14. Additionally, within the framework of interregional nuclear infrastructure training courses, the Agency organized an online training course in cooperation with Électricité de France in September/October 2020, during which 21 participants from 15 Member States learned about economic and financing aspects to consider when developing a national position and reviewed lessons learned from countries that operate nuclear power plants. A course on nuclear power plant financing and risk allocation, organized in cooperation with Argonne National Laboratory in the United States of America in November 2020, which offered a training opportunity on financing of nuclear power plants to support decision makers and those responsible for developing and implementing a nuclear programme in Member States, considering the introduction of nuclear power, as well as those preparing to invite bids or negotiate a contract for a nuclear power plant. 26 participants from 15 Member States attended.

15. The development of an IAEA-TECDOC series publication on case studies on management systems and of revisions to three IAEA Nuclear Energy Series publications *Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes* (NG-T-3.11), *Milestones in the Development of a National Infrastructure for Nuclear Power* (NG-G-3.1 (Rev. 1)) and *Preparation of a Feasibility Study for New Nuclear Power Projects* (NG-T-3.3) were initiated in 2021.

16. The Agency conducted the virtual Technical Meeting on Case Studies for Developing a Comprehensive Report on Phase 1 of the IAEA's Milestones Approach (October 2020, with 27 participants from 17 Member States) and a Technical Meeting on Enhancing Safeguards Infrastructure to Support the Introduction of Nuclear Power (April 2021 with 76 participants from 29 Member States). The meeting participants also discussed the ongoing development of documents on the same topics.

17. The Agency reviewed and confirmed the applicability of the Milestones approach and of the conditions in *Evaluation of the Status of National Nuclear Infrastructure Development* (IAEA Nuclear Energy Series No. NG-T-3.2 (Rev. 1)), most recently during the Technical Meeting on the Application of the IAEA Integrated Nuclear Infrastructure Review Evaluation Methodology for Small Modular Reactors, which was organized as a virtual meeting in October 2020 with 51 nominations from 16 Member States and more than 65 persons connected during the four-day sessions.

18. The outcomes and guidance materials developed by the SMR Regulators' Forum and other Agency activities will be taken into account during the revision of the Milestones approach publication and further reflected in the INIR Evaluation Methodology.

19. Within the framework of the ongoing Peaceful Uses Initiative project on "Supporting the Development of Management Systems and Nuclear Safety Culture Programmes" the Agency continued to assist Member States embarking on new or expanding existing nuclear power programmes in the development of management systems by enhancing understanding and execution of leadership and responsibility for management systems to ensure safety, security, effectiveness and sustainability; and in establishing an adequate organizational culture in key organizations through the organization of capacity building workshops for senior management. Two virtual expert missions were conducted for senior managers of the owner/operators in Ghana in October 2020 and Poland in June 2021. Other planned reviews were postponed due to the outbreak of COVID-19. The Agency also participated as an observer in the World Association of Nuclear Operators' review mission of the integrated management systems of Turkey's Electricity Generation Company EÜAŞ.

20. The Technical Meeting on Case Studies on the Development of Management Systems in Countries Embarking on New Nuclear Power Programmes, related to a draft TECDOC of the same title under development, was held as a virtual meeting in May 2021 with 72 participants from 19 Member States. The meeting served as an opportunity for embarking Member States as well as those States participating actively in the Peaceful Uses Initiative project or in the development of the publication to share their experience and lessons learned on establishing management systems processes for the key organizations of a nuclear power programme.

21. The Agency updated its reactor technology assessment methodology by incorporating the lessons learned in seven years of its application with embarking countries, and expanded the methodology to advanced reactor technologies, including SMRs, and non-electric applications: a new Nuclear Energy Series publication on the methodology will be published in the fourth quarter of 2021.

22. The virtual Interregional Training Course on Nuclear Power Plant Contract Specifications and Reactor Technology Assessment (Part I) was conducted in November 2020 with 18 participants from 10 Member States. Another Interregional Training Course on Nuclear Power Plant Contract Specifications and Reactor Technology Assessment (Part II) is planned to be conducted in October 2021.



# Small and Medium Sized or Modular Reactors — Development and Deployment

## A. Background

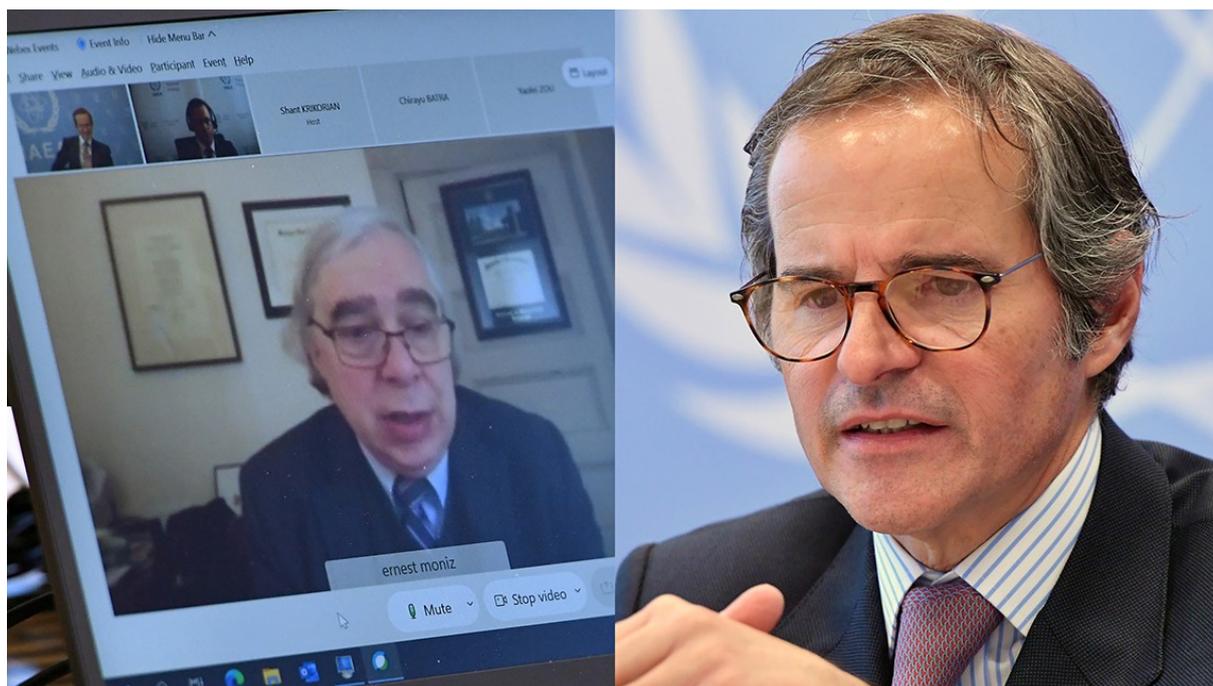
1. In resolution GC(64)/RES/12.B.8, the General Conference encouraged the Secretariat to continue consultations and interactions with interested Member States, the competent organizations of the United Nations system, financial institutions, regional development bodies, and other relevant organizations regarding advice on the development and deployment of SMRs. It also encouraged the Secretariat to continue working on defining indicators of safety performance, operability, maintainability, and constructability so as to assist countries in assessing advanced SMR technologies, and developing guidance for SMR technology implementation.

2. The General Conference called upon the Secretariat to continue to promote effective international exchange of information on options as regards SMRs available internationally and invited the Secretariat and Member States that are in a position to offer SMRs to foster international cooperation in undertaking studies of the social and economic impacts of SMR deployment in developing countries, their potential integration with renewables, and their non-electric applications.

3. The General Conference, in resolution GC(64)/RES/12.B.9, requested the Director General to report on the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its 65th regular session.

## B. Progress since the 64th Regular Session of the General Conference

4. In September 2020, the Agency published a new edition of *Advances in Small Modular Reactor Technology Developments*. The new booklet reports on advances in design and technology development of SMRs of all the major technology lines within the category of SMRs. It covers land based and marine based water cooled reactors, high temperature gas cooled reactors, heavy liquid metal, sodium and gas cooled fast neutron spectrum reactors, molten salt reactors, and the recently developed sub-category of micro modular reactors with electrical power typically up to 10 MW(e). For the first time, the booklet also provides some insights on associated fuel cycles and radioactive waste management of the SMR designs reported therein.



*FIG. B.1. Former United States Energy Secretary Ernest Moniz and IAEA Director General Rafael Mariano Grossi discussed opportunities and challenges of microreactors in a virtual dialogue.  
(Source: IAEA)*

5. In April 2021, the Agency held the Technical Meeting on the Status, Design Features, Technology Challenges and Deployment Models of Microreactors. The meeting was attended by 41 experts from 14 Member States and 2 international organizations. The meeting was followed by a high level dialogue where the Director General and Mr Ernest Moniz, Co-Chair and Chief Executive Officer (CEO) of the Nuclear Threat Initiative and CEO of the Energy Futures Initiative, discussed the potential role of microreactors, their challenges and opportunities, as well as the compatibility and integration of microreactors with other clean energy sources.

6. In April 2021, the Agency launched a new project aimed at addressing codes and standards, design engineering, testing and manufacturing of components of SMRs.

7. In August 2020, the Agency conducted the Third Research Coordination Meeting on Development of Approaches, Methodologies and Criteria for Determining the Technical Basis for Emergency Planning Zone for Small Modular Reactor Deployment. The meeting concluded that the methodologies proposed by many designers and sometimes already accepted by the regulators for SMRs may be substantially different from the methodology currently published by the Agency on large nuclear power plants. One aspect that differs is the use of cut-off probabilities to exclude from the methodology very low frequency events. Others use the concept of risk to set a figure of merit to establish the size of the emergency planning zone. It is generally accepted that a graded approach may be applied to SMRs.

8. A virtual Technical Meeting on Generic User Requirements and Criteria of Small Modular Reactor Technologies for Near Term Deployment was held in May 2021. This activity is being carried out in the framework of the Peaceful Uses Initiative project entitled “Small Modular Reactors Deployment and their Applications for Embarking Countries”.

# Nuclear Knowledge Management

## A. Background

1. In resolution GC(62)/RES/9.C, the General Conference commended the Director General and the Secretariat for their significant, interdepartmental efforts in addressing issues of preservation and enhancement of nuclear knowledge, and encouraged the Director General and the Secretariat to continue to strengthen their 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 managing nuclear knowledge.

2. The General Conference requested the Secretariat to continue to gather, and make available to Member States, nuclear data, information and knowledge resources on the peaceful use of nuclear energy, including the International Nuclear Information System (INIS) and other valuable databases as well as the IAEA Library and the International Nuclear Library Network. The General Conference also called on the Secretariat to continue to focus, in particular, on activities aimed at helping interested Member States assess their human resource needs and to identify ways to address those needs, inter alia by encouraging the development of new tools and opportunities to gain practical experience through fellowships.

3. The General Conference also invited the Secretariat, in consultation with Member States, to further develop and disseminate guidance and methodologies for planning, designing, implementing, and evaluating nuclear knowledge management programmes and practices. It also encouraged the Secretariat to continue to facilitate the establishment of effective human resource and knowledge management networks in developing countries, and where appropriate in collaboration with other United Nations organizations and with the support of existing such networks in developed countries.

4. The General Conference requested the Director General to take into account the continuing high level of interest of Member States in the range of issues associated with nuclear knowledge management when preparing and carrying out the Agency's programme.

5. Furthermore, in resolution GC(64)/RES/12.C the General Conference requested the Director General to report on progress in the implementation of resolution GC(62)/RES/9.C to the Board of Governors and to the General Conference at its 65th regular session. This Annex has been prepared in response to that request.

## B. Strengthening Nuclear Knowledge Management

6. The annual meeting of the Technical Working Group on Nuclear Knowledge Management (TWG-NKM) was held virtually in May 2021. A total of 23 participants (7 women) from 14 Member States and 4 independent observers attended the meeting. The meeting provided discussions on activities delivered by the Agency in the period 2019–2021 and generated advice and guidance on future

programmatic activities. Out of the fourteen TWG-NKM members present at the meeting, three were attending a TWG-NKM meeting for the first time.

7. The International Conference on Nuclear Knowledge Management and Human Resource Development: Challenges and Opportunities has been re-arranged to take place in Moscow from 13 to 16 June 2022. This conference was originally scheduled to be held in Moscow in June 2020 but was postponed due to the COVID-19 pandemic. The purpose of the event is to review global developments relating to human resource development and nuclear knowledge management, consider the current and future challenges and opportunities, and provide participants with practical solutions that they can use at organizational, national, and international levels to develop and maintain the human resources needed to support safe and sustainable nuclear power programmes.

8. In efforts to promote nuclear leadership, management systems, and quality assurance and control for the nuclear industry and the whole life cycle of facilities and activities, the Agency-facilitated International Nuclear Management Academy (INMA) MSc programme has been developed at the request of Member States to help nuclear graduates prepare better for nuclear leadership and management roles. Three virtual INMA missions were completed during the reporting period at the Budapest University of Technology and Economics in July 2020, and in March 2021 at the Sofia University “St Kliment Ohridski” and at the University of West Bohemia.

9. Phase 1 of the new NKM Hub went live in November 2020 on the IAEA CONNECT platform. The digital platform offers easy access for Member States to the latest information on NKM guidance and services to support Member States with operating nuclear facilities and those considering or developing new nuclear programmes. The hub brings together professionals and experts from the Secretariat and Member States to facilitate the sharing of information and capacity building while offering a centralized one-stop-shop access to key NKM areas and resources.

10. During the reporting period, the following new publications were released: *Application of Plant Information Models to Manage Design Knowledge through the Nuclear Power Plant Life Cycle* (IAEA-TECDOC-1919); *International Nuclear Management Academy Master’s Programmes in Nuclear Technology Management* (IAEA Nuclear Energy Series No. NG-T-6.12); *Mapping Organizational Competencies in Nuclear Organizations* (IAEA Nuclear Energy Series No. NG-T-6.14); and *Exploring Semantic Technologies and Their Application to Nuclear Knowledge Management* (IAEA Nuclear Energy Series No. NG-T-6.15).

11. During the reporting period, the Agency conducted the following virtual events: in July 2020, a Technical Meeting on Mentoring and Coaching Practices for Nuclear Knowledge Management with 16 participants from 11 Member States and two international organizations (9 women); in September/October 2020, a Technical Meeting to Develop Guidance on a Methodology for Defining Key Performance Indicators for Knowledge Management in Nuclear Organizations with an average number of 28 participants each day; in October 2020, Training Activities on Nuclear Knowledge Management for Educational Networks bringing together regional and national educational networks with 40 participants from 31 Member States and 4 international organizations (16 women); in November 2020, a Training Workshop on the Methodology for the IAEA Knowledge Management Maturity Assessment Tool with 25 participants from 22 Member States (9 women) and the Annual Technical Meeting of the International Nuclear Management Academy with 34 participants from 19 Member States (7 women); in December 2020, the Annual Meeting of the Nuclear Energy Management School Coordinators and Organizers with 18 participants from 9 Member States and 1 international organization (5 women); and in April 2021, a Technical Meeting on the Preparation of Country Reports for Status and Trends in Nuclear Education with 40 participants from 34 Member States (11 women).

## C. Implementing Nuclear Knowledge Management and Building Capacity

12. Due to the COVID-19 pandemic travel restrictions, it was not possible to hold any in-person Nuclear Energy Management (NEM) or NKM Schools in Member States. However, the Agency adjusted and delivered 25 webinar on NKM from September to December 2020. In total there were 1679 attendees from 70 Member States. All the webinars were recorded and are available via the NKM Hub for future viewing by Member States. Webinars were split into 5 topics: NKM methodologies and processes, NKM School lectures, Knowledge Management Assist Visits (KMAVs), global collaboration for sustainable nuclear education networks, and new publications to support NKM programmes in Member States.

13. Moreover, due to travel restrictions, the annual Joint ICTP–IAEA NEM and NKM Schools were hosted virtually by the Agency. The 16th Joint ICTP–IAEA Nuclear Knowledge Management School Webinar Series was conducted in cooperation with the Abdus Salam International Centre for Theoretical Physics (ICTP) in May 2021. The webinar series attracted 157 participants from 59 Member States. The 11th Joint ICTP–IAEA Nuclear Energy Management School Webinar Series was conducted in cooperation with the ICTP in May/June 2021. The webinar series attracted 249 participants from 60 Member States. For both webinar series, recorded lectures of each module were shared on a daily basis to participants and an open forum to provide questions was available to participants for 24 hours. In addition, live chat sessions were established each day and a two-hour panel discussion with six panellists took place on the last day.

14. The Joint ICTP–IAEA School on FPGA-based SoC - Field Programmable Gate Arrays (FPGA)-based Systems-On-Chip (SoC) and its Applications for Nuclear and Related Instrumentation was held in January/February 2021 and was attended by 25 participants from 20 Member States. The design tools and hardware platforms were installed on the ICTP computers in Trieste, Italy, and on the Nuclear Science and Instrumentation Laboratory computers in Seibersdorf, Austria. The participants could log in remotely to the computers at both sites and perform laboratory exercises individually according to written instructions.

15. The Joint ICTP–IAEA School on Citizen Science with Application to Nuclear, Seismic and Air Quality Monitoring took place in March 2021. The virtual event focused on how to balance low cost scientific tools and academic rigour in their usage/application to nuclear, seismic and air quality monitoring and was attended by 92 participants (30 women), from 46 Member States.

16. During the reporting period, the Agency delivered eleven virtual KMAV missions as follows: in September 2020, a Level 1 KMAV workshop on knowledge management for Viet Nam with 15 participants from 3 Member States (6 women) and 3 organizations; in October 2020, a Level 1 KMAV workshop on knowledge management for Uzbekistan with 15 participants (3 women) and 9 organizations; and, a Level 2 KMAV mission for Hungary with 30 participants from 4 Member States (9 women); in November 2020, a Level 1 KMAV workshop on the practices of nuclear knowledge management and human resources development for Chile with 11 participants (2 women); in December 2020, a Level 1 KMAV workshop for Romania with 16 participants (4 women) and 4 organizations; in April 2021, a Level 1 KMAV workshop for Brazil with 20 participants (10 women); and, a Level 1 KMAV pre-SALTO workshop for Mexico with 11 participants (4 women) and 2 organizations; in May 2021, a Level 1 KMAV workshop for Jordan with 30 participants from 4 Member States (10 women) and 4 organizations; in June 2021, a Level 1 KMAV workshop for Indonesia with 143 participants (51 women) from 3 national organizations; and, a Level 1 KMAV workshop for Sudan with 25 participants

from 4 national organisations (10 women) and 4 organizations; and in July 2021, a Level 2 KMAV mission in Armenia with the Armenian national nuclear authorities.

17. A virtual Workshop on National Human Resource and Knowledge Development Networks took place in November 2020 with 17 participants from 3 Member States (Indonesia, Japan and Turkey). Agency experts presented an overview of human resource and knowledge development projects and case studies, while Indonesian participants shared the current status of human resource and knowledge development in Indonesia. The workshop laid the groundwork for the effective implementation of an expert mission planned for 2021/2022.

18. The Agency held one virtual workshop and one hybrid support mission on knowledge management and the human resource aspects of long term operation for Koeberg NPP, South Africa, in July and September 2020, respectively.

## **D. Applying Nuclear Knowledge Management to Development**

19. Human resource development is a priority in the Africa region and, in 2020, efforts continued to provide training to skilled mid-level personnel such as engineers and technicians through short- and long-term academic training to build capacities and ensure the availability of skilled staff in African Member States. Under regional project RAF0052, “Supporting Human Resource Development in Nuclear Science and Technology (AFRA)”, 36 candidates from 28 Member States (of which 13 are least developed countries) were provided with support through a sandwich programme to carry out their PhD research work in foreign universities.

20. Building, collecting, maintaining, sharing, preserving and utilizing knowledge is important for Member States in the Asia and the Pacific region, particularly gaining the necessary technical expertise and competencies required for nuclear power programmes and the application of other nuclear technologies. Throughout 2020, the technical cooperation (TC) programme in Asia and the Pacific continued to collaborate with Member States to maintain and preserve nuclear knowledge institutional memory by establishing platforms for Member States to exchange knowledge, promote nuclear science and foster interest in nuclear science and technology, including among secondary and tertiary education students. A webinar on the future of nuclear energy was arranged under TC project SIN0003, “Building Capacity in Nuclear Power Technology and Safety”, in November 2020, hosted by the Singapore Nuclear Research and Safety Initiative. Aimed at an audience unfamiliar with nuclear energy including university students, academia, industry and government, over 150 participants attended the webinar, which discussed the prospects of nuclear power in addressing global energy needs and addressing the threat of climate change and reducing global carbon emissions.

21. In Europe, efforts continued to support the education and training of professionals in nuclear science and technology at various stages in their careers. Nuclear power plays an important role in the region with eleven Member States operating NPPs and four considered as NPP newcomers. Non NPP Member States also make various uses of nuclear applications. Nuclear knowledge development is a priority for the Czech Republic, given an increasing demand for nuclear personnel. Under the national project CZR0009, “Strengthening Human Resources Capacity, Nuclear Knowledge, Skills Preservation, Supplementary Enlargement of Knowledge and Expertise in Relevant Fields of the Peaceful Use of Nuclear Energy”, training is provided to ensure the safe, sustainable and reliable operation of institutions and services in the nuclear field. In Romania, construction of a near surface repository is planned within the Cernavodă nuclear power plant exclusion zone, with the first phase of the new repository to be built

and licensed for waste disposal around 2026. In 2020, a mission to gain an understanding of the national nuclear knowledge management programme, as well as the readiness and status of human resource development strategies and processes for knowledge management, was conducted under ROM9038, ‘Improving the Capacity for Long Term Safe Management of Radioactive Waste and Spent Nuclear Fuel’.



*FIG. D.1. Young nuclear professionals and trainees visit Brazil’s Nuclear and Energy Research Institute (IPEN) to study the services it regularly helps to provide to users around the country, and throughout the region. (Photo: IPEN)*

22. Efforts to promote the education and training of young professionals in the field of nuclear science and technology continue in the Latin America and the Caribbean region. In the framework of regional project RLA0057, “Enhancing Nuclear Education, Training, Outreach and Knowledge Management”, the Latin American Network for Education in Nuclear Technology (LANENT) has developed a multimedia educational programme, NUCLEANDO, that equips both primary and secondary school teachers with pedagogic tools and resources, allowing them to introduce nuclear and isotopic sciences into their curricula in an engaging and innovative manner, and to clearly demonstrate the benefits of the peaceful application of nuclear technology to younger generations. The NUCLEANDO programme was first introduced as a pilot course in July 2019, and in 2020, it was brought to 150 teachers from Chile, Colombia, Mexico and Uruguay, reaching more than 5000 students in one year. Moreover, the Agency worked with Argonne National Laboratory to deliver a six-week online training course on strategic communication for nuclear facilities in Latin America and the Caribbean. The course was attended by managers and heads of nuclear installations from 19 countries in the region, and organized in the framework of regional project RLA0069, “Promoting Strategic Management and Innovation at National Nuclear Institutions through Cooperation and Partnership Building — Phase II (ARCAL CLXXII)”. The training course enabled national nuclear institutions to engage with key stakeholders more effectively, using purposeful messages that educate and address the priorities of targeted audiences.



*FIG. D.2. Nearly 300 students, young professionals and government delegates from 43 countries attended the 11th edition of the International Youth Nuclear Congress, 12 of whom were sponsored through the TC programme. (Photo: IYNC)*

23. Also, under RLA0069, the Agency launched a three-month training course in November to strengthen the capacities of future leaders of national nuclear institutions in strategic planning and management. Course topics include stakeholder analysis; threat analysis; action planning and reviewing; facility operations and management; organizational structure and personnel development; finance; marketing; and change management. The 21 course participants received a certificate upon successful presentation of case studies relevant to their respective fields.



*FIG. D.3 Primary and secondary school teachers in Uruguay test some of NUCLEANDO's interactive components during an IAEA training course. (Photo: CNEA)*

24. Furthermore, several virtual activities were carried out in 2020 under regional project RAS0080, “Promoting Self-Reliance and Sustainability of National Nuclear Institutions”, including a regional training course entitled “Financial/Economic Feasibility Study of Radiation Technology Projects”. This provided over 20 participants from 10 countries with ‘hands-on’ training on the use of the United Nations Industrial Development Organization’s Computer Model for Feasibility Analysis and Reporting software and the Agency’s Extended Input Output Model for Nuclear Power Plant Impact Assessment software for macroeconomic impact assessments of radiation technology projects. Two feasibility study prototypes, on gamma irradiators for industrial applications and on accelerators for radiopharmaceutical productions, were developed under the project. Another regional training workshop with 15 participants from 12 countries was organized to discuss the Milestones approach that is being prepared for the development and establishment of irradiation facilities.

## **E. Applying Nuclear Knowledge Management to Nuclear Safety, Security and Safeguards**

25. The Nuclear Safety and Security Online User Interface provides users with easy access to the content of Agency publications on nuclear safety and security, namely IAEA Safety Standards and Nuclear Security Series publications. It facilitates direct access to the content of the publications and

navigation between them. Its user interface includes functionality that enables authorized users to provide feedback on the publications.

26. During the reporting period, the Agency adapted the curriculum of the International School on Nuclear Security to a virtual format. Two International Schools on Nuclear Security were held virtually: in Russian, in September 2020 and May–June 2021, and in English in April 2021. In addition, the Joint ICTP–IAEA International School on Nuclear Security celebrated its tenth anniversary. Since the initiation of the first Joint International School, it has benefited around 500 young professionals from around the world.

27. The Agency held a virtual Regional Workshop on Policies and Strategies for Nuclear Safety Capacity Building in December 2020 to support Arab Member States in their efforts to establish and maintain nuclear safety capacity building programmes, including education and training, human resources development, knowledge management and knowledge networks.

28. The Agency’s Steering Committee on Education and Training in Radiation, Transport and Waste Safety met virtually in November–December 2020 to advise the Agency on the implementation of its Strategic Approach to Education and Training in Radiation, Transport and Waste Safety 2011–2020, and on the status of the establishment of national strategies in this area. Also, the Agency’s Steering Committee on Regulatory Capacity Building and Knowledge Management met virtually in December 2020 to exchange information on the current activities of the Agency in managing, developing and strengthening regulatory competence.

29. In 2020, the Agency launched the IAEA Comprehensive Capacity-Building Initiative for State Systems of Accounting for and Control of Nuclear Material (SSACs) and State or Regional Authorities Responsible for Safeguards Implementation (SRAs) (COMPASS). COMPASS is designed to further support States in their efforts to strengthen and sustain the effectiveness of their SRA responsible for safeguards implementation and of their respective SSAC.

30. Through its Safeguards Traineeship Programme for young graduates and junior professionals, the Agency provides knowledge and technical skills to young trainees in implementing safeguards. In 2020, six trainees participated in the Programme and completed it successfully.

31. The Agency continued to expand its State Declarations Portal (SDP), a web-based system that supports secure and swift communication exchanges between the Agency and SRAs. Through the SDP, SRAs can provide the Agency with a wide variety of submissions, as well as receive feedback communications from the Agency. To increase institutional memory, the SDP also offers a log of the historical communication exchanges between the Agency and SRAs.

## **F. Strengthening Networks Related to Nuclear Education and Training**

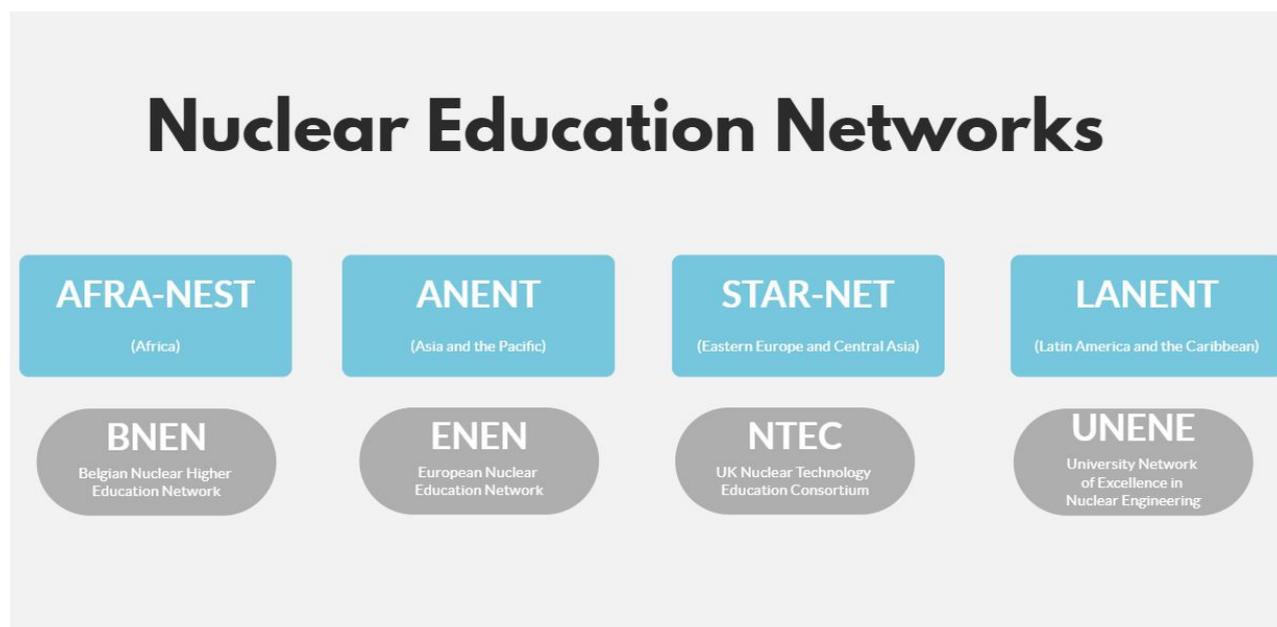
32. The Agency provides support to the AFRA Network for Education in Science and Technology (AFRA-NEST) through TC project RAF0059. The results of the first survey conducted for AFRA-NEST were published in 2021. The survey aimed to evaluate the current situation as well as specific needs and requirements of providing e-learning materials and platforms, and to further understand people’s experiences with e-learning, their preferences concerning topics, platform features, and learning habits.

33. Regular virtual cooperation meetings were also held with regional networks, such as the Association of Southeast Asian Nations and the African Commission on Nuclear Energy (AFCONE), and the Agency further participated in two AFCONE webinars entitled “Safe and Secure Development of Nuclear Power Programs in Africa: Development of Clean Energy, Mitigation of Climate Change Impact and Set Up of Appropriate Regulatory Framework” held on 10 December 2020, and “Capacity Building for Safe and Secure Development in Africa of Peaceful Uses of Nuclear Energy, including Nuclear Power” held on 31 March 2021.

34. Under TC project RAS0075, “Networking for Nuclear Education, Training, and Outreach Programmes in Nuclear Science and Technology in the Framework of ANENT (Asian Network for Education in Nuclear Technology)”, a web portal has been developed consisting of a learning management system and a learning object repository. The portal’s resources help in capacity building and human resource development in the Asia and the Pacific region, particularly for developing countries and countries with limited access to high-quality educational resources in nuclear science and technology. A webinar on ANENT and its platforms for web based learning and nuclear knowledge sharing was held in April 2021. Monthly teleconference meetings of ANENT were conducted with the aim of increasing the educational resources for the network and its utilization.

35. The Agency provides support to LANENT through project RLA0065 “Furthering Knowledge Management Implementation in Nuclear Organizations and Strengthening Nuclear Education”. The project has made an essential contribution to preserving, promoting and sharing nuclear knowledge, as well as fostering nuclear knowledge transfer in the Latin America region in areas such as education, health, industry, agriculture, government, the environment and mining. LANENT also seeks to communicate the benefits of nuclear technology to the public, with the aim of stimulating interest in nuclear technology in younger generations. In October 2020, representatives from LANENT joined representatives from other regional educational networks in a virtual meeting in order to share best practices and enhance interregional cooperation.

36. A dedicated NUCLEANDO website has been created, and related events took place virtually in August 2020 in Chile, in November 2020 in Colombia, and in December 2020 in Mexico, with the aim of encouraging the engagement of 250 000 young students in nuclear science and technology by 2021.



*FIG. F.1. The IAEA promotes partnerships among nuclear education and training institutions across the globe. It has directly fostered regional educational networks in Africa, Asia, Eastern Europe and Central Asia, and in Latin America and the Caribbean.*

37. On 21 February 2021, the Collaboration Agreement that has been standing among Regional Networks since 2013 was renewed and extended to National Networks. Networks signatory of the agreement are as follows:

- Regional Networks: AFRA-NEST, ANENT, LANENT, the European Nuclear Education Network Association and the Regional Network for Education and Training in Nuclear Technology.
- National Networks: the Belgian Nuclear Higher Education Network (BNEN), the Nuclear Technology Education Consortium (NTEC) and the University Network of Excellence in Nuclear Engineering (UNENE).

38. The objective of the Collaboration Agreement is to sustain a framework of collaboration between Regional and National Networks in nuclear education, training and related research and outreach. Building on their respective strengths and achievements, signatory networks will further their collaborative efforts towards common objectives and activities of mutual interest in three main areas: human resource development, outreach and educational tools, and technology.

39. The International Nuclear Security Education Network (INSEN) annual meeting, marking its tenth anniversary, was held virtually in July 2020. The 2021 INSEN Leadership Meeting was held virtually in March 2021, discussing INSEN's ongoing activities and the impact of COVID-19 on nuclear security education. The INSEN secretariat also conducted an education impact assessment survey during the reporting period.

40. The International Network for Nuclear Security Training and Support Centres (NSSC Network) facilitates sharing of information and resources to promote coordination and collaboration among States with an NSSC or those having an interest in developing such a centre. A webinar was held in September 2020 on the recently published Agency publication *Establishing and Operating a National Nuclear Security Support Centre*. The 2021 Annual Meeting of the NSSC Network was convened virtually in

April 2021. The Agency continued to work with the NSSC Network to implement a systematic and structured plan of activities to support the Network's members.

41. The IAEA CONNECT platform is an easy-to-use online environment to facilitate the sharing of information and capacity building while offering a centralized resource hub in topical areas. Serving more than 6300 members on over 20 topical networks, the IAEA CONNECT platform has established itself as the place to bring together professionals and experts from the Secretariat and Member States. In addition to new collaboration sites to facilitate Technical Meetings and Technical Working Groups, a new external network was launched in a joint agreement with the World Nuclear University.

42. During 2020–2021, IAEA CONNECT added five new networks, including the Nuclear Knowledge Management Hub. The IAEA CONNECT platform is currently undergoing upgrades to the underlying technology and a redesign to improve usability. Enhancements in recent years to IAEA CONNECT include a new “Nuclear Wiki”, which has been launched on IAEA CONNECT members sites, containing technical articles developed and maintained by the Secretariat with the support of international experts. The addition of case studies provided by and available to network members provides opportunities for professionals practicing in Member States to share and exchange practical information on finished and ongoing projects in their respective subject matter areas, with the goal of providing practical technical advice and lessons learned. Access to case studies is currently reserved for authorized members of the IAEA CONNECT platform to encourage information exchange between Member States and professionals working in relevant fields.

43. As a fundamental element of the Agency's strategic approaches to education and training, the Cyber Learning Platform for Network Education and Training (CLP4NET) experienced significant growth during this reporting period as the Agency's standard delivery mechanism for e-learning. By the end of April 2021, registered users to CLP4NET increased to over 45 500, and the number of courses increased to 676 (compared to the last reported figure of 400). In addition to e-learning courses, the Agency has started to offer webinars through CLP4NET. As of now, 30 webinars have been made available on CLP4NET with many more expected in the coming years. A new Agency e-learning governance framework to improve quality and optimize resources while developing e-learning materials and products and control the lifecycle of those outputs is close to completion. A learning resources catalogue will soon be made available on the Agency's website, which should serve to increase the visibility and accessibility of the e-learning offerings available to Member States.

44. In order to ensure that Member States have continuous access to basic safeguards knowledge, the Agency's updated CLP4NET is now used as the primary learning management system for all Agency safeguards training aimed at Member States. During the reporting period, the Agency developed new safeguards e-learning courses for Member States, including a “Basics of Safeguards” course in safeguards implementation as well as several modules on nuclear material accounting.

## **G. Nuclear Information**

45. The International Nuclear Information System (INIS) continues to be maintained and expanded as a repository of information on the peaceful uses of nuclear energy. Over 100 000 high-quality metadata records are acquired every year — reaching a total number of nearly 4.5 million. The information is indexed and made freely available to Member States through the INIS Repository, which reaches over 1.7 million users every year. Major improvements in technical capacity included substantial enhancement to the front end of the INIS Repository search, as well as increasing usage of automation

including artificial intelligence. The INIS Thesaurus, a ‘knowledge organization system’ containing over 31 000 descriptors, has been further enriched with new relevant terms, taking into account input from Member States and the INIS Thesaurus Advisory Group. INIS embarked on special preservation projects, including those related to Chernobyl, the High Temperature Materials Laboratory at the Jülich Research Centre in Germany, and the Contact Expert Group for International Nuclear Legacy Initiatives in the Russian Federation. INIS expanded its promotion, education and capacity building activities by conducting a continuing series of webinars targeting specific Member States.



46. The IAEA Library continued to provide access to nuclear information by connecting users to all available information resources, in both print (90 000+ items) and electronic formats (81 000+ electronic journal titles and 68 databases). The IAEA Library selected over 13 500 new and relevant items to add to the collection. The library held 21 training sessions in 2020, reaching a total of 192 participants in-person and virtually. The International Nuclear Library Network (INLN) membership increased to 62 members from 42 Member States who are able to communicate directly and efficiently through the INLN Forum on NUCLEUS.



*FIG. G.1. Director General's visit to the IAEA Library on the occasion of the celebration of the World Book and Copyright Day 2021. (Source: IAEA)*

47. Since the reinstatement of the Memorandum of Agreement between the IAEA and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) for the distribution of OECD/NEA Data Bank nuclear computer codes and processed nuclear data libraries to eligible IAEA Member States, 27 OECD/NEA Data Bank liaison officers were delegated to 29 IAEA institutions in 14 IAEA Member States, while 20 code requests were received and processed. The following countries have directly benefited from the resumed service: Austria, Belarus, Brazil, China, Croatia, Egypt, Jordan, Qatar, South Africa, Ukraine and Yemen.





**IAEA**

International Atomic Energy Agency

*Atoms for Peace and Development*

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