Chapter 3. **Country reports**

Australia

As the newest member, Australia is an active and enthusiastic member of the Generation IV International Forum (GIF) and continues to increase its engagement with the activities of the Forum. Australia remains committed to undertaking research and development into the next generation of nuclear reactor technologies to advance the peaceful use of the atom.

Within GIF, this includes ongoing contributions to the VHTR System Steering Committee. Australia's contributions to the VHTR Materials Project Arrangement have now been included in the Materials Project Plan, and the signature of the Project Arrangement is in due course.

Similarly, as an active participant in the MSR provisional System Steering Committee, Australia supports the goal of this group to advance to a System Arrangement, and takes the lead on the MSR Materials and Components Project Arrangement.

Turning to other nuclear news, Australia's new nuclear medicine production facility, ANM, is fully operational. On 24 May 2019, ARPANSA, Australia's nuclear regulator, amended its initial conditional hot commissioning licence to allow ANSTO to commence routine production of molybdenum-99 in the ANM facility for both Australian and International markets.

In parallel, construction has started on ANSTO's SyMo nuclear waste plant that will treat the liquid intermediate waste from the ANM facility using ANSTO Synroc technology. The plant will be the first full-scale implementation of Australia's innovative Synroc technology and is expected to be completed by 2021.

The project to select a site for, and establish, the National Radioactive Waste Management Facility (NRWMF) continues, with further detailed site characterization and community consultation. Two sites have been nominated in South Australia, two in the district of Kimba and one in the district of Hawker. Community engagement is ongoing, with consultative committees established and operating in both areas. Unfortunately, community votes in both districts have been delayed by legal action. The facility will be located only where it is broadly supported. The NRWMF will receive Australia's low-level waste for disposal and will temporarily store Australia's intermediate level waste pending the establishment of a separate ILW disposal facility.

Second 2019 semester, there has been increased governmental interest in the potential role of both uranium mining and nuclear energy in Australia. Within the Federal Government, on 2 August 2019, the Hon. Angus Taylor MP, Minister for Energy and Emissions Reduction, established a Parliamentary inquiry into the prerequisites for nuclear energy in Australia. The inquiry is being conducted by the House of Representatives Standing Committee on the Environment and Energy. The Terms of Reference for the inquiry require that members of the Committee specifically investigate, and report on, the circumstances and prerequisites for any future Australian government's consideration of nuclear energy generation, including small modular reactor technologies. The Committee is expected to report by the end of the 2019 year. A separate examination of the nuclear industry in Australia was conducted by the House of Representatives Standing Committee on Industry, Innovation, Science and Resources in Sept. 2019. There has been similar activity within the State Parliaments of New South Wales and Victoria.

On 6 June 2019, the New South Wales Legislative Council's Standing Committee on State Development established an inquiry to consider a bill to repeal the State's ban on uranium mining and the establishment of nuclear facilities. It is anticipated that this inquiry will conclude in 2020.

On 19 August 2019, the Victorian Legislative Council voted to establish an inquiry to examine the merits in lifting that State's ban on nuclear power, with reference to the benefits of nuclear power in mitigating climate change. The 12-month inquiry will investigate whether nuclear power is feasible and suitable for Victoria in the future, and will consider waste management, health and safety issues, and possible industrial and medical applications.

ANSTO plays a vital role in providing expertise and technical advice to government on all matters related to nuclear science and nuclear technology, including nuclear power. In this capacity, ANSTO was asked and has provided, technical advice related to nuclear power and other fuel cycle activities to both the Federal and State-level inquiries.

Australia will host the Policy and Expert Group meetings in Sydney (May 2020). That means Australia will have hosted every GIF committee on which it have representation since joining in late 2017.

Canada

Nuclear Energy in Canada: There are currently 18 operational nuclear power reactors in Canada and one unit undergoing refurbishment. Today, 15% of Canada's electricity comes from nuclear. In the Province of Ontario, home of 18 of Canada's reactors, approximately 60% of the province's electricity comes from nuclear. The Province of New Brunswick, home of the other operational reactor, approximately 35% of its electricity comes from nuclear.

On 21 October 2019, Canada will hold its federal election. In this context, Canada's non-partisan public service is getting ready to brief new ministers.

Refurbishments in Canada: Refurbishments are the number one priority for Canada's nuclear sector. Ontario Power Generation (OPG) – the largest nuclear operator in Canada – is investing CAD 13 billion dollars in the refurbishment of the Darlington nuclear generating station. The project is progressing ahead of time and presently below budget. The first unit was taken offline in October 2016 for refurbishment, and will be reconnected to the grid in 2020.

Canada's subnational government of Ontario has given OPG permission to proceed with refurbishment of the next unit because of the progress being made one the first unit at Darlington.

At the same time, Bruce Power – operator of the largest operational nuclear station in the world – is proceeding with its plans to refurbish their remaining six units at the Bruce Generating Station, with the first unit due to come off line early in 2020.

Small modular reactors (SMRs): Canada's SMR Roadmap was released in November 2018 and can be found https://smrroadmap.ca. In brief, the development of the Roadmap took a national approach over a ten-month period with extensive engagement with industry, initial dialogues with Indigenous peoples, and expert analysis. The process was driven by four provincial and two territorial governments and interested utilities.

There were six workshops held across Canada involving 55 organizations and over 180 participants. This included three Indigenous engagement sessions, with a commitment to continuing the conversation.

Supporting the development of the Roadmap, five expert working groups were established and supported by 18 organizations. These working groups were focused on: 1) Technology assessments; 2) Regulatory readiness; 3) Waste management regime; 4) Economics and finance; 5) Public and indigenous engagement. Each working group developed a report that feed into the Roadmap. These reports are available to the public and can be found online on the above-mentioned SMR site.

Multiple tracks are being pursued to advance small modular reactors (SMRs) development in Canada, notably, 11 SMR vendors have engaged the CNSC under the optional pre-licensing Vendor Design Review Process, and more than 5 SMR vendors are involved in CNL's "Invitation for SMR Demonstration Projects". Canada's nuclear operators (Ontario Power Generation, NB Power, Bruce Power) are also in various stages of engagement with vendors, ranging from technical advisory boards to commercial partners.

In July 2019, the Canadian Nuclear Safety Commission (CNSC) commenced the environmental assessment (EA) of Global First Power's project proposal, in collaboration with Ultra Safe Nuclear Corp. (USNC) and Ontario Power Generation (OPG), for the demonstration of a Micro Modular Reactor at Chalk River, Ontario. The proposed project includes the site preparation, construction, operation, and decommissioning of a single 15 MWth Micro Modular Reactor (MMR) with an expected 20-year core life at Chalk River Laboratories.

On 1 October 2019, Advanced Reactor Concepts (ARC) Nuclear Canada completed the first phase of CNSC's Vendor Design Review (VDR) and will now move to the second phase of the process. The second phase will involve a more detailed review of the reactor concept and will take between 18 to 24 months. To date, three SMR vendors have moved to the second phase of CNSC's VDR process: ARC, Terrestrial Energy and Global First.

Regulatory update: Eleven vendors have engaged with the Canadian Nuclear Safety Commission (CNSC), Canada's nuclear regulator, on their Vendor Design Review process – with the latest application received in March 2019.

In addition, on March 20, Global First Power submitted an application for a license to prepare site for an SMR on Atomic Energy of Canada Limited's land at Chalk River Laboratories. This is the first step in the formal licensing process. The next step would be for the CNSC to issue a notice of commencement, after which the project description would be made available for public comment as part of an environmental assessment process

At the same time, Canada's experienced nuclear operators are working with SMR vendors to vet potential demonstration projects. The Province of New Brunswick, which is open to hosting a demonstration project, has launched a nuclear research cluster with two SMR vendors, ARC Nuclear and Moltex Energy Canada. OPG has recently started a process to extend a site license that it has available now to host new nuclear reactor projects at its Darlington site.

In May 2019, the Province of Saskatchewan announced that it is considering SMRs as a replacement for its coal-fired generation fleet.

Canada's new Impact Assessment Act came into force on 28 August 2019, overhauling the federal environmental assessment system to better protect the environment, respect Indigenous rights and rebuild public trust in how project decisions are made. The new legislation includes a new impact assessment process and a revised list of activities that will trigger an impact assessment. Key features of the new system include:

- Proactive strategic and regional assessments would evaluate big-picture issues (e.g. climate change, biodiversity, species at risk), the cumulative effects of development and provide context for impact assessments;
- An early planning and engagement phase for all projects would build trust, increase efficiency, improve project design, and give companies certainty about the next steps in the review process;
- Indigenous engagement and partnership throughout the process;
- Increased public participation opportunities;
- Legislated timelines to provide clarity and regulatory certainty; and
- Strengthened monitoring, follow-up, and enforcement.

New nuclear reactor projects will be a designated project and trigger an impact assessment if:

- that activity is located within the licensed boundaries of an existing Class IA nuclear facility and the new reactors have a combined thermal capacity of more than 900 MWth; or;
- that activity is not located within the licensed boundaries of an existing Class IA nuclear facility and the new reactors have a combined thermal capacity of more than 200 MWth.

Previously all nuclear reactors would have been designated projects, regardless of size and location. A new project involving a nuclear reactor not designated a project and does not trigger the new impact assessment process is still subject to the existing environmental assessment process.

Canadian Nuclear Laboratories: Five SMR vendors are participating in Canadian Nuclear Laboratories' process to site SMR demonstration projects at CNL sites. In February 2019, CNL announced that two vendors, Starcore Nuclear and Terrestrial Energy, have been invited to advance to the second stage of their four stage process. The second stage has greater focus on due diligence of their technical and economic merits, financial viability, and safety and security requirements.

Meanwhile, Global First Power and its key partners, OPG and Ultra-Safe Nuclear Corporation, have progressed through CNL's second stage and have been invited to participate in preliminary, non-exclusive discussions on siting with CNL.

GIF update: In May, NRCan endorsed Terrestrial Energy's signing of the Memorandum of Understanding for Collaboration on the Molten Salt Reactor System. In addition, NRCan is supporting CNL's participation as an observer in the MSR provisional System Steering Committee as well the Very-High-Temperature Reactor System Steering Committee.

Moltex Energy Canada is seeking observer status for GIF's Molten Salt Reactor system. Canada is supportive of the request. As such, Moltex Energy Canada's participated in the recent Molten Salt Provisional Steering Committee Meeting.

Canada has renewed its participation in the Supercritical Water-Cooled Reactor Thermal-Hydraulics and Safety Project Arrangement, with Atomic Energy of Canada Limited as signatory and Canadian Nuclear Laboratories as the performing organization. In May 2019, Canada hosted the Policy and Expert Group meetings in Vancouver.

China

Nuclear Energy Policy: China's Nuclear Safety Law strengthens China's industry standards. The legislation includes more than 90 items, went into effect in January. It ensures the appropriate treatment of nuclear materials and facilities, and reduces risks and nuclear waste. It is the legal foundation that clarifies protocols, responsibilities and punishments for various government agencies, businesses and civilians when dealing with nuclear-related subjects. The Atomic Energy Law of the People's Republic of China has been included in the national legislative plan, as a basic law in nuclear field.

China issued a white paper to introduce its approach to nuclear safety on 3 September. The white paper titled "Nuclear Safety in China" has been published by the State Council Information Office to elaborate on China's basic principles and policies in the field, share the concepts and practices of regulation, and clarify its determination to promote global nuclear safety governance and the actions it has taken to achieve this. The document says China has always regarded nuclear safety as an "important national responsibility, and integrated it into the entire process of nuclear energy development and utilization". The industry, it says, has "always developed in line with the latest safety standards and maintained a good safety record, pursuing an innovation-driven path of nuclear safety with Chinese characteristics."

The Nuclear Energy Development: By the end of September, there are 47 nuclear power units in operation, with the total installed capacity of 48.73 GW; 11 nuclear power units are under construction, with the total installed capacity of 12.14 GW.

Cold hydrostatic testing has begun on 27 April at unit 5 of the Fuqing nuclear power plant in China's Fujian province, the first of two demonstration HPR1000 under construction at the site. The tests mark the first time the reactor systems are operated together with the auxiliary systems.

In a first for China, China National Nuclear Corporation (CNNC) has uprated its oldest power reactor, Qinshan 1, to 350 MWe (net) from its original 300 MWe in mid of April. The engineering work "*has important reference significance for the power enhancement of subsequent power stations, and plays an exemplary role in the prolongation management of domestic nuclear power plants*".

Long-term irradiation testing of CF3 pressurized water reactor (PWR) fuel has been completed in March. CF3 fuel assemblies are designed for use in the HPR1000.

Members of the World Association of Nuclear Operators (WANO) have voted to establish a new branch office and support centre in Shanghai, China on 21 February during its General Assembly in South Africa. Over the past 30 years, China has become a key player in the commercial nuclear sector. The decision to proceed with establishing a WANO Branch Office and Support Centre in China has the overwhelming support of the worldwide membership.

CNNC announced the launch of a project to construct an ACP100 small multipurpose modular reactor at Changjiang in Hainan Free Trade Pilot Zone on 18 July. Construction of the demonstration unit-also referred to as the Linglong One design – is scheduled to begin by the end of this year.

Having completed a 168-hour test run, Unit 2 of Taishan Nuclear Power Plant became the world's second European pressurized reactor (EPR) qualified for commercial operation on 7 September.

China has started mass production of fuel assemblies for its first self-developed large-scale advanced pressurized water reactor for commercial use. The assemblies can be used for long-cycle refueling and are suitable for the Hualong One reactor and the Yanlong low temperature heating reactor.

Gen-IV nuclear energy systems activities

SFR: CEFR restarted and was operating at low power since February 2019. Pre-conception design of CFR1200 with SCO_2 system as the candidate of power conversion system is in process, and major research work is focused on thermal-hydraulic, SCO_2/Na reaction and code development of SCO_2 system. SFR is planning to conduct irradiation test in CEFR. The design of CN-1515 irradiation rig has finished. Experimental facility for the research on interaction between sodium and supercritical CO_2 has been constructed. Sodium-supercritical carbon dioxide heat exchanger has been designed and is under manufacturing currently.

VHTR: HTR-PM demonstration project will connect to grid in 2020 in accordance with the current plan. The installation is now in the final stage and commissioning test has started already. The process for joining HP-PMB is undergoing. With the contributions from all members, the project plan for CMVB was finished, and was approved by VHTR SSC, the formal signing process can be started. The R&D in FFC and MAT PMB progress as planned.

SCWR: The R&D on SCWR and pre-conceptual design of the China SCWR CSR1000 is ongoing. The small SCWR named CSR-150 is being developed to meet flexible and wide demands. In terms of co-operation in SCWR, a new international benchmark exercise is just set up based on the SCW parallel pipe density wave instability tests from NPIC for assessing the system analysis code. China has taken part in the TH&S PMB and M&C PMB and work is proceeding according to the project plan. The MOST (Minister of Science and Technology) of China is planning to fund the Chinese universities and institutes in the TH&S and M&C PMBs field.

LFR: The Institute of Nuclear Energy Safety Technology, China Academy of Science has been actively participating in GIF LFR activities as an observer and made its contribution to the development of LFR pSSC since 2013. Considering widely involving of Chinese institutions in R&D of LFR and its importance, China was interested in acceding to GIF LFR. The signature was done in October 2019.

Euratom

Research

The Euratom contribution to the Generation IV International Forum relies on three main pillars: Indirect Actions, which are research projects carried out by research institutions of EU Member States, co-funded with EU budget; direct actions, which are research projects carried out directly by the European Commission's Joint Research Centre, and activities carried out by EU Member State Institutions.

Indirect and direct actions are both defined and funded by the multiannual Euratom Research and Training Programme. The 2019-2020 extension of the Euratom Research and Training Programme (2014-2018), complementing the Horizon 2020 European Research Programme was adopted on 15 October 2018.

The ongoing collaborative projects are progressing steadily and cover Molten Salt Reactors (MSR), Lead-cooled Fast Reactors (LFR), Sodium-cooled Fast Reactors SFR, Very-High-Temperature Gas Reactors (VHTR), Gas-cooled Fast Reactors (GFR), as well as cross-cutting fuel and material topics. Additional direct action contributions to GIF: co-ordination, co-operation with Working Groups (Risk and Safety – RSWG, Proliferation Resistance and Physical Protection – PRPPWG), Task Forces (TF) (Advanced Manufacturing Methods – AMME TF and Research and Development Infrastructure – RD TF), and committee work (SSC, PMB, and others).

The last call for proposals of around EUR 140 million was published in December 2018 and proposals will be selected for financing by February 2020. Funded reactor systems will include advanced nuclear systems for increased safety (Gen-IV), SMRs, Partitioning and Transmutation, and support to the Jules Horowitz Research Reactor currently under construction in France. Overall, 62 proposals were submitted, 15 projects are competing for EUR 40 million whereof 6 projects are expected to be funded in relation to advanced nuclear systems. The winning projects will be launched by mid-2020.

The European Commission has presented the most ambitious framework programme for research and innovation ever. The Horizon Europe (2021-2027) proposed budget of EUR 100 billion also includes EUR 2.4 billion for the Euratom Research and Training Programme and EUR 3.5 billion from the InvestEU Fund (gathering several risk sharing financial instruments). The proposed financial envelope for the implementation of the Euratom Research and Training Programme for the period 2021-25 is EUR 1.6 billion, in current prices, with the following indicative distribution: (a) EUR 724 million for fusion research and development; (b) EUR 330 million for nuclear fission, safety and radiation protection; and (c) EUR 619 million for direct actions undertaken by the Joint Research Centre.

The Joint Research Centre has consolidated its activity in the domain of Generation IV systems in three major projects. SEAT-GEN IV (Safety of Advanced Nuclear Systems and Innovative Fuel cycles) project, SAETEC (System Analysis of Emerging Technologies) and WAIF (Waste from Innovative fuel). The topics covered are: Reactor Safety of Generation IV reactor designs, including modular reactors (safety analysis including severe accident modelling); Materials R&D programme with focus on LFR and Supercritical Water Reactor (SCWR); safety of fuel for the SFR, LFR, VHTR, MSR systems, conditioning matrices for waste from innovative fuels, and safeguards. Activities in support to the GIF PRPP WG are carried out in the project MEDAKNOW (Methods, data analysis and knowledge management for Nuclear Non Proliferation, Safeguards & Security).

Euratom continues to rely on its High Flux Reactor (HFR) in Petten, The Netherlands. The governments of the Netherlands and France have agreed to support the Supplementary Research Programme for the period 2020-2024 with about EUR 30 million, which will be implemented by the European Commission's Joint Research Centre. Relevant for GIF are in particular irradiation tests of fuel and materials as well as the ensuing post-irradiation examinations.

The Nuclear Research and consultancy Group (NRG, The Netherlands) has announced the completion of the SALIENT-01 test, the first irradiation experiment in the MSR research programme that started in 2015. Research under this programme is partly funded by the Dutch Ministry of Economic Affairs and is being carried out in collaboration with the Joint Research Centre (JRC) of the European Commission.

Romanian utility Nuclearelectrica has signed a Memorandum of Understanding (MoU) with FALCON, the consortium constituted by Italian and Romanian entities aiming at the construction of Advanced Lead Fast Reactor European Demonstrator (ALFRED). The MoU addresses the pre-project works and the research and development activities which are to be implemented in order to develop the ALFRED project: exchange of information and data regarding the technology; the co-ordination of the research activities; the in-kind contribution of each party; the studies and analyses independently conducted by each party for their organization; and the planning of the necessary framework for preparing the demonstration activities.

The Sustainable Nuclear Energy Technology Platform (SNETP) is currently updating its Strategic Research and Innovation Agenda. Generation IV (within the European Sustainable Nuclear Industrial Initiative) will continue to be an important pillar and new topics will be introduced such as SMRs. SNETP is divided into three main areas: Current Reactor Research (NUGENIA), Research on fast reactors with closed fuel cycle (ESNII), and Nuclear Co-Generation (N2CI), primarily with high-temperature gas-cooled reactors. The priorities for ESNII are in Sodium Fast Reactor and a specific (ADS – Accelerator-Driven System) of Lead/Bismuth Fast Reactor (MYRRHA) to support the technology development. In this frame, the Belgian Federal Government decided in September 2018 to invest EUR 558 million during the 2019-2038 period in phase 1 of MYRRHA which includes the construction of the 100 MeV MINERVA linear accelerator, Proton Target Facility and Fusion Target Station. Other priorities are the Lead Fast Reactor (ALFRED) in the shorter term and Gas Fast Rector (ALLEGRO) in the longer term. Within the third area NC2I, the Very-High-Temperature Reactor has a special role in cogeneration. The Polish Ministry confirmed full interest at the October 2018 HTR conference in Warsaw (Poland) which was confirmed after elections in November 2019. The Polish HTR Committee for Analysis and Preparation of Conditions for Deployment of High-Temperature Nuclear Reactors recommends beginning preparation of HTGR deployment as the Polish HTR strategy is being written into the Polish Energy Policy.

The Euratom FISA 2019 and EURADWASTE '19 conferences took place in Pitesti, Romania, on 4-7 June 2019. The conferences addressed all Euratom Fission safety research and training, innovative projects of reactor systems and radioactive waste management within the frame of Horizon 2020 framework programme. Overall, some 95 projects co-funded by Euratom (with around EUR 350 million out of EUR 500 million) were presented. A significant number of these projects are contributing to GIF. More than 400 scientists from 200 organizations from 40 European countries and worldwide attended. These conferences provided additional opportunities to address and engage with all relevant stakeholders, to further strengthen the EU's innovation potential, careers' attractiveness to the young generation, the research community, policy makers and civil society.

Policy

On 28 November 2018, the European Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 – A Clean Planet for All. The strategy shows how Europe can lead the way to climate neutrality by investing into realistic technological solutions, empowering citizens, and aligning action in key areas such as industrial policy, finance, or research – while ensuring social fairness for a just transition. The strategy

envisages that, by 2050, more than 80% of electricity will be coming from renewable energy sources, which – together with a nuclear power share of approximately 15% – will be the backbone of a European low-carbon power system.

In May 2019 European Parliament elections took place in all EU Member States after which a new European Commission was set up. The Ursula von der Leyen Commission for the next five years took office on 1 December 2019, and will focus on six main priorities:

- a European Green Deal;
- an economy that works for people;
- a Europe fit for the digital age;
- promoting our European way of life;
- a stronger Europe in the world; and
- a new push for European democracy.

The European Parliament presented a motion to the COP25: The European Parliament "believes that nuclear energy can play a role in meeting climate objectives because it does not emit greenhouse gases, and can also ensure a significant share of electricity production in Europe; considers nevertheless that, because of the waste it produces, this energy requires a medium and long-term strategy that takes into account technological advances (laser, fusion, etc.) aimed at improving the sustainability of the entire sector". European Parliament resolution of 28 November 2019 on the 2019 UN Climate Change Conference in Madrid, Spain (COP 25) (2019/2712(RSP)).

France

French energy policy: In November 2018, President Macron presented the ten-year Multiannual Energy Plan (PPE), the government released the complete document (January 2019). This steering tool presents the path to be followed in terms of energy policy and ecological transition. The two intricately linked main objectives are to reduce French fossil fuel consumption and to ensure clear, fair and sustainable transition for all. On power generation, the government sticks to the goal of diversifying the energy mix, with the development of renewables. The target of achieving a 50% nuclear power share in the electricity mix is set by 2035 – instead of 2025 as planned in the 2015 Energy transition law. A correlative reactor shutdowns should be progressively decided, subject to conditions related to the electricity market and to the evolution of the electricity system in the neighboring countries. At the same time, the government and the nuclear industry are committed to release a plan by mid-2021 in order to enable a fact-based political decision on coming new reactor construction in France.

The PPE confirms the strategy for nuclear fuel treatment and recycling, at least until the 2040's horizon. To this end, a certain number of 1 300 MW reactors are going to be adapted for the use of MOX fuel, considering the to-be-decided closure of 900 MW reactors, which currently use MOX fuel. Alongside this adaptation of a part of the existing fleet, the French nuclear industry and CEA have launched the feasibility study of nuclear fuel multi-recycling in PWR. This option is considered as a possible intermediate step.

Thus this new law will integrate the revised objective to reduce the share of nuclear power to 50% in 2035, as well as a new objective for France to reach net carbon neutrality by 2050. It also implements new tools for monitoring, governance and evaluation of the climate policy, such as the introduction of a five-year plan setting out the main energy policy objectives.

Regarding radioactive materials and waste management, Emmanuelle Wargon, French Government Secretary to the Minister of Ecological Transition, signed on 4 October the territory project that will support the construction of CIGEO, the geological storage centre for radioactive waste. A wide national debate on the National Plan for the Management of Radioactive Materials and Waste (PNGMDR) took place in 2019, underlining namely the importance of the recycling of nuclear materials.

Status of the French R&D program on closed fuel cycle: The Multiannual Energy Plan confirms the long-term sustainability objective of a fully closed fuel cycle, implying the deployment of fast reactors in the power generation mix. However, the implementation time frame to meet French power generation needs has been reassessed through a review of fast neutron reactors and fuel cycle strategy jointly conducted by CEA and French nuclear industry. The conclusion was jointly reached that the industrial deployment of fast reactors is very likely to be more remote in time and that the option must be kept open. Thus with regard to the updated deployment timeline, the CEA and the nuclear companies have proposed to postpone the ASTRID project. The Government has endorsed this position, as expressed in the Multiannual Energy Plan. But keeping the option open requires maintaining skills, progressing on technological barriers and further developing knowhow. Based on the results and knowledge that stemmed from the ASTRID program, the challenges to be dealt with in order to prepare the future sodium-cooled fast neutron reactor development have been listed by CEA. Consistently with the revised timeline of fast reactor commercial deployment, the R&D roadmap towards a fully closed fuel cycle has been established in continuity with the ASTRID program. It is mainly dedicated to SFR – which remains the most mature technology and the reference option. It involves basic research, modelling, numerical simulation, technological development and experiments, benefiting from useful innovative methodologies (advanced manufacturing, massive data processing, digital design). It also seeks for reactor design innovations. Evaluation of other fast reactor technologies and systems is also a part of the program, with very preliminary design studies. France has now a revised R&D roadmap to implement and support its energy policy for low CO_2 energy system including nuclear energy and renewables.

Other projects: As for the short-term future, considering the need for a decarbonized baseload offer in small and medium power segments internationally, the French nuclear industry leads a light water SMR development project, currently starting the basic design phase. This project (NUWARD) is taking place through a consortium made of CEA, EDF, Technicatome and Naval Group. Consequently, during the IAEA General Conference, the French joint industrial initiative for the development of a small modular reactor (SMR) was unveiled. The NUWARD-TM project is a PWR technology-based solution, designed to meet the growing need of low-carbon electricity market worldwide in the 300-400 MWe power segment. In addition to that, CEA envisions to explore other SMR-concepts both for power generation and non-electrical application purpose, in the framework of an integrated approach of energy systems.

Jules Horowitz Reactor: Significant progress have been made with reactor components manufacturing of the future international user facility JHR. The project has gone through a thorough governmental review process and a set of decisions are going to be implemented to secure the revised overall schedule.

In May, after a high-level review, the French government reinforced the significance of the JHR as a key tool for the nuclear sector, not only for France but also internationally. The reactor has entered a new phase, dedicated to the installation of major components. On-site, the completion of the reactor pool liner was reached in August. This major milestone paved the way to the ongoing reactor pile-block implementation and to the coming installation of other key components such as the heat exchangers of the primary circuit.

EDF nuclear new build activities in France: Progress are being made for the commissioning of Flamanville with the start of hot tests in February 2019. In parallel, the safety authority should deliver its ruling regarding how to proceed further with the deviations detected in welds on the main steam transfer pipes. At the end of June, the ASN announced the discovery of eight non-conforming welds in hard-to-reach areas on the four steam evacuation pipes that need to be taken over. EDF has recently unveiled how it will proceed to correct these welds, which will take a few months. The start-up of the reactor is consequently planned for 2022.

CEA energy integrated approach: The CEA is highly committed on developing an integrated approach of the energy system as a whole, taking into account all the energy needs. This renewed approach considers the increasing penetration of intermittent renewable energies and the emergence of new electrical uses, and the subsequent need for energy storage and conversion systems development. This will lead to a multi-vector and multi-network energy system. It also requires optimization by developing closed material cycles, and a strong digital monitoring (smart grids). The integrated approach of the comprehensive energy system, either

at the global or at the local scales, is also taking into account the capacities to meet the future needs and their mutual articulation, in order both to advise the French government and to contribute to the technological developments.

Japan

Current Status of Nuclear Policy of Japan: In December 2016, the Cabinet of Japan approved the policy on the fast reactor development. Based on this, the government built in December 2018 the Strategic Roadmap which determines development activities in the coming decade. This Roadmap highlights the significance of nuclear fuel cycle technologies for Japan, focusing on the efficient use of resources, as well as the minimization of the volume of high-level radioactive waste and its potential toxicity. As part of it, JAEA has been making efforts for the fast reactor development.

Ensuring the highest level of safety is top priority. Japan will also aim to reduce the generation cost of nuclear power. To achieve this, flexible approaches are necessary in deal with uncertainties in the future, including cost competitiveness with other energy sources and the social environment. The Roadmap specifies the roles of driving forces who lead the nuclear development, namely, the government, electric utilities, JAEA, and manufacturers. In addition, it declares that Japan will co-operate with other countries by, in particular, efficiently using the network of the GIF to further advance Japan's technology platform and innovation. The Advisory Committee for Natural Resources and Energy of Ministry of Economy, Trade and Industry of Japan discussed how to further facilitate the nuclear innovation in April 2019. Japan has already started government-funded projects towards it. Thus, movements that encourage nuclear research, development, and demonstration are increasing in private sectors in our country.

Another international co-operation ongoing is a project with Poland. The fifth Strategic Energy Plan approved by the Cabinet in July 2018 states that "*While watching global market trends, Japan, in co-operation with other countries, will further develop technologies that contribute to improving nuclear safety, such as the high-temperature gas-cooled reactor (HTGR) which features its safety*". In January 2019, JAEA jointly held a seminar with the National Centre for Nuclear Research of the Republic of Poland on the technology of the HTGR.

Current Status of Fukushima Daiichi Nuclear Power Station: In Fukushima, the damaged reactors are in cold shutdown status. Based on the Mid-and-Long-Term Roadmap for the plant, Tokyo Electric Power Company (TEPCO) has been inspecting the inside of the cores and developing the procedure towards the fuel debris retrieval scheduled in 2021 and the decommissioning of the plant. TEPCO removed spent fuel from the pool in Unit 4 in 2014, and started removing fuel from Unit 3 in April 2019.

Safety Review of Nuclear Power Stations and Nuclear Fuel Cycle Facilities by Nuclear Regulation Authority (NRA): Among nuclear power plants in Japan, 27 units of 16 plants, in total, applied for the conformity assessment of the Nuclear Regulation Authority (NRA) to restart their operations. As a result, the NRA granted the permission for 15 units of 8 plants to alter their installations. As of today, nine units are in operation.

Current Situation of Facilities of Japan Atomic Energy Agency (JAEA): JAEA is working on the restart of High Temperature Engineering Test Reactor (HTTR), and the experimental fast reactor JOYO. The conformity assessment of the upgrading of HTTR's installations is in the final stage. Regarding JOYO, JAEA submitted the amendment of the facility upgrading to the NRA in October 2018, and is waiting for the result.

Russia

Nuclear Power in Russia: In 2018, Russian NPPs produced 204.3 billion kWh that is 18.7% of the total electricity production. The increase in power production was 0.7% as compared to 2017, with the load factor equal to 80%. Currently, 36 power units with total electrical capacity of all Russian nuclear power plants is 28.9 GW. At the same time, the share of nuclear generation in

the country's total energy balance is 18.6% of the total electricity production in Russia. In 2018, 2 power units were put into commercial operation: power unit 4 of the Rostov NPP with the WWER-1000 reactor and power unit 1 of the Leningrad NPP-2 with the WWER-1200 reactor of GEN 3+, which safety is justified taking into account the lessons of the accident at the Fukushima-1 NPP. Power unit 2 of the Novovoronezh NPP-2 also with the WWER-1200 reactor was put into operation on 1 May 2019. Two power units were decommissioned: power unit 1 of the Bilibino NPP with the EGP-6 reactor and power unit 1 of the Leningrad NPP with the RBMK-1000 reactor.

In November 2018, the first criticality was reached for both reactors of the floating nuclear power plant "Academician Lomonosov". In August-September 2019, it is planned to transport the floating NPP to Pevek in Chukotka Region and to provide its putting into operation in December 2019. The deployment of the FNPP in Pevek will create conditions for accelerated social and economic development of neighboring regions and Chukotka as a whole. In addition, it will become one of the key elements of the infrastructure of Northern Sea Route. An extensive program for the construction of an icebreaker fleet, including nuclear power plants, has been adopted, which will ensure reliable year-round operation of the Northern sea route. Delivery of the nuclear icebreaker "Arctic", which is the head in the new series of nuclear icebreakers of the project "Leader", planned to May 2020 after additional tests of the steam power plant, respectively, other representatives of the project – icebreakers "Siberia" and "Ural", are planned to pass in 2021 and 2022.

Today, Russia is a leader in new nuclear construction abroad. Rosatom ranks first in the number of simultaneously implemented projects for the construction of nuclear reactors (6 in Russia and 36 abroad). The following projects are mentioned here, they moved to the practical implementation stage:

- 4-unit Akkuyu NPP in Turkey with WWER-1200 reactors;
- power units 3 and 4 of the second phase of the Kudankulam NPP and power units 5 and 6 of the third phase of the Kudankulam NPP in India with WWER-1000 reactors;
- 4-unit El-Dabaa NPP in Egypt with WWER-1200 reactors;
- 2-unit Ruppur NPP in Bangladesh with WWER-1200 reactors;
- power units 7 and 8 of the Tianwan NPP in China with WWER-1200 reactors;
- 2-unit Belarusian NPP of the "NPP-2006" type.

The competitiveness of Russian proposals can be explained by advanced and the latest technologies developed by Russian scientists and designers. The projects proposed for construction are based on modern reactor facilities of a modernized design of VVER (Russian light water power reactor under pressure), which have long-term good performance indicators. The construction projects of the Russian nuclear power plant are Generation III+ reactors equipped with active and passive safety systems. All design projects comply with current international requirements and IAEA recommendations.

Improvement of VVER technology is necessary for the transition from an open to a closed fuel cycle. The innovative development of VVER projects includes: reduction of capital and operating costs, taking into account the experience gained in construction and licensing; ensuring competitiveness in the domestic and foreign markets; compliance with the achieved level of security; providing the ability to work in the conditions of the short and medium-term nuclear strategy (combination of an open and closed nuclear fuel cycle); fuel tolerance development program. VVER-1200 is the flagship nuclear reactor and the main product of the integrated solution of Rosatom State Corporation. As a development of the VVER-1000 reactors, which were recently built in Iran, India and China, the new design has improved characteristics in all respects.

Perspective nuclear technologies: Russia is a recognized leader in the field of fast sodium reactors (FSR). At present, two power units of the Beloyarsk NPP with BN-600 and BN-800 reactors, as well as the BOR-60 research reactor in NIIAR, Dimitrovgrad, are in operation. The total operational experience of the FSR, accumulated in Russia, exceeds 158 reactor years as of

September 2019. Next year, the life of a power unit with a BN-600 reactor will reach 40 years. The task of BN-800 is to demonstrate the possibility of a closed fuel cycle, improve the technology of fast neutron reactors, and also test new design solutions for machines and reactors designed to increase its economic efficiency, reliability and safety. BN-800 can operate on uranium or mixed uranium-plutonium fuel. The use of MOX fuel helps to dispose of weapons-grade plutonium and burn long-lived radioactive isotopes (actinides) from irradiated fuel from thermal reactors. The initial fuel load of the BN-800 reactor was formed mainly from traditional uranium oxide fuel. At the same time, part of the fuel assemblies contains MOX fuel manufactured at the pilot plants of other Rosatom enterprises – NIIAR (Dimitrovgrad, Ulyanovsk region) and Mayak Production Association (Ozersk, Chelyabinsk region). Currently, the second batch of industrial fuel assemblies based on MOX fuel produced by the mining and chemical plant (Zheleznogorsk, Krasnoyarsk territory) has passed acceptance tests.

In the framework of the project "Proriv" on the BN-600 reactor tests are conducted, and subsequent studies of the mixed nitride uranium-plutonium fuel (MNUP-fuel) production to the Siberian chemical combine, which plan to use in the project BREST-OD-300 and BN-1200. As of now, 18 experimental fuel subassemblies with more than 1 000 fuel elements of various types are under irradiation. For 11 experimental fuel subassemblies, irradiation studies already completed, the maximum burn-up level has reached 7.5% of heavy atoms.

The development of two projects which meets the requirements for the 4th generation reactor systems is continuing: the BREST-OD-300 Lead Fast Reactor – the construction is planned to start on 2020 at the site of the Siberian chemical plant in Tomsk –, and the commercial power unit BN-1200 fast sodium reactor.

At the NIIAR site in Dimitrovgrad, the MBIR research fast reactor with sodium coolant is being constructed, which is intended to replace the BOR-60 reactor, which has been operating for almost 50 years. Russia organized an international research center on the basis of the MBIR reactor, and now the process of legalizing the partnership relationship is ongoing. Key areas of research for the project IRC MBIR are: materials (new fuels, structural materials and coolants, verification data), safety (the rationale for the new security system, studies under transient and abnormal conditions), physical examination (study on closed nuclear fuel cycle, reprocessing of minor actinides and other long-lived radionuclides, verification codes), and endurance tests (fuel, elements of CPS and the active zone, system monitoring and cooling circuits diagnostics).

The transition to the closed nuclear fuel cycle in the transition period allows to stop the rate of accumulation of spent nuclear fuel (SNF) of thermal reactors and its increasing cost of handling. Replacing one thermal reactor with a Fast Reactor prevents the formation of about 1 000 tons of spent fuel during VVER operation for its design lifetime period of 60 years and the cost of its storage until reprocessing; increases by ~15 times the yield of a commercial product – Pu during processing (15% Pu in SNF FR). The use of reprocessing products is an effective way to solve the problem of already accumulated VVER SNF. One new FR can utilize all SNF during the life of one VVER; replacing 10 GW of thermal reactors with fast ones almost completely solves the problem of accumulated Russian VVER SNF (~10 thousand tons), and also ensures the economic result of its reprocessing.

Generation IV update: In 2018, Rosatom has signed the GIF Project Arrangement on SFR Advanced Fuel, and early in this year it agreed extension of the GIF Project Arrangement on SFR Safety and Operation for the next ten years. As part of revision of the System Research Plan on Sodium Fast Reactor, it was added with the BN-1200 concept as a design track meeting the Gen-IV requirements. In addition, Rosatom is actively participating in preparation to signing the GIF System Arrangement on Molten Salt Reactor.

In 2018 – early in 2019, representatives of Rosatom have delivered lecturers at GIF webinars on topics:

- Molten Salt Actinide Recycler & Transforming System (MOSART) with and without TH-U support;
- BN-600 and BN-800 Operating Experience;
- Scientific and Technical Problems of Closed Nuclear Fuel Cycle in Two-Component Nuclear Energetics.

In 2019, Rosatom agreed to extend for the next ten years the validity of the GIF Project Agreement on Safety and Operation of FNR.

South Africa

Energy planning and the nuclear program: After substantive and extensive stakeholder consultation and engagement processes, South Africa's electricity generation master plan, the Integrated Resource Plan was tabled before and approved by Cabinet in October 2019. The approved 2019 Integrated Resource Plan (IRP) calls out for preparations to commence on the 2 500 MW nuclear programme, in particular "*Decision 8: Commence preparations for a nuclear build programme to the extent of 2500 MW at a pace and scale that the country can afford because it is a no-regret option in the long term*". The IRP proposes that the nuclear power programme must be implemented at an affordable pace and modular scale (as opposed to a fleet approach) and taking into account technological developments in the nuclear space. The IRP further advocates for energy system requirements with incremental capacity addition (modular) and flexible technology, to complement the existing installed inflexible capacity. In addition, lessons learnt from the procurement under the Independent Power Producer (IPP) programme has shown that there is a business case for modular and smaller power plants (300 MW and 600 MW) hence spelling clearly South Africa's stance to deploy small modular reactors.

Legislative and policy developments

a. New legislation and policies: The draft position paper on the Decommissioning Policy was developed and currently subjected to stakeholder consultation. This policy is necessary to guide the decommissioning of aging infrastructure including major nuclear installations such as the Koeberg Nuclear Power Station and the SAFARI-1 research reactor as well as future nuclear installations.

The development of a national policy and strategy on nuclear research, development and innovation is work in progress. The R&D policy and strategy is envisaged to span areas of power and non-power applications of nuclear energy.

The safe and long-term management of radioactive waste and spent fuel is pivotal and as such, South Africa is developing a Fund Bill for radioactive waste and spent fuel management. The Draft Bill is subjected to consultation with key stakeholders and in parallel, a socio-economic impact assessment of the Bill is undertaken. Radioactive Waste Management Fund Bill is informed by the polluter pays principle where levies and taxes will be collected from the operators of nuclear installations and facilities to fund management of radioactive waste.

b. Legislative amendments: South Africa also continues with the review and amendments to the National Nuclear Regulator Act to among others strengthen nuclear security, enhance on regulation of radioactive sources and ensure effective independence of the nuclear safety regulator in light of lessons learnt from the Fukushima Daichii accident. The Draft Amendment Bill is subjected to stakeholder consultation and in parallel a socio-economic impact assessment undertaken.

Aging management and plant life extension: The South African Nuclear Energy Corporation (Necsa) continues to implement an aging management programme for the SAFARI-1 research reactor in line with the IAEA SSG-10 Safety Guide on Aging Management for Research Reactors. SAFARI-1 research reactor has an excellent record of accomplishment of operational safety and ranks among the world's highly utilized and available research reactors. Aging Management for SAFARI-1 reactor also continues and in parallel, the Minister of Mineral Resources and Energy in April 2019 commissioned a Task Team to oversee the delivery of the Multi-Purpose Reactor Project, a replacement for the SAFARI-1 Research Reactor. The Task Team is expected to complete the Project Initiation Report for Cabinet consideration by April 2020.

The twin-unit Koeberg Nuclear Power Station continue to implement plant life extension programme. The plan is to extend the life of the plants from an original design lifetime of 40 years to 60 years. The Koeberg Plant Life Extension projects includes Steam Generator

Replacement, Thermal Power Upgrade, Reactor Pressure Vessel Head Replacement, and Refueling Water Tank Replacement. As per regulatory requirements, Koeberg plans to submit a Safety Case for long-term operation to the Nuclear Safety Operator in 2022.

Nuclear safety and operation: NTP Radioisotopes, a subsidiary of the South African Nuclear Energy Corporation has been operating intermittently since the issuance of directives by the National Nuclear Regulator ceasing production operations at the subsidiary following repeated deviations from safety protocols. The cessation of operations at NTP Radioisotopes is taken in serious light due to the adverse impact on the medical fraternity relying heavily on nuclear medicine for cancer diagnosis and therapy; however, safety remains an overriding factor for the nuclear industry. NTP Radioisotopes continues to work closely with the National Nuclear Regulator to address safety concerns, comply with regulatory requirements and ensure uninterrupted supply of molybdenum-99.

Spent fuel management: Work continues on the establishment of the Centralised Interim Storage Facility for Spent Nuclear Fuel to mainly address storage capacity challenges faced by Koeberg and also in line with international best practice to have away from reactor storage of spent nuclear fuel. The Ministerial Task Team overseeing this project is led by the Department of Mineral Resources and Energy for implementation by the National Radioactive Waste Disposal Institute upon Cabinet approval.

Research & development: Eskom continues with research and development for the Advanced High Temperature Reactor towards a "Proof of Concept" machine to demonstrate a set of technical aspects prior to commercialization.

During early 2019, the Department of Mineral Resources and Energy established an inter-departmental task team to oversee and co-ordinate the delivery of the Multi-Purpose Reactor project aimed as a replacement reactor for SAFARI-1. This is mainly to continue nurture nuclear research, development and innovation as well as sustain radioisotope production.

In addition, South Africa undertakes research and development in non-power applications of nuclear under the IAEA Technical Cooperation Project and the African Regional Cooperation Agreement for Research, Development and Training related to nuclear science and technology.

Korea

Nuclear power in Korea: 25 nuclear power plants are being operated in Korea by July 2019. The nuclear power plants generated 11 678 GWh of electricity, which is responsible for 23.5% of the total electricity production in Korea. The generating capacity of the 25 plants accounts for 18.04% (21 850 MWe) of the total generating capacity. Four nuclear power plants, Shin-Hanul units 1 & 2 and Shin-Kori units 5 & 6, are under construction and will be completed by 2020 and 2024 each of two.

Shin-Kori unit 4 (APR1400) obtained an operation permit on 1 February 2019 and started commercial operation in August. APR1400 is designed by Korean state-owned companies Korea Electric Power Corp. (KEPCO) and Korea Hydro and Nuclear Power Co. (KHNP). The US Nuclear Regulatory Commission (NRC) has issued key safety and design approvals for the APR1400. APR1400 recently received DC (Design Certificate) from the US NRC in September 2019 and registered on 10 CFR Part 52 subpart B. Meanwhile, the first of four APR1400 reactors at the Barakah site in the United Arab Emirates (UAE) was completed in March 2018 and unit 1 is preparing for a fuel loading into the initial core in February 2020.

Nuclear Energy Policy in Korea: An energy transition policy was announced in October 2017 that implies lowering the share of coal and nuclear energy in Korea. The new policy includes shut down of aged coal power plants over 30 years and the expansion of the share of renewable energy to 20% in total electricity generation by 2030. At the end of 2018, a strategy to enhance future safety technologies was newly established. This strategy focuses on expanding investment and developing new technology to ensure the safety of nuclear facilities and spent fuel management. This strategy means that Korea still maintains activities in promoting international collaboration for peaceful and safe uses of nuclear science and technology. The

Korean government actively supports the transfer of domestic nuclear technology to other countries in accordance with the global non-proliferation framework. The exporting nuclear technology includes advanced power reactors, small modular reactors (SMRs), and other diverse applications.

The construction of a new research reactor, Gijang Research Reactor, was approved by the Nuclear Safety and Security Commission (NSSC) on 10 May 2019. This research reactor will responsible for producing radioactive isotopes for medical and industrial purposes, and providing for R&D platform. The construction of the research reactor unit in Gijang, about 450 kilometers southeast to Seoul, will be completed by 2024, with further cost assessment in accordance with the decision of the Nuclear Safety and Security Commission. The reactor will be the first of its kind in having a fission molybdenum (Mo-99) production facility.

In May 2019, the spent nuclear fuel (SNF) management policy re-examination commission has been launched to review the previous national policy (submitted in 2016). The commission will submit policy recommendations to the government on the management of SNF including the construction of intermediate storage and final disposal.

R&D on nuclear energy system in Korea: In 1997, the Korean government established the Comprehensive Nuclear Energy Promotion Plan (CNEPP), which includes the national policy on nuclear energy utilization and promotion and its sectoral tasks. As a part of the plan, a national nuclear R&D plan has been formulated every five years since 1997. The national nuclear R&D plan from 2017 to 2021 was set up with the vision of the advancement on nuclear technology development for reassuring people and the goal of nuclear safety enhancement and core technology completion. It focuses on five research fields: 1) nuclear safety; 2) radioactive waste management; 3) advanced reactors and fuel; 4) application of radiation and radioisotopes; and 5) fundamental technologies. A technology innovation project for operating nuclear power plants has also been developed for the nuclear industry.

Future nuclear technology development strategy was established to support for the R&D part of the Energy Transition Policy and expand the socio-economic application of nuclear technology. Five specific R&D strategies were suggested for successful achievement: 1) Secure plant safety and decommissioning technology; 2) Expand use of nuclear and radiation technology; 3) Overseas export promotion; 4) Secure new future engine sources such as fusion energy; 5) Commercialization of nuclear technology. In line with this future nuclear technology strategy, the Ministry of Science and ICT established a Strategy for the Strengthening Future Nuclear Safety Capabilities at the end of 2018.

Under the energy transition policy (lowering the share of coal and nuclear energy gradually, and expand the use of renewable energy), it is the most important to secure the safety of operating nuclear power plants that will be run at least for the next 60 years. The strategy also presents the direction in which the accumulated nuclear capabilities in the power sector can be expanded to securing nuclear safety and technology innovation. Based on this change of direction, the strategy for the strengthening future nuclear safety capabilities promotes three development strategies: 1) Support for the safe operation of domestic NPPs for the next 60 years; 2) Expanded utilization of safety based technology capability; 3) Securing and spreading innovative capability of future nuclear safety technology and establishment of foundation on sustainable safety innovation.

Currently, an advanced nuclear energy system that couples pyroprocessing and Gen-IV sodium-cooled fast reactors (SFRs) plays an important role for the efficient management and utilization of spent fuel. Korea is concentrating its R&D resources on VHTR projects and is actively participating in the Gen-IV International Forum.

Sodium-cooled Fast Reactor (SFR): The long-term development plan for the future nuclear energy systems was authorized by the Korean Atomic Energy Commission in 2008 and updated by Korea Atomic Energy Promotion Council in 2011; it includes a construction of a prototype SFR by 2028 for demonstration of TRU transmutation technologies. The national project to develop the Prototype Gen-IV sodium-cooled fast reactor (PGSFR) was initiated to achieve the national mission stated above in 2012. For this, the SFR Development Agency dedicated to the PGSFR development was established in the middle of 2012. KAERI is in charge of the design and the validation of the nuclear steam supply system (NSSS) and fuel development, and domestic

participants were responsible for balance of the plant system design. Argonne National Laboratory (ANL) supported KAERI with their experiences in SFR development through international co-operation programs.

The electric power of PGSFR was determined to be 150 MWe suitable for technology demonstration and can be classified as a small modular reactor (SMR), and can be developed as a new non-light water reactor SMR in the near future. The first design phase of the PGSFR was done at the end of 2015 by issuing a preliminary safety information document (PSID). The second phase of the development was done at the end of 2017 by issuing the specific design safety analysis report (SDSAR) with design documents and safety analyses results sufficient for assessing safety of PGSFR. Ten Topical Reports for keys technical issue such as major design codes and methodologies were also published at the end of 2017 and submitted to regulatory body in 2018. All of the basic design concepts of structures, systems and components were determined and incorporated into the specific design safety analysis report (basic design requirements, system descriptions, results of safety analysis for postulated accident scenarios).

To support and demonstrate the safety performance of the PGSFR, verification and validation activities are being performed in parallel with the design progress. A large-scale sodium thermal-hydraulic test program called STELLA is being progressed in 2016. First the sodium component tests of the PDHRS (STELLA-1) has been completed, the data obtained from which are to be used for validating computer codes for thermal sizing, and system transient analysis. As the second step, an integral effect test loop (STELLA-2) has been started to demonstrate the plant safety and to support the PGSFR design certification. The construction of STELLA-2 facility is scheduled by the end of 2019 and the demonstration of the integral effect test will be completed in the middle of 2020.

Various R&D activities are being performed, including verification and validation of computational codes and development of the metal fuel fabrication technology. The reactor mock-up physics experiment in the BFS facility was completed in 2015 in collaboration with Institute of Physics and Power Engineering (IPPE) in Russia. The irradiation test of advanced cladding material (FC92) and test fuel was started at the BOR-60 experimental fast reactor.

In 2017, it was decided to suspend the design intensification of PGSFR in consideration of the national energy environment and select a new policy direction after 2020. The new SFR development program will be decided by reassessing future schedules and discussing rational directions based on the research outcomes so far obtained. Accordingly, Korean SFR developments focus on further improvements of strategic key technologies, the construction and validation of the STELLA-2 facility, and the development of the licensing environment through the review of topical reports.

Very-High-Temperature Gas-cooled Reactor (VHTR): In preparation for the advent of the hydrogen society, research on the nuclear hydrogen key technologies using VHTR has been developing with the government support. Key technology developments for VHTR performance improvement have been performing since 2017. The purpose is to improve the level of key technologies to support high temperature nuclear cogeneration system. The key technologies are the design analysis codes, thermo-fluid experiments, TRISO fuel (tri-structural isotropic), high-temperature materials database, and high temperature heat applications. These technologies are related to GIF VHTR projects such as Fuel and Fuel Cycle (FFC), Hydrogen Production (HP), Materials (MAT), and CMVB (Computational Methods Validation and Benchmark). KAERI signed the extension of FFC and HP Project Arrangements. KAERI will also participate in the CMVB project.

In the fuel research, ZrC/SiC coating technology is under development in order to improve TRISO fuel performance. Inner ZrC layer will have an effect on protecting SiC layer from Palladium attacks in high temperature. As GIF collaboration, a round robin leach-burn-leach test to validate the detection technology of defected TRISO fuel particles is almost finished and the resulting data from KAERI was delivered to Idaho National Laboratory (INL).

Research on high-temperature heat utilization is performed. It is focused on a cogeneration technology that VHTR system is coupled to both hydrogen production system and electricity generation system to maximize heat utilization. Hydrogen and electricity production costs and economics are evaluated for each combination of reactor outlet temperatures and three

different hydrogen production methods: S-I thermo-chemical process, high-temperature steam electrolysis, and steam-methane reforming process.

In high temperature materials, the research is focused on securing data on nuclear-grade graphite, high temperature metal materials and high-temperature composite materials. In 2019, tests for compression strength of nuclear graphite is conducting in the high temperature up to 1 400°C. For the high temperature metal, mechanical and creep properties of thermally aged high nickel alloy (Alloy 617) and creep properties of the weld metals (Alloy 800H) has been investigated. Most of these data will be contributed to the development of GIF VHTR materials database.

KAERI has performed the development of VHTR design analysis codes and its validation and improvement. A hybrid RCCS (Reactor Cavity Cooling System) test facility has been built to simulate the safety of a hybrid RCCS concept developed by KAERI. Several tests have been carried out to verify this concept. It will contribute to the CMVB project for thermo-fluid system code validation.

The Korean government announced its plan for hydrogen economy which focus on two axes of hydrogen powered vehicles and hydrogen fuel cell in early 2019. The plan increases the supply of hydrogen vehicles by 6.2 million units in 2040 and the number of charging station to 1 200. The plan also boosts the supply of fuel cells and the capacity of fuel cell batteries will be 17.1 GW in 2040. The required hydrogen in 2040 is expected to reach 5.26 million tons in a year. In order to support and realize the hydrogen economy plan, the government has launched a joint private-public committee to draw a roadmap for hydrogen technology development. Nuclear hydrogen production using VHTR is reviewed as one of green hydrogen production technologies but decision has not been made yet. Regardless of the roadmap to hydrogen technology development, VHTR R&D will continue to focus on technologies needed to realize the core outlet temperature of 950°C for economical hydrogen production.

Switzerland

GIF activities: Activities for GIF are ongoing as planned. Switzerland organized the 26th GIF VHTR System Steering Committee (April 2019). The main contribution of Switzerland to the VHTR system is on material side. The materials of interest are metals and ceramics. A new study was started recently regarding the additive manufacturing of ODS. The microstructural investigations of the so produced samples are ongoing and will be followed by micromechanical testing.

M. Pouchon presented new results on “Oxide dispersion strengthened steels via additive manufacturing” at the 27th GIF VHTR System Steering Committee meeting beginning of October with a detailed characterization of the strengthening particles.

Politics and regulation: The discussion about the implementation of the energy strategy plan 2050, incorporating the phase out of the running reactors, are still ongoing. The strategic plan for energy research (2021-2024) is under discussion at the government level. The conservation of nuclear competence should be included as a priority.

The draft version of the Swiss strategic plan for energy research (2021-2024) has been published. The relevance of the nuclear plants for helping a smooth transition to a zero emission energy production is stated in the paper. The need to conserve nuclear competences in Switzerland is also clearly recognized.

Operation of the Swiss nuclear power plants and waste management: All units are in operation with KKL (BWR) still running with limited Power (about 92%) due to unexpected CRUD formation (CRUD for corrosion and wear products (rust particles, etc.) that become radioactive (i.e. activated) when exposed to radiation) on some fuel elements. Post-Irradiation Examinations (PIE) and theoretical analyses are still ongoing in order to better understand the root cause of this very local CRUD formation.

The preparation for the definitive shut down of the Mühleberg reactor (BWR) end of 2019 are ongoing according to plan. The regulator has approved the shutdown and decommissioning plan. Its implementation should start soon after the definite shut down of reactor operation.

The process to find the best site for a deep geological waste repository is ongoing according to plan. Nagra, the company in charge of realizing the final repository for nuclear waste in Switzerland has started deep drillings to acquire detailed information on the geology of the three possible locations for a geological waste repository. These extensive studies will allow the final choice for the location of the site and support the safety analysis.

Nuclear power related research in Switzerland: The focus of the NES division is to deliver a strong contribution to the education of the next generation of nuclear experts, the scientific support for the safe operation of light water reactors (LWRs), the delivery of the scientific basis for the assessment of the deep geological repositories safety and the technology monitoring including research work on Gen-IV concepts.

The financing of a Professorship on Nuclear Engineering at the Polytechnic School of Zürich has been finalized. This insures the further teaching of nuclear engineering at ETHZ after the retirement of Professor M. Prasser. The search for candidates is ongoing. Two professor positions and laboratory heads in the division are also open (Laboratory for simulation and modelling/Laboratory for system analysis). Interview of candidates for the three open Professor positions in the Nuclear Energy and Safety division at PSI are ongoing. The final selection and nomination is expected for the end of the year or beginning 2020.

On June 2019, the EPFL Laboratory of Reactor Physics and Systems Behavior was officially designated as a Collaborating Centre of the International Atomic Energy Agency (IAEA) in the fields of open-source data and code development for nuclear applications. This is the second Swiss collaborating center after the Spiez Laboratory.

United Kingdom

Nuclear energy: Nuclear energy continues to be one of UK's largest low-carbon energy sources, producing around 10% of primary energy and around one fifth of the UK's electricity. The amount of nuclear generation capacity is expected to decrease in the 2020s, as the majority of existing nuclear power stations reach the end of their operational lives. One PWR power station (Sizewell B) has a projected end of life beyond the 2020s and one new plant is currently under construction developed (Hinkley Point C). A rapid recent rise in other solar photovoltaics (PV) and wind power maintains, along with nuclear energy, a significant amount of low-carbon electricity generation on the UK's grid.

The UK has set into law a move to zero net emissions by 2050, this government legislative commitment to zero carbon is the priority policy driver and along with the recent rise in UK solar photovoltaics (PV) and wind power, the UK is planning for a future of significant amount of low-carbon energy. Part of this future energy mix requires replacement of existing nuclear power plant with other Generation III systems and as part of this, the UK has launched a consultation on the use of a new financial model, the Regulated Asset Base, as a way of financing new power plants. This approach has already been highly successful in other large infrastructure projects and is now being investigated for use in nuclear construction projects.

GIF Framework Agreement: In October 2018, the UK submitted its instrument of ratification for the Generation IV International Forum (GIF) Framework Agreement for International Collaboration on Research and Development of Generation IV Nuclear Energy Systems. UK participation in GIF R&D activities has started in 2019.

Following the accession in 2019 of the UK to the Generation IV International Forum (GIF) Framework Agreement, the UK has initially engaged in a minimum of two systems, the SFR and HTGR systems, UK appointments to these systems and programme arrangements have been made, formal agreement from the groups are in progress. The UK has also nominated experts to the SIAP, and various Working groups and Task Forces, these nominees are now participating in these meetings. We believe these appointments are bringing significant nuclear industry experience and expertise to these groups.

Nuclear R&D: The UK perceives nuclear energy as a contributor to secure, low-carbon energy supply in the future and recognizes the importance of investing in innovation to support

this. The current UK nuclear innovation programme runs from 2016 to 2021, the UK is investing ~GBP 180 million in nuclear innovation over this period and covers a number of areas. Of particular note are recent programmes under delivery.

Advanced nuclear fuels and fuel cycles: A further programme of Advanced Fuel has recently been confirmed by the Department of Business Energy and Industrial Strategy. This Fuel development work extends beyond LWR fuels to cover research into improved manufacturing processes for coated-particle fuels, exploration of a range of coatings and deposition and fabrication techniques for the fuel kernels. The fuels programme includes improved fast reactor fuels, including plutonium containing fuels. This experimental work is complemented by a programme to develop and validate innovative techniques to model the physics and performance of new reactor fuel types developed as part of their validation prior to reactor testing. Research into fuel recycling processes is also being undertaken to reduce future environmental and financial burdens. The research aims to demonstrate radical improvements in economics, proliferation resistance, waste generation and the environmental impact of nuclear fuel recycle technologies.

Developing materials, advanced manufacturing and modular build for future reactors: An integrated programme of R&D on advanced materials and manufacturing is underway. This programme encompasses the development of new nuclear materials, the mechanisation and automation of nuclear component manufacture at different scales, pre-fabricated module development and verification and development of appropriate nuclear design codes and standards for use in the development of Gen-IV reactors. It also includes the modularisation and more effective manufacture of reactors in general.

Research to underpin the development, safety and efficiency of the next generation of nuclear reactor designs: This research and innovation is intended for establishing collaborative design projects with partners, with areas of focus being on Generation IV designs and on increased modularity and off-site manufacture for current and future reactors. This is complemented with the development of improved reactor design methodologies for security and safeguards.

Advanced nuclear technologies: The Department for Business, Energy and Industrial Strategy (BEIS) has established an Advanced Modular Reactor (AMR) feasibility and development programme. For this competition, AMRs are defined as a broad group of non-LWR advanced nuclear reactors. The aim is to target improvement on current technology through:

- Generating low cost electricity.
- Increasing flexibility in delivering electricity to the grid.
- Increasing functionality, such as the provision of heat output for domestic or industrial purposes or facilitating the production of hydrogen.
- Alternative applications that may generate additional revenue or economic growth.

Nuclear Innovation and Research Advisory Board (NIRAB): NIRAB was reconvened in 2018 to provide independent expert advice to Government. It published key messages to the UK Government:

- A broad role for nuclear that extends beyond baseload, brings a flexible supply, heat and hydrogen.
- Urgent action is needed to accelerate the development and demonstration of technologies that can service new applications and markets.
- Government support is already having an impact through the Nuclear Innovation Program (NIP). NIRAB recommend over the next spending review (2021-2026) that government consider investing up to GBP 1 billion to accelerate and enable the private sector to commercialize new products.
- Effective delivery of the NIP should occur through a delivery body with responsibility for the strategic direction, delivery and integration of the NIP creating maximum value for money.

United States

Nuclear energy continues to be a vital part of the United States' energy development strategy for an affordable, secure, and reliable energy future. The Department of Energy (DOE) is aggressively working to revive, revitalize, and expand nuclear energy capacity. One of DOE's top priorities is to enable the deployment of advanced nuclear energy systems, including advanced light water and non-water-cooled reactor concepts being pursued by US nuclear developers. The development of improved advanced nuclear reactor designs and technologies, as well as application of advanced reactor technologies to improve the operation of the existing domestic fleet of nuclear power plants is critical to ensuring that nuclear power will be a viable option for the United States (US) energy requirements for generations to come. By focusing on the development of innovative advanced reactors – such as small modular reactors – and investing in the existing fleet, we can ensure a clean, reliable, and secure power source for our nation.

Congressional support for nuclear energy is apparent by the many acts going through the House and the Senate. In addition to the Nuclear Energy Innovation Capabilities Act (NEICA), which was signed by the President on 28 September 2018, and the Nuclear Energy Innovation and Modernization Act (NEIMA), signed by the President on 14 January 2019, the following Acts are currently being considered by the House or the Senate.

The Advanced Nuclear Fuel Availability Act (H.R.1760) was passed by the House on 9 September 2019 and directs the Office of Nuclear Energy in the Department of Energy to develop and deploy high-assay low-enriched uranium for domestic commercial use and to develop a schedule for recovering costs associated with such development. If this Act becomes law, it will pave the way for many advanced reactor fuel types which require fuel with enrichment greater than five per cent.

The Nuclear Energy Leadership Act (S.903, H.R.3306), was introduced on 6 September 2018, and reintroduced in the Senate on 27 March 2019. This bill extends the allowable period of federal power purchase agreements from 10 to 40 years and requires the Secretary to enter an agreement to purchase commercial nuclear power by December 2023 with priority placed on new nuclear technologies. This bill would also direct the Secretary to carry out at least two advanced nuclear reactor design demonstration projects by the end of 2025, and two to five more by the close of 2035. Additionally, the bill states "Not later than 1 year after the date of enactment of this section, the Secretary shall establish a program to make available high-assay, low-enriched uranium, through contracts for sale, resale, transfer, or lease, for use in commercial or non-commercial advanced nuclear reactors".

Additionally, the Advanced Nuclear Energy Technologies Act (H.R.3358), introduced in the House on 19 June 2019, moves to amend the Energy Policy Act of 2005 to direct the Secretary of Energy to carry out demonstration projects relating to advanced nuclear reactor technologies to support domestic energy needs, and for other purposes.

The Nuclear Energy Renewal Act of 2019 (S.2368) was introduced in the Senate on 31 July, 2019 and moves to amend the Atomic Energy Act of 1954 and the Energy Policy Act of 2005 to support licensing and relicensing of certain nuclear facilities, nuclear energy research, demonstration and development.

Finally, the Nuclear Powers America Act of 2019 (S.1134, H.R. 2314) allows a tax credit for investments in qualified nuclear energy property placed in service before 1 January 2026. The credit applies to any amounts paid or incurred for refueling or other specified expenditures for a nuclear power plant for which an application for license renewal was or will be submitted to the Nuclear Regulatory Commission before 1 January 2026.

The FY20 Presidential Budget Request asked for USD 75M specifically for advanced reactor technologies. The House Committee on Appropriations congressionally directed projects with USD 105M for advanced reactor technologies. The Senate Committee on Appropriations did not congressionally direct projects for advanced reactor technologies specifically but did direct USD 10M for a MW-scale reactor, USD 40M for the versatile test reactor, and USD 22M for continuation of two performance-based advanced reactor concepts which refer to Southern Company's project to develop a molten chloride fast reactor and X-energy LLC's high temperature gas reactor. Separately, the Senate directed funds for proposals from industry to

build two demonstration advanced reactors. The Committee recommended USD 200 000 000 for the first year of the two demonstrations.

DOE continued an industry-focused, comprehensive, multi-year funding opportunity announcement (FOA) to support innovative, domestic nuclear reactor designs and technologies that have high potential to improve the overall economic outlook for nuclear power. These projects address first-of-a-kind nuclear demonstration readiness, advanced reactor development, and regulatory assistance. In the sixth round, this FOA awarded three projects in three states for a total of approximately USD 15 million in funding including an award to FirstEnergy Solutions Corporation which will develop a light water reactor integrated energy system. The proposed project installs an electrolysis (LTE) unit at the Davis-Besse Nuclear Power Station. The total provided to date for all six rounds of awards is approximately USD 195 million. Subsequent quarterly application review and selection processes will be conducted over the next three years. Additionally, in continuation of the Gateway for Accelerated Innovation in Nuclear (GAIN) effort to move innovative nuclear energy technologies towards commercialization, two companies, Analysis and Measurement Services Corporation, and HolosGen, LLC, were awarded funding during the fourth quarter of 2019.

In the area of light water reactors (LWRs), construction of two Westinghouse AP1000 pressurized water reactors at the Alvin W. Vogtle Electric Generating Plant in Georgia continues, with completion of construction expected by 2021 and 2022 for Units 3 and 4, respectively. On 22 March 2019, Secretary Perry visited the Vogtle plants and announced that DOE reached financial close for USD 3.7 billion in additional guarantees of loans. The Department will now guarantee a total of up to USD 12 billion in loans for the project, including existing guarantees of up to USD 8.3 billion in loans to Georgia Power Company, Oglethorpe Power Corporation, and the Municipal Electric Authority of Georgia Power subsidiaries provided in 2014 and 2015.

The DOE LWR Sustainability (LWRS) program conducts research and development to enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetime of this reliable source of electricity. The program is currently focused on plant modernization, flexible plant operation and generation, physical security, risk-informed systems analysis, and materials research. With respect to extending operating lifetimes, Florida Power & Light became the first utility to submit a subsequent license renewal for their Turkey Point plant in January 2018. Approval of this license renewal would allow these units to operate until 2052 and 2053. The Nuclear Regulatory Commission has set an 18-month review period for the Turkey Point application with a final decision likely in 2020. Exelon and Dominion also submitted subsequent license renewal applications for the Peach Bottom plant in Pennsylvania and the Surry plant in Virginia, respectively, which would mean a total of up to 80 years of operation for these reactors. Dominion also expects to submit a subsequent license renewal application for the North Anna reactors at the end of 2020. Additionally, Duke Energy announced in September 2019 that it intends to renew the operating licenses of 11 reactors for an additional 20 years. Duke Energy plans to submit the license renewal application for Oconee Nuclear Station in 2021, followed by its other nuclear stations. Oconee is the company's largest nuclear station, with three generating units that produce more than 2 500 megawatts (MW).

A number of plants are under economic pressure to close. Eight units have shut down since 2013, leaving 96 operating commercial nuclear reactors in the United States. In response to the economic pressure, state and local governments and regional electricity markets are considering changes to properly value nuclear power's contributions to clean energy production and grid stability. Following successful actions by New York, Illinois, Connecticut, and New Jersey, a draft law updating the Pennsylvania Alternative Energy Portfolio Standards (AEPS) Act to include nuclear energy was introduced to the state's legislature in March 2019. However, the efforts in Pennsylvania were not successful and this led to the shutdown of Three Mile Island Unit 1 in September 2019. Separately, in July 2019, Ohio passed a bill that would charge new fees to consumers statewide to create a fund to help keep FirstEnergy Solutions' two nuclear power plants open. However, there are petitions to put this bill up for a public referendum vote in November 2020 so it is uncertain whether the bill will remain law in the next year.

DOE views small modular reactors (SMRs) as an innovative and emerging technology that can help meet the nation's growing energy demands, providing a safe, affordable option for the replacement of aging fossil plants, or for deployment in remote locations where electricity

demand is lower. From 2012 to 2017, the DOE SMR Licensing Technical Support (LTS) program provided cost-shared financial support to accelerate the design, certification, and licensing of innovative SMR technologies that have the potential to improve SMR safety, operations, and economics of these designs. Among SMR LTS program participants, NuScale Power, LLC made significant progress towards its certification goals, meeting key project milestones such as completion of critical plant component testing and development of plant safety analyses, and the submittal of its design certification application (DCA) to the NRC on 12 January 2017. A significant outcome of this review involved NRC acceptance of the NuScale position regarding eliminating the need for Class 1E power for its SMR design. This is the first time that a reactor designer, large or small, has established a basis for safe nuclear reactor operations without reliance on, or requirement for, any safety-related electrical power. The NRC completed the 3rd phase of the DCA review in July 2019, completing an Advisory Committee on Reactor Safeguards (ACRS) review on all chapters of the Safety Evaluation Report (SER) with some open items remaining, and is on track to complete the review on or before the January 2021 schedule.

In FY 2018 and FY 2019, NuScale received two separate awards (Phases 1 and 2) from the Department through the industry-focused FOA (mentioned above) to continue the licensing work, finalize the design, and develop the supply chain required for commercialization. Phase 1 of this effort was completed in March 2019, and Phase 2 will be completed in September 2019. Additional Phases of work are expected to be proposed to have the plant fully commercialized and available for deployment in FY 2026.

NuScale has also partnered with Utah Associated Municipal Power Systems (UAMPS) to deploy the first NuScale SMR, for which a preferred site was identified at the Idaho National Laboratory (INL). UAMPS is currently developing a business case to inform its decision on whether to proceed in the development of a combined license application (COLA) for the proposed site. If favorable, a COLA will be developed and submitted to the NRC sometime in the 2023-2024 time frame with commercial operation projected for the mid-to-late 2020s. On 25 September 2018, NuScale Power announced that they selected Virginia-based BWX Technologies, Inc. (BWXT) to start the engineering work to manufacture NuScale's small modular reactor (SMR). BWXT immediately started work on the first manufacturing phase of NuScale's SMR, which is expected to continue through June 2020.

In May 2016, the Tennessee Valley Authority (TVA) submitted to the NRC a technology-neutral early site permit (ESP) application for the development of an SMR project at its Clinch River site in Tennessee. The ESP application, which references a plant parameter envelope encompassing characteristics of all US light water-based SMR designs currently under development, was docketed by the NRC on 30 December 2016. On 3 April 2019 the ESP review was completed and the final Environmental Impact Statement was issued by the NRC, the final Safety Evaluation Report was issued on 14 June 2019, and the NRC Mandatory Hearing occurred on 14 August 2019. Pending approval from the commission, it may be possible for the ESP to be issued in the 1st or 2nd quarter of fiscal year 2020.

Another important initiative within DOE involves the development of accident-tolerant fuels, a new fuel for the current generation of light water reactors with higher performance and greater tolerance for severe, beyond-design-basis accidents. In addition to enhanced performance, these fuels would give operators additional time to respond to conditions such as those experienced at Fukushima Daiichi. The congressionally directed program is framed on a phased approach from feasibility to qualification and is executed through strong partnerships between national laboratories, universities, and the nuclear industry. The industrial research teams, led by Framatome, Westinghouse, and General Electric, are conducting irradiations of their proposed fuels at the INL Advanced Test Reactor and other facilities in the United States. Several US nuclear utilities are interested in accelerating the development and use of accident-tolerant fuel concepts and in arrangement with the industrial research teams have initiated installation of lead test rods in commercial reactors in 2018 and commercial lead test assemblies continue in 2019. Commercial batch loads may start as early as 2023.

In support of the nuclear energy industry's long-term viability, DOE is working to train the next generation of nuclear engineers and scientists by sponsoring research and student educational opportunities at US universities. In March 2019, the Nuclear Energy University Program (NEUP) program announced awards of more than USD 5 million for 45 undergraduate

scholarships and 33 graduate fellowships to students pursuing nuclear energy-related disciplines. Through this program, undergraduates receive a USD 7 500 scholarship, while fellowship winners receive up to USD 50 000 annually over the next three years. The graduate fellowships also include USD 5 000 towards a summer internship at a US national laboratory. For FY19, DOE also awarded more than USD 28.5 million through NEUP to support 40 university-led nuclear energy research and development projects in 23 states. NEUP seeks to maintain US leadership in nuclear research across the country by providing top science and engineering faculty and their students with opportunities to develop innovative technologies for civil nuclear capabilities. Additionally, DOE continues to run the Millennials for Nuclear Caucus, a nuclear energy outreach and communications group to further engage the next generation of nuclear engineers.

As DOE strives to meet the challenges of energy security in safe and economically viable ways, the United States will rely heavily upon nuclear energy as a key element in modernizing the US energy portfolio. The Department recognizes the need to reinvigorate and revitalize the US nuclear industry to ensure that nuclear power can remain a part of the domestic energy mix for decades to come.