Strategic Energy Technology Plan

Key Action 10 Implementation Plan:

'Maintaining a high level of safety of nuclear reactors and associated fuel cycles during operation and decommissioning, while improving their efficiency'

30 April 2019

Preamble

Only interested SET Plan countries[1] will participate on voluntary basis in the activities presented in this Implementation Plan according to their national priorities. Fission-related R&I actions are expected to be supported primarily through the national programmes of interested SET Plan countries and by industry.

It should be recalled that financial support (if any) via the Euratom Research and Training Programme will continue to be restricted to research addressing safety, radioactive waste/spent fuel management, radiation protection as well as education and training, in accordance with the underlying legal framework Council Regulation (EURATOM) No 1563/2018 of 15 October 2018 on the Research and Training Programme of the European Atomic Energy Community (2019 -2020) complementing the Horizon 2020 Framework Programme for Research and Innovation and with its successor post-2020.

[1] Formal notification of endorsement of Implementation Plan received from: BE, CH, CZ, ES, FI, FR, HR, HU, IT, LT, NL, PL, RO, SI, SK, TR & UK. Following the SET Plan Steering Group meeting on 13th February 2019.

Contents

Preamble ... 2

Executive summary ... 4

Introduction ... 5

1. Safety and Efficient Operation of Nuclear Power Plants ... 6

R&I Activity 1: Plant safety, risk assessment and severe accidents, integrity assessment of systems, structures and components ... 6

R&I Activity 2: Innovative LWR Generation III design, improved reactor operation and fuel developments ... 7

R&I Activity 3: Effects of low doses of ionising radiation ... 9

2. Radioactive waste/spent fuel management, geological disposal and decommissioning ... 10

R&I Activity 4: Geological Disposal ... 10

R&I Activity 5: Spent fuel and radioactive waste management, decommissioning ... 11

3. Efficiency and competitiveness aspects, sustainability and better use of fuel resources, and cogeneration of heat ... 12

R&I Activity 6: Partitioning and Transmutation, nuclear fuel reprocessing, and qualification of new fuel for demonstrators ... 12

R&I Activity 7: Innovative materials to improve plant safety and efficiency, and qualification for operation under Gen-IV conditions ... 13

R&I Activity 8: Support the development, licensing, construction and commissioning of high priority Gen-IV demonstrators, and for alternative reactor technologies ... 14

R&I Activity 9: Cogeneration of heat and electricity ... 16

4. Fusion ... 17

R&I Activity 10: Implementation of the European fusion roadmap, F4E support to the construction of ITER and following operation, and preparation of DEMO as a step towards a fusion power plant ... 17

Key enabling conditions (KEC) ... 19

KEC 1: Nuclear security and safeguards ... 19

KEC 2: Stable and predictable investment conditions ... 20

KEC 3: Harmonization of licensing rules, certification, and standards ... 21

KEC 4: ETKM Education and Training ... 22

KEC 5: Supporting Infrastructures ... 23

KEC 6: INCO International cooperation ... 25

ANNEXES ... 32

Annex 1: References (complementing annex 2 of the Declaration of Intent) ... 33

Annex 2: List of abbreviations and acronyms ... 37

Executive summary

This is an Implementation Plan (IP) supporting the execution of SET Plan Key action no. 10 concerning increased safety in the use of nuclear energy. This IP aims, in accordance with current legislation and Union policy, to maintain a high level of safety of nuclear reactors in Europe and associated fuel cycles during operation and decommissioning, while improving their efficiency. It provides a roadmap for attaining the targets of the SET-Plan Declaration of Intent[1] in the nuclear field, agreed by interested Member States, research and industry stakeholders. .

Nuclear Research and Innovation actions (R&I) foreseen in the plan will be supported primarily through national programmes of interested Member States and by industry. Support from the Euratom Research and Training Programme will be strictly limited to the research areas covered by Council Regulation (Euratom) no. 1563/2018 and its successor. This plan is indicative and not legally binding on the participants.

Today the main IP priority is safety of the current and future nuclear fleet in Europe, management of spent nuclear fuel, other radioactive waste and decommissioning (Figure 1). Continuous improvement of nuclear safety requires addressing of broad spectrum of issues going often beyond R&I. Apart from organisational, operational and regulatory aspects, there are also important considerations concerning the availability of critical research infrastructures.

. Moving towards 2030 (Figure 2), the goal of interested countries is to develop reactors offering process heat, small modular reactors (SMR) and co-generation plants. The ultimate objective is the development of reactors' designs offering increased uranium resource efficiency and low-level of long-lived waste generation.

This plan provides detailed outline of ten main R&I activities grouped in four areas of (i) nuclear safety, (ii) radioactive waste management, (iii) efficiency and competitiveness, and (iv) fusion. Implementation of these actions will depend on Member States decision regarding their capabilities in nuclear research. To support them, this plan also identifies and specifies a number of Key Enabling Conditions (KECs) in nuclear security, investment conditions, standardisation, education and training, research infrastructures (Figure 3) and international cooperation.

The present document was drafted around a vision for the European energy system transitioning to a low carbon economy. It should be regarded as a catalyst that will stimulate enhanced coordination of national programmes, public and private funding and joint actions in line with the agreed principal themes which involve not only the specific targets but also, where necessary, the key enabling conditions boosting research and demonstration efforts.

[1] This Declaration of Intent was endorsed by Belgium, the Czech Republic, Finland, France, Italy, the Netherlands, Poland, Slovakia, Spain and the United Kingdom.
https://setis.ec.europa.eu/system/files/integrated_set-plan/setplan_doi_nuclear-final.pdf

Introduction

The Energy Union strategy[2] is built on the ambition to achieve a fundamental transformation of Europe's energy system in a cost-effective way. This will be achieved by moving to more sustainable, smarter, more flexible, more decentralized, more integrated, secure and competitive ways of delivering energy to consumers. As part of the deliverables of the Energy Union strategy, the European Commission adopted a Communication for an Integrated Strategic Energy Technology (SET) Plan[3]. The Communication identifies ten key priority actions to accelerate the energy system transformation through coordinated or joint investments between EU Member States, private stakeholders (including research and industry) and the European Commission. These key priority actions have been defined building on the proposals of the Integrated Roadmap (that was developed with stakeholders and Member States) and in line with the new political priorities defined in the Energy Union strategy.

The goal of the Implementation Plan is to translate the SET Plan key actions into specific recommendations for R&I engagements and/or policy measures related to innovation, identifying strategy and R&I activities that need to be implemented to reach targets set in the Declaration of Intent, coordinating R&I activities and stimulate joint actions by funding actors, also considering international cooperation.

This Implementation Plan for SET-Plan key action 10 ‘increase safety in the use of nuclear energy’ outlines ten research and innovation activities required to achieve the targets agreed by stakeholders and interested Member States in the 2016 Declaration of Intent. Nominated national representatives contributed to the drafting of the implementation plan of task working group on key action n.10 chaired by UK and co-chaired by FR and BE.

Any of the research activities and actions addressing barriers to nuclear research presented in this Implementation Plan are open to all Member States and research stakeholders which are interested. Equally, there is no requirement or obligation for any MS to participate in any activities that do not fit within their national policy in this area. The investment of EU-funded research and training activities will be strictly defined by the scope of Regulation EURATOM [] and its successors.

When this document indicates an EU Member State, this should be understood as a Member State interested in the implementation of the Implementation Plan.

[2] COM(2015) 80
[3] C(2015) 6317 final

Detailed R&I activities' report

1. Safety and Efficient Operation of Nuclear Power Plants

KEY ISSUES

Secure the safe operation of nuclear power plants by continuously improving their safety while maintaining the competitiveness and contribution of carbon emission reduction of nuclear energy to the mix.
Provide further scientific evidence on the radiation risk of low doses due to industrial and medical applications.

R&I Activity 1: Plant safety, risk assessment and severe accidents, integrity assessment of systems, structures and components

Scope: This includes the development of models and codes for probabilistic safety assessments (PSA) and deterministic assessments of plant transients, use of advanced safety methodologies (including better simulation methods and consideration of ageing effects), assessment of operational margins and new reactor safety systems (increased diversification, robustness and use of passive systems for safety functions) as well as seismic and fire propagation modelling. The highest priority safety research challenges for preventing severe accidents are related to in-vessel and ex-vessel corium/debris coolability and interactions, containment behaviour including hydrogen explosion risks, evaluation of the source term for any potential radioactive releases, potential impact on the environment and evaluation of scenarios should a severe accident occur, emergency preparedness and response. It also includes integrity assessments of systems, structures and components, in-service inspection and qualification, definition of updated integrity requirements, load quantification, ageing and reliability of components of different systems using different types of materials being metallic, concrete or polymers.

Deliverables:

Main deliverables are related to generic and accurate risk assessment methods improving safety, reliability and availability of systems for present and future reactors, reinforcing Nuclear Power Plant safety provisions through a better understanding of some predominant phenomena, updating of Severe Accident Management Guidelines (SAMGs) and designing new prevention devices/systems mitigating the consequences of any severe accident. They also relate to the development of methods and tools to increase safety, availability of systems, structures and components needed for reliable and safe management of nuclear power plants, monitoring, prevention and mitigation of the ageing of materials and components for long-term operation.

Expected impact:

Improve safety in operation and by design

Improve performance in Long Term Operations (LTO) conditions,

Improve modelling phenomena in NPPs,

Improve Preparedness for Nuclear and Radiological Emergency, Response and Recovery, and obtain a high reliability of structural components

KPIs:

Implementation of stress tests in Europe

R&D investments / Costs: EUR 250 million / year (MS, 2017-21),

Timeline: 5 to 10 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. Participants are mainly members of NUGENIA association (106 full members and 7 honorary members from 24 countries (as of September 2017): Industry, utilities, research institutions, SMEs and technical safety organisations).

Implementation and monitoring:

- EU/Euratom Nuclear Safety Directive (2009/71/Euratom) and its latest amendment (2014/87/Euratom), implementation of EU nuclear stress tests and peer reviews
- High-performance Monte Carlo methods for safety demonstration, from proof of concept to realistic safety analysis and industrial applications, NURESIM platform (European platform for nuclear reactor simulation), McSAFE yearly public report in 2018-20
- New approach to reactor safety improvements by providing improved supporting tools for operational and severe accident management, NARSIS final report by 2021
- In-vessel melt retention severe accident management strategy for existing and future NPPs, improved numerical tools and harmonised methodology, IVMR final report by 2019
- CANDU safety R&D progress reports, 2017-30
- Fast nuclear emergency tools to improve capabilities of a technical emergency centre, FASTNET final report by 2019
- Safe long-term operation of light water reactors based on improved understanding of radiation effects in nuclear structural materials, SOTERIA progress and final reports, 2015-19
- Increasing safety in nuclear power plants by covering gaps in environmental fatigue assessment, INCEFA-PLUS progress and final reports, 2015-20
- Advanced structural integrity assessment tools for safe long-term operation, ATLASplus progress and final reports, 2017-21
- Advanced inspection of complex structures, ADVISE progress and final reports, 2017-21
- Non-destructive Evaluation (NDE) System for the inspection of operation-induced material degradation in nuclear power plants, NOMAD progress and final reports, 2017-21

R&I Activity 2: Innovative LWR Generation III design, improved reactor operation and fuel developments

Scope: Innovative reactor designs and technologies for the medium term (including Small Modular Reactor (SMR) and Supercritical Water-cooled Reactor (SCWR)) able to reduce the generation of radioactive waste and improve the use of natural resources. R&D should support existing and new light water reactor (LWR) concepts to improve long-term operation by design, safety by design, passive systems and to develop innovative components fabrication fostering reduced maintenance and enhanced economics. Digital representation of NPPs will be developed for all stages including design, operation and maintenance. Research programmes will enable the development of digital twins for the major components such as reactor cores or steam generators. In addition, advanced cooling systems will be developed to minimize environmental impacts. Research on human and organisational factors on plant safety and operation is embedded, safe long-term operation, safe integration of digital technologies, safe and optimal core management. Operational safety and flexibility of existing Gen II-III plants is encompassed, especially with new build, cost benefit analysis, and options for large Gen-III reactors and Small and Modular Reactors of different concepts to respond to demand fluctuations, R&D studies on how to optimize the combination of renewable and

nuclear power plant electricity generation, grid integration and how to better use any excess generation capacity of the nuclear power plants.

Deliverables:

Main deliverables are related to evolutionary technology for mid-term application, breakthrough technology for the longer term, advanced LWR designs with higher conversion ratio or Small and Modular Reactors as well as digital twins. They are also related to safety improvements of the present fuels, new fuel concepts for present and future reactors such as accident tolerant fuels (ATF), recommendations for improvement of safety culture and man-machine organisations (MMO), and safe integration of digital technologies. Confirmation of the margins for flexible and safe operation of nuclear reactors to adapt to predicted demand, assessment of integration of nuclear generation with energy storage options, technologies to optimize integration of nuclear plants into future energy grids or smart grids, including multiple-criteria and cost benefit analyses, assessment of options available on how to integrate nuclear and variable renewable generations; development of technologies to optimize any integration; and increase of public awareness are also included.

Expected impact:

Improve safety performance, reliability of accident tolerant fuel (ATF) and long-term operation (LTO)

Improved efficiency through digital design and advanced modelling

Contributing to facilitate the secure and efficient integration of nuclear systems and variable renewable energy sources into a low-carbon and smart energy system

KPIs:

New materials processing, manufacturing and assembly technologies for enhanced performance

Develop advanced digital approach to life plant management

Implementation of flexible operations on existing plants and ensure flexibility by design for new build

R&D investments / Costs: EUR 270 million / year (MS, 2016-20),

Timeline: 5 to 15 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. Participants are mainly members of NUGENIA (106 full members and 7 honorary members from 24 countries (as of September 2017): Industry, utilities, research institutions, SMEs and technical safety organisations).

Implementation and monitoring:

- European tools and methodologies for an efficient ageing management of nuclear power plant cables, Team Cables final report by 2022

- Numerical twins, Big Data Handling, passive systems progress reports

- Advanced manufacturing and materials, safety engineering progress reports

- First-of-a-kind EPR unit (European Pressurized Reactor or Evolutionary Power Reactor) of 1600 MWe connected to the grid in Europe by 2020

- Innovative cladding materials for advanced accident tolerant fuels (ATFs) for use in Gen-II and Gen-III/III+ Light Water Reactor, validated in industrial-relevant environment (i.e. under neutron irradiation), IL TROVATORE progress and final reports, 2017-22

- Licensing of western nuclear fuel manufactured for reactors of VVER design operating in the EU, ESSANUF progress and final report, 2015-18

- Role of technologies in an energy efficient economy – model-based analysis of policy measures and transformation pathways to a sustainable energy system (REEEM), Navigating the Roadmap for Clean, Secure and Efficient Energy Innovation (SET-Nav), Analysis of the European energy system

under the aspects of flexibility and technological progress (REFLEX), Modelling the Renewable Energy Transition in Europe (MEDEAS, progress and final reports, 2016-19

- Fundamental understanding of smart grid stability, technology development, smart grid modelling, load following, cybersecurity, progress reports, 2016-20

R&I Activity 3: Effects of low doses of ionising radiation

Scope: The present state of knowledge and main R&D activities are in line with priorities identified within MELODI's Strategic Research Agenda, ALLIANCE's (radioecology) and EURADOS's (dosimetry), NERIS (nuclear emergency preparedness) and EURAMED (medical exposures) strategy objectives. It is relevant for workers that are professionally exposed to low level doses, within the industrial but also health sectors, and to the patients receiving low doses for diagnosis or treatments.

Deliverables:

Main deliverables are related to better understanding of dose response relationships for cancer or non-cancer effects, human radiation sensitivity, hereditary and trans-generational effects, improvement of the nuclear and radiological emergency response and recovery methodologies, better understanding of radiation in the environment and improving dosimetry methodologies.

Expected impact:

Capitalise the Multi-disciplinary European Low-Dose initiative on low-dose radiation risk research (MELODI) together with the European Radiation Dosimetry group on dosimetry research (EURADOS), the European radioecology group on radioecology research (ALLIANCE), nuclear emergency preparedness (NERIS) and medical low dose exposures (EURAMED)

KPIs:

Understanding mechanisms contributing to radiation risk at low dose and dose-rate exposure

Update fundamental dose concepts and improved radiation protection of workers and the public

Improve human and environmental protection by integrating radioecology

R&D investments / Costs: EUR 150 million / year (MS, 2015-20),

Timeline: 10 to 20 years

Modality of implementation:

Increased cooperation and joint programming between EU and Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. The European Joint Programme CONCERT consortium is composed of 34 National Programme Managers and Programme Owners from 23 European Member States including Norway and Switzerland, and five radiation protection associations being MELODI, ALLIANCE, NERIS, EURAMED and EURADOS.

Implementation and monitoring:
- EU/Euratom Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, Member States transposition, progress report by 2018
- European concerted programme on radiation protection research aiming to contribute to the sustainable integration of European and national research programmes in radiation protection, European Joint Programme EJP-CONCERT yearly reports, 2015-20
- Implications of medical low-dose radiation exposure to enhance the scientific bases and clinical practice of radiation protection, MEDIRAD results, recommendations, 2017-21

2. Radioactive waste/spent fuel management, geological disposal and decommissioning

KEY ISSUES

To provide long-term radioactive waste/spent fuel management solutions, the development of a world-leading decommissioning sector, including through R&D on characterisation and conditioning of these waste, building on the EU's safety culture and know-how in waste management by 2030, and operation in Europe of the world's first deep geological repositories for spent nuclear fuel and/or heat-generating high-level radioactive waste by 2025.

R&I Activity 4: Geological Disposal

Scope: The main thematic areas for demonstration include research in support of the safety case, waste forms and their behaviour, technical feasibility and long-term performance of repository components, development strategy of the repository, safety of its construction and operation, monitoring, governance and stakeholder involvement.

Deliverables:

Main deliverables are related to the demonstration of the geological disposal technologies at full scale and with realistic load aiming at the operation of prototype installations by 2025.

Expected impact:

Safety, technical feasibility and long-term performance of repository

KPIs:

Realisation of a first geological disposal in Europe

Operation of prototype installations by 2025

R&D investments / Costs: EUR 150 million / year (MS, 2016-20),

Timeline: 10 to 20 years

Modality of implementation:

Increased cooperation and joint programming between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations potentially benefitting from a Euratom contribution with high leverage. A European Joint Programme on Radioactive Waste Disposal would enable 'programme owners' and 'programme managers' from over 21 EU Member-States to support any coordination at European level of national research programmes and the associated research and development (R&D) activities on geological disposal for high activity long lived radioactive waste.

Implementation and monitoring:
- Implementation of Council Directive 2011/70/Euratom that establishes a Community framework for the responsible and safe management of spent fuel and radioactive waste (both from fission and fusion systems) by Member States through transposition, national programmes and national reports provided on 3 year basis

- Towards a European Joint Programming, JOPRAD final report by 2017 and EJP on Radioactive Waste Disposal expected to be launched in 2019

- Demonstration of the geological disposal technologies at full scale and with realistic load aiming at the operation of prototype installations by 2025

R&I Activity 5: Spent fuel and radioactive waste management, decommissioning

Scope: This includes research on long-term behaviour of the spent fuel and high-level wastes in interim storage conditions, retrievability, radioactive waste management for other radioactive waste categories and radiation protection during operation, maintenance, dismantling and decontamination of nuclear facilities.

Deliverables:

Main deliverables are related to the demonstration of long-term behaviour and assessment of the desired retrievability of spent fuel/radioactive waste from disposal facilities, operational waste minimization and management, efficient and remote dismantling technologies, and decommissioning.

Expected impact:

Ensure that interim storage, operational minimization of waste, decommissioning, and geological disposal provide a solution for the management of high-level wastes, protection of the environment and of the population. Transfer of knowledge and competences between generations and across Member States' programmes in decommissioning, radioactive waste and spent fuel management.

KPIs:

Improve operational excellence, minimise operational and decommissioning wastes

Implementation of the strategy for interim storage, repository, safety, operations, monitoring of wastes, and stakeholder involvement

R&D investments / Costs: EUR 100 million / year (MS, 2017-20),

Timeline: 5 to 20 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations.

Implementation and monitoring:
- Improved nuclear site characterization for waste minimization, safe spent fuel storage and disposal as well as safe decommissioning operations under constrained Environment, INSIDER progress and final reports, 2017-21

3. Efficiency and competitiveness aspects, sustainability and better use of fuel resources, and cogeneration of heat

KEY ISSUES

Increase sustainability in the long term by making more efficient use of nuclear fuel resources, by minimising high level radioactive wastes and by optimising their management. Ensure the availability of suitable materials for sustainable nuclear energy systems to withstand high temperatures and high irradiations using aggressive coolants, so as to fully guarantee their safe and efficient operation including cogeneration and heat applications. In the longer term, thorium-based fuels in Molten Salt Reactors (MSR) could be developed.

R&I Activity 6: Partitioning and Transmutation, nuclear fuel reprocessing, and qualification of new fuel for demonstrators

Scope: Separating and recycling Minor Actinides (MA) through Partitioning and Transmutation (P&T) within Gen-IV fast neutron critical reactors or sub-critical Accelerator Driven Systems (ADS) such as MYRRHA can reduce the volume of ultimate nuclear waste by a factor of at least 50 in comparison with the open cycle currently promoted in some countries. The industrial deployment of Generation-IV reactors in Europe is likely to be progressively introduced at a gradual pace in order to benefit from lessons learned from the operation of prototypes. The availability of dedicated fuel for fast neutron reactors which requires LWR fuel reprocessing and adequate fuel cycle facilities is challenging. Closing the fuel cycle involves different steps including fuel reprocessing for the separation of uranium and plutonium from residual waste products, and fabrication of recycled fuel in dedicated plants producing mixed oxide fuel (MOX) as driver fuel for the European Sustainable Nuclear Industrial Initiative (ESNII).

Deliverables:

Main deliverables are related to partitioning which requires further basic research to bring the reprocessing technologies applied to minor actinides from a laboratory scale to an industrialization stage. R&D on transmutation applies to specific reactor technologies and includes the fabrication of fuels for transmutation having a high content of plutonium and Minor Actinides, optimization of national and regional fuel cycle strategies using partitioning and transmutation and updated nuclear data libraries to optimize those technologies. It also relates to the fabrication of MOX driver fuel for ESNII

Expected impact:

Mastering of partitioning and actinide fuel fabrication processes in the framework of P&T

Fabrication of americium (Am) bearing segment fuel pin

KPIs:

Reprocessing technologies applied to MA from a laboratory scale to an industrialization stage

R&D investments / Costs: EUR 100 million / year (MS, 2017-25),

Timeline: 10 to 30 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. Partitioning and Transmutation activities are mainly encompassed within MYRRHA, an innovative research project, led by SCK•CEN (BE). In September 2018, the federal government of Belgium decided to invest 558 million euros during the 2019-2038 period in phase 1 of MYRRHA, including: (i) the construction of the MYRRHA accelerator up to 100 MeV and its proton target facilities; (ii) the preparatory phases of design and R&D for extending the accelerator up to 600 MeV; and (iii) design and R&D for the MYRRHA reactor. MYRRHA is the very first prototype of a nuclear reactor driven by a particle accelerator in the world. Partitioning and fuel recycling strategies are led by CEA (FR), NNL (UK) and JRC, and gathers 24 partners from 10 EU countries.

Implementation and monitoring:

- Integrated Oxide fuels recycling strategies in support to Gen-IV, GENIORS progress and final reports, 2017-21
- MYRRHA Research and Transmutation Endeavour, MYRTE progress and final reports, 2015-19
- Reprocessing and fabrication process development for Fast Reactor Mixed Oxide Fuel fabrication, reprocessing / recycling facility, progress report, 2017-2025
- Integrated Oxide fuels recycling strategies in support to Gen-IV, GENIORS progress and final reports, 2017-21

R&I Activity 7: Innovative materials to improve plant safety and efficiency, and qualification for operation under Gen-IV conditions

Scope: R&D performed within EERA Joint Programme on Nuclear Materials (JPNM) include: (i) qualification of structural materials to be used in prototype reactors developed within ESNII Gen-IV and for Molten Salt Reactors MSR, and able to sustain higher temperatures and fast neutron irradiation exposures; (ii) development and qualification for the nuclear environment of advanced steels for high temperature, fast spectrum and high burn-up operation; (iii) development and characterization of advanced ceramic/metal composites for very high temperature nuclear environments and compatibility with gas or liquid metals; (iv) development of physics-based multiscale models for the prediction of the behaviour of structural materials under fast spectrum irradiation and in contact with specific coolants; (v) determination of the high quality data needed for the development of advanced fuels and the improvement of fuel performance codes; and (vi) development of physics-based models for the understanding of the behaviour of advanced fuels through cross-cutting multiscale modelling and separate effect experiments.

Deliverables:

Main deliverables are related to qualifying structural and fuel materials suitable for the construction of efficient and safe Gen-IV reactor systems; Pre-normative research recommendations for component design rule modifications in support to ESNII's demonstrators, and prototypes for MSR; Innovative materials for continuously increased safety and efficiency of Gen-IV reactor systems; Standardized test procedures to codify and disseminate results of R&D&I activities on advanced materials; Robust understanding of the physical mechanisms determining the response of materials to Gen-IV reactor operating conditions and relevant predictive models.

Expected impact:

Development for ESNII demonstrators or MSR of prototypes of materials, innovative steels, refractory materials, ceramic composites and metal-base alloys, modelling and experimental validation of materials, irradiation and qualification of advanced fuels

KPIs:

Obtain suitable materials and fuels for advanced / innovative reactor designs

R&D investments / Costs: EUR 50 million / year (MS, 2017-21),

Timeline: 10 to 20 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. EERA-JPNM is an Alliance of European public research centres and universities, launched under the European Strategic Energy Technology Plan (SET-Plan) initiative in 2007. It is coordinated by CIEMAT (ES) and gathers 56 partners from 18 European countries, including also JRC.

Implementation and monitoring:

- Investigations supporting MOX fuel licensing in ESNII prototype reactor, INSPYRE progress and final reports, 2017-21
- Investigations supporting liquid fuel behaviour for MSR demonstrators, SALIENT publications, 2017-23
- Generation-IV materials maturity, GEMMA progress and final reports, 2017-21
- Multiscale modelling for fusion and fission materials, M4F progress and final reports, 2017-21
- EERA JPNM Pilot Projects' reports, 2017-21

R&I Activity 8: Support the development, licensing, construction and commissioning of high priority Gen-IV demonstrators, and for alternative reactor technologies

Scope: ESNII has agreed upon its priorities and supports ASTRID-like Generation-IV sodium-cooled fast reactor demonstration plant as the reference technology and MYRRHA, a flexible fast spectrum lead-bismuth-cooled irradiation facility able to contribute to the demonstration of Generation-IV lead-cooled technology, transmutation at an industrial scale and to irradiate materials for tests in support to other technologies. The lead-cooled technology has been identified as the short-term alternative to sodium-cooled fast reactor reference technology with ALFRED as a Generation-IV demonstrator (LFR). Gas-cooled technology is a longer term alternative technology with ALLEGRO as a Generation-IV demonstrator (GFR) as endorsed by ESNII. Also, Small and Modular Reactors (SMR) based on fast reactor technologies could be further developed. On the longer term, thorium-based fuels and Molten Salt Reactors (MSR) could be developed. Access to experimental facilities is needed and benefitted from a detailed survey listing available and needed facilities in the framework of Euratom projects ADRIANA and ESNII+.

Deliverables:

Main deliverables are related to the start of operations of demonstration facility MYRRHA by 2030.

Main deliverables are also related to developing technologies in support of the system design and component development; as well as material qualification and specific coolant technology for those alternative reactor technologies, i.e. SFR, LFR, GFR and MSR on the longer term.

Expected impact:

Construction of MYRRHA demonstrator

Construction of ALFRED (shorter term) and ALLEGRO (longer term) demonstrators, supporting R&D allowing development of a SFR ASTRID-like demonstrator, supporting R&D allowing development of an MSR demonstrator internationally

KPIs:

Basic design of the SFR Demonstrator ASTRID

Basic design, licensing and start of construction of MYRRHA Accelerator Driven System ADS

Basic design, licensing and start of construction of LFR ALFRED Demonstrator

Basic design, licensing and start of construction of GFR ALLEGRO Demonstrator

R&D supporting the development of MSR Demonstrator

R&D supporting the development of SFR ASTRID-like demonstrator

R&D investments / Costs: ASTRID EUR 100 million / year (FR, 2012-19), MYRRHA EUR 40 million / year (BE, 2012-19), ALFRED EUR 40 million / year (RO, IT, 2016-19), ALLEGRO EUR 20 million / year (CZ, 2017-20), MSR EUR 20 million / year (NL, FR, 2015-19),

Timeline: 10 to 30 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations.

Demonstration of a new generation (Gen-IV) of fission reactors with increased sustainability is mainly via the European Sustainable Nuclear Fission Industrial Initiative (ESNII). Sodium-cooled Fast Reactor (SFR) technology is considered to be the reference technology since it already has substantial technological and operations feedback in Europe. The basic design of the ASTRID demonstrator (Advanced Sodium Technological Reactor for Industrial Demonstration) should be achieved by 2019.

Lead-cooled Fast Reactor (LFR) technology has significantly extended its technological base. It can be considered as the shorter-term alternative technology, supported by the FALCON consortium set up for the construction of a LFR demonstrator and comprising in 2016 Italy's National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), ANSALDO Nucleare, the Romanian Nuclear Research Institute (RATEN ICN) and CV-Řež (Czech Republic).

Gas Fast Reactor (GFR) technology is considered to be a longer-term alternative option supported by the Visegrád Group countries (Czech Republic, Slovakia, Hungary and Poland).

Implementation and monitoring:

- ASTRID-like SFR studies for fuel qualification, component qualification, monitoring, inspection and repair, severe accident mitigation device, simulation codes, progress reports, 2012-2019
- MYRRHA accelerator driven system (ADS), progress reports, 2017-2030
- European Sodium Fast Reactor Safety Measures Assessment and Research Tools, ESFR-SMART progress and final reports, 2017-21
- Thermal hydraulics simulations and experiments for the safety assessment of metal cooled reactors, SESAME progress and final reports, 2015-19
- ALFRED design supported by the FALCON consortium (RO, IT, progress reports, 2018-22
- ALLEGRO design, capacity building and Centre of Excellence supported by Visegrád V4G4 (CZ, SK, HU, PL) and FR, progress reports 2017-25 and VINCO final report by 2018
- MSR, a paradigm shift in reactor safety with the Molten Salt Fast Reactor, SAMOFAR progress and final report, 2015-19
- Euratom participation in Generation IV International Forum (GIF) – JRC is an implementing agent, annual reports

R&I Activity 9: Cogeneration of heat and electricity

Scope: Cogeneration technologies could extend the low-carbon contribution from nuclear fission to the whole energy system by directly providing heat for different applications such as process-heat, district heating, seawater desalination, or contribution to transportation by providing synthetic fuels or hydrogen. High Temperature Gas-cooled Reactor (HTGR) designs able to deliver today process steam close to 600°C deserve special attention for cogeneration applications. Other types of reactor such as LWRs, and FRs might be deployed for electricity generation, cogeneration or other applications including Small and Modular Reactors (SMR).

Deliverables:

Main deliverables are related to support to research developments of the Nuclear Cogeneration Industrial Initiative (NC2I), validation of High Temperature Reactor (HTR), LWR and Fast Reactor (FR) as candidate reactors for cogeneration initiatives, standardization and cost reduction, design tools for different temperature ranges, design of the coupling between the power generating plant and process plants, analysis of transients and buffering technologies, licensing requirements, development of cooling and desalination pilot processes.

Expected impact:

Facilitating research developments of the Nuclear Cogeneration Industrial Initiative (NC2I), technology and feasibility of coupled installations at industrial scale and facilitating market deployment.

KPIs:

Construction of a SMR or larger demonstrator for cogeneration

R&D investments / Costs: EUR 20 million / year (MS, 2017-20),

Timeline: 10 to 20 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. Nuclear cogeneration, high temperature nuclear reactors, and industrial demonstration is gathering today 27 partners from 11 EU countries including partners from US, JP, KR. In addition, a Polish Committee for Analysis and Preparation of Conditions for Deployment of High-Temperature Nuclear Reactors (HTR Committee) was appointed by the Minister of Energy on July 13, 2016. The HTR Committee recommended on January 15, 2018, to begin preparation of HTGR deployment and a HTR strategy has been written within the Polish Energy Policy plan.

Implementation and monitoring:

- Conceptual design for a high temperature nuclear cogeneration system, GEMINI+ progress and final reports, 2017-20

- HTR High Temperature Research Reactor, HTGR high-temperature gas-cooled reactor safety analysis, including SMR, progress reports, 2018-26

4. Fusion

KEY ISSUES

Further develop fusion technology to implement the fusion roadmap (Figure 4) through EUROfusion and the activities of the Fusion for Energy Joint Undertaking (F4E) in view of the construction and operation of ITER in line with its new baseline, DEMO design and construction, and progress towards eventual fusion power plants while keeping the EU as a world leader in research and development of fusion technology.

R&I Activity 10: Implementation of the European fusion roadmap, F4E support to the construction of ITER and following operation, and preparation of DEMO as a step towards a fusion power plant

Scope: Include R&D activities needed to demonstrate the scientific and technological feasibility of fusion energy within tokamaks; test and validate experimental data within key supporting infrastructures; implementation of the European fusion roadmap; F4E support to the construction and operation of ITER; (pre)-conceptual design of DEMO, a first of a kind fusion reactor, are the needed steps towards a first commercial fusion power plant.

Deliverables:

Main deliverables are related to the construction of the ITER device to achieve First Plasma by 2025 with the main objective to demonstrate fusion power production (duration of 15 min and fusion energy gain factor Q=10) in a deuterium-tritium plasma (2035 onwards). Work will also be carried out to address the key issues identified by the fusion roadmap for the development of DEMO using key research infrastructures: (i) plasma operating scenario; (ii) breeding blanket concept and, in particular, selection of blanket coolant and the Balance of Plant; (iii) divertor concept and layout configuration; (iv) first-wall design and integration to the blanket (mechanical and hydraulic), taking into account that the first-wall might be exposed to higher heat loads than assumed in previous studies; (v) feasibility of tritium cycle direct recirculation to minimise inventory; and (vi) remote maintenance scheme. The pre-conceptual design of DEMO (2014-2020) will be followed by conceptual design phase starting in 2021. Feedback from ITER D-T operations would allow further DEMO engineering design and construction activities to take place.

Expected impact:

Fusion has some key features, which make it an attractive option in a future energy mix: inherently safe; waste which will not be a burden for future generations; no emission of greenhouse gases; and the capacity for large scale energy production. In addition, the required raw materials for the fuel are abundantly and widely available around the world. The combination of these features gives fusion the potential to make a substantial contribution to satisfying world energy demand by providing baseload electricity later this century, thus also contributing to the long term decarbonisation of the planet. The first step to its realisation is the completion of ITER.

KPIs:

Support to EUROfusion basic research, technology project and human resources training coherent and in line with the updated fusion Roadmap
F4E Joint Undertaking's contribution provided accordingly
ITER construction progress according to its new baseline
DEMO pre-conceptual and conceptual activities progress

R&D investments / Costs: EUR 300 million / year (MS, 2014-20), EUR 0.57 billion / year (Euratom, 2014-20)

Timeline: 5 to 20 years

Modality of implementation:

Increased cooperation and joint programming between EU and Member States, Public and Private investments involving industry, research centres, academia, nuclear regulators and technical safety organisations.

Implementation and monitoring:

- European Fusion Joint Programme on R&D according to the fusion roadmap, progress reports, EUROfusion EJP, 2014-20
- F4E Joint Undertaking, EU's support to the construction and operation of ITER, F4E progress reports, 2014-50
- ITER construction progress according to its new baseline and operations, ITER progress reports, 2014-50

Key enabling conditions (KEC)

KEY ISSUES

Further develop necessary key enabling conditions boosting research and demonstration efforts. Europe can retain technological leadership in the nuclear field, in line with the objective stated in the Energy Union Communication, only if interested Member States maintain a diverse and well-funded nuclear R&D capability, including education and training aspects. However, it will not be easy for Europe to retain leadership in all areas in view of the significant increase in nuclear generating capacity in other regions of the world. This underlines the importance of international cooperation, especially in areas such as development of advanced and innovative reactors.

KEC 1: Nuclear security and safeguards

Scope: Research and development to enhance a strict non-proliferation regime and physical protection of nuclear materials and facilities, including Chemical, Biological, Radiological and Nuclear (CBRN) threats and cybersecurity. This also includes promotion of synergies between safety, security, and safeguards, taking into account operability requirements.

Deliverables:

Main deliverables are related to strengthening of national and international safeguards, non-proliferation and physical protection, improving capabilities to verify absence of undeclared activities, combating of illicit trafficking, and enhancing of synergies between safety, security and safeguards aspects for existing Gen II-III and future Gen-IV systems. Establishment of a knowledge centre on strategic trade control and dual use items/technologies.

Expected impact:

Maintenance and further development of the effective and efficient nuclear safeguards and non-proliferation regime in Europe and internationally. R&D improvements of methods, technologies and reference materials, including nuclear material measurements, innovative safeguards approaches, improved sealing technologies, containment surveillance and process monitoring, as well as a robust verification of the absence of undeclared activities. This also includes enhanced methods for trace & particle analysis and in-field tools for detection / inspection. Enhanced nuclear non-proliferation regime through stringent export control, more detailed trade and material transport analyses, and dual use item & technology assessments. Improvements in combating of illicit trafficking through development of tools to identify illicit procurement and transport activities. Enhanced scientific, technical and operational support to further build Member States', EU and international capacities, including in nuclear forensics and detection, as well as in nuclear emergency preparedness and response. Improved promotion and dissemination of the highest EU's safety and security standards & culture.

KPIs:

Strengthening of national and international safeguards, non-proliferation and physical protection capabilities

Development of advanced safeguards approaches, methods, and tools

Provision of scientific, technical, and operational assistance to Member States and international bodies to enhance proliferation resistance and nuclear safeguards

R&D investments / costs: EUR 10 million / year (MS, 2014-20),

Timeline: 10 years

Modality of implementation:

With EU having an exclusive competence in the safeguard domain, the strengthening of Euratom scientific, technical and operational contributions to and cooperation in European and international nuclear non-proliferation initiatives, including with IAEA in the implementation of the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/140, and its Additional Protocol) and in the frame of European Safeguards and Research and Development Association (ESARDA). Establishment of an EU

Knowledge Centre for Strategic Trade Control, improving overall EU response to security concerns, addressing common commercial and competitiveness needs, conducting trade analysis in strategic goods and duel item export control, and providing support to international political as well as legal commitments, including the implementation of the Euratom Treaty (Chapter VII), as well as the UN Security Council Resolution 1540(2004).
Improved cooperation between Member States, involving among others research centres, industry, and technical support organisations to enhance non-proliferation aspects, to conduct underpinning research activities, as well as to develop integrated safety-security-safeguards methods and concepts.
Knowledge sharing and capacity building activities are promoted to stimulate interoperability within and between Member States, including development of best practices and standardisation.

Implementation and monitoring:
- EU/Euratom, EC JRC safeguards and security, European Safeguards and Research and Development Association (ESARDA) progress reports, 2014-20
- Towards the fuel (HEU to LEU) conversion of high performance research reactors in Europe, HERACLES-CP and LEU-FOREVER progress and final reports, 2015-21

KEC 2: Stable and predictable investment conditions

Scope: This includes an implementation of the latest regulatory and multi-financial frameworks (e.g. energy and climate supporting competitiveness, sustainability and security of supply) promoting technology neutral investments in all low carbon technologies, to ensure stable / predictable investment conditions, availability of appropriate financing and legal schemes including contracts for difference, an effective supply chain and a more appropriate carbon price (ETS) as referred to within the latest Nuclear Illustrative Programme (PINC) and Energy Union's Clean Energy for all Europeans communications. Both near - and long - term solutions should ensure 'a safe and efficient operation of nuclear systems, development of innovative reactor concepts and sustainable solutions for the management of radioactive waste' including extension of operating lifetimes, a flexible electricity grid catering for all Low Carbon Energy and Efficiency suppliers, as well as R&I investments or safety upgrades towards future closed fuel nuclear cycle infrastructures.
Deliverables:
Main deliverables are related to incentives or grants dedicated to research and innovation, infrastructures, centres of excellence and/or support provided through EIB loans, cohesion policy, the European Fund for Strategic Investments (EFSI), Innovation Fund investments benefitting from CO_2 revenues, private investors, energy providers or research organisations, and low-carbon generation revenue support through feed-in tariff with Contracts for Difference.
Expected impact:
Support to EU Energy and climate policies, competitiveness, sustainability and security of energy supply, and promotion of investments in all low carbon technologies
Evolution of EU regulatory frameworks offering an additional drive for a cost-efficient decarbonisation, secure, affordable and sustainable energy
A robust demonstration of sustainable nuclear scientific and technological excellence benefitting from advanced nuclear research and innovation
Maintain nuclear technology and industrial leadership towards both energy (only for Member States committed to the Action 10) and non-energy applications
KPIs:
Implementation of EU/Euratom nuclear safety, waste and basic safety standards directives
Commitment for MS using nuclear power to provide a stable political and regulatory environment providing clear, stable, integrated energy and climate policies
Broad and early stage planning, stakeholder engagement and international cooperation

Technology-neutral and market-based mechanisms favoured and investment conditions that facilitate the required financing of the energy system and supporting research infrastructures
R&D investments / Costs: EUR 10 million / year (MS, 2015-20),
Timeline: 5 to 20 years
Modality of implementation:
Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. In 2017, Euratom has committed EUR 20 million to support fission research & innovation (R&I) investment projects of pan-European relevance through the InnovFin instrument. The European Commission approved in 2011 European Regional Development Fund (ERDF) funding support of EUR 5.5 million for the construction of a new research facility in Rez in the Czech Republic hosting today helium and supercritical water research loops. Early 2014, the Czech Republic obtained a further EU ERDF funding support of EUR 85 million (total costs of EUR 100 million) towards their SUStainable ENergy project (SUSEN). Building such a research infrastructure extends their energy research possibilities with emphasis on nuclear technologies at the Research Centre of Rez and at the Pilsen University of West Bohemia. It also allows them to act as a relevant research partner within the EC smart specialisation platforms promoted for cooperation in the field of energy with the establishment of partnerships and cooperation with other European research centres.

Implementation and monitoring:
- Implementation of EU/Euratom nuclear safety, waste and basic safety standards directives, stress tests, Nuclear Illustrative Programme (PINC), EU/national progress reports, 2017-25
- Contract for Difference (CfD), UK Hinkley Point C £18 billion investment decision on 15/09/2016, progress reports, 2017-25
- EIB loans, Euratom loans, H2020 InnovFin, European Fund for Strategic Investments (EFSI), progress reports, 2017-25
- Cohesion funds and ERDF Structural Funds, SUSEN project in the Czech Republic, progress reports, 2017-25

KEC 3: Harmonization of licensing rules, certification, and standards

Scope: Pre-normative research for new design and operating conditions, establishment of shared codes and standards with a strategy providing methods to progressively enlarge consensus among stakeholders. This also includes a digital approach to nuclear, optimisation of supply chain, mutual recognition by regulatory activities, streamlining of design approval and harmonised classification schemes.
Deliverables:
Main deliverables are related to providing the basis for an effective standardisation of reactor component assessments and improving the safety level of the nuclear installation through shared design approaches and licensing processes for existing Gen II-III and future Gen-IV systems.
Expected impact:
To maintain the highest standards for a safe utilization of nuclear technologies in Europe and help to maintain competitive energy costs including for industrial energy intensive applications. Safety R&D improvements fostering safety standards integrating lessons learned from the Fukushima accident, and underpinning lifetime extension programmes of the current NPP fleet contributing significantly to their safe operation in a cost-effective manner. To improve the competitiveness and industrial leadership of European nuclear industry (only for Member States committed to the Action 10) , including its supply chain and applying the highest safety standards.
KPIs:
Development of EU nuclear safety-related normalisation and adoption by EU members
Incorporate good design principles for proliferation resistance, security aspects and physical protection into new designs

R&D investments / costs: EUR 10 million / year (MS, 2016-20),
Timeline: 10 years
Modality of implementation:
Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations This includes activities conducted in the frame of the international and European collaborations within ISO, CEN (incl. CEN Workshop 64), ASTM, NUGENIA Technical Area 7, comparable activities to be further developed in ESNII & NC2I, as well as GIF Risk and Safety Working Group (RSWG) and Proliferation Resistance and Physical Protection Working Group (PRPPWG), in support to the implementation of Nuclear Safety Directive (2014/87/Euratom), Nuclear Waste Directive (2011/70/Euratom) and Basic Safety Standards Directive (2013/59/Euratom).

Implementation and monitoring:
- AFCEN, CEN-CENELEC Workshop 64 (and follow-up), harmonisation of licensing rules, certification and standards, harmonization of nuclear design and construction codes at EU level, progress reports (e.g. RCC-MRx update on 3 years' basis), 2016-2027
- Support to the implementation of Nuclear Safety Directive (2014/87/Euratom), Nuclear Waste Directive (2011/70/Euratom) and Basic Safety Standards Directive (2013/59/Euratom), progress reports, 2017-20

KEC 4: ETKM Education and Training

Scope: This includes a fit-for-purpose system for the education and training of scientists and engineers (STEM) (multi-national, ENEN and FuseNET, EHRO-N observatory, JRC (safety, security and safeguards), DEVCO, ERC, EIT, MSCA, ERASMUS+, mobility, ECTS, EFTS, ECVET where appropriate) that ensures skilled and high-level personnel are available when needed in all relevant disciplines throughout the nuclear sector (industry, research, regulatory bodies, WMOs, TSOs, etc.) and supports the mobility of these personnel, including through a European Credit System for Vocational Education and Training (ECVET). One of the objectives is to improve the synergy and to develop tools between the world of education and the world of work, while helping universities modernise and enhance quality and innovation. Structured partnerships should be set up between higher education institutions and businesses, which develop innovative ways of producing and sharing knowledge, foster creativity and deliver new curricula and qualifications in a programmatic approach where governmental bodies and stakeholders are sharing common objectives. Overall, it is building an effective 'critical mass', of promoting the creation of 'centres of excellence' with an increased support for 'open access to key research infrastructures', exploitation of research results, management of knowledge, dissemination and sharing of learning outcomes.
Deliverables:
Main deliverables are related to meeting the skill/competencies gaps, strengthening and developing existing skills/competencies, promoting mobility, life-long learning, workforce training, national and international networks, industry involvement and partnerships including with international organisations (e.g. OECD/NEA, IAEA), sector skills assessments (e.g. EUROPASS) and observatories (e.g. EHRO-N), online information and other tools.
Expected impact:
Towards a common nuclear safety and security culture world-wide, based on technical and organisational excellence
Towards scientific and technological excellence, thereby ensuring a new generation of European highly qualified experts in all nuclear sectors
Towards a robust demonstration that the use of nuclear energy is beneficial, responsible and sustainable
KPIs:

Planning and enabling skills development
Filling the skills, competences and knowledge gap
Fostering involvement, access and up-take by the labour market
Implementation of stress tests recommendations on ETKM in Europe
Implementation of EU/Euratom nuclear safety, waste and basic safety standards directives
R&D investments / Costs: EUR 50 million / year (MS, 2015-20),
Timeline: 5 to 20 years
Modality of implementation:
Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations. The European Nuclear Education Network non-profit association (ENEN AISBL) gathers 73 members being public or private corporate, universities, research organisations, nuclear industry, and regulatory bodies. The European Fusion Education Network (Fusenet Association) is gathering 61 universities, research institutes, industry and other organisations providing a platform for the coordination of European fusion education activities.

Implementation and monitoring:
- ENEN and FuseNET, EHRO-N observatory, JRC (safety, security and safeguards), DEVCO, ERC, EIT, MSCA, ERASMUS+, mobility, ECTS, EFTS, ECVET where appropriate, progress reports, 2015-20
- European Nuclear Education Network association (ENEN), European Fusion Education Network (FuseNET), European Technology Platforms (ETPs) progress reports, 2015-20
- Attract, retain and develop new nuclear talents beyond academic curricula, ENENplus, MEET-CINCH, CORONA-II, BRILLIANT progress and final reports, 2015-20

KEC 5: Supporting Infrastructures

Scope: This includes the need to ensure any availability of state-of-the-art research infrastructures (RIs at research organisations, universities and industry, public and private) (e.g. identified within ESFRI roadmap, fission, fusion, and in particular for materials research and innovation, irradiation facilities, nuclear safety, research reactors and hot cells, including for non-power sector applications such as radioisotope production) that promote ease of access of scientists and engineers from across Europe and further, supporting international collaborations of key European interest. It needs appropriate mobility arrangements from available (and new, when appropriate) funding schemes, both grant- and loan-based, and legal frameworks benefitting to research efforts in key fields, promoting the creation of centres of excellence with an increased support for open access, networking of key research infrastructures, sharing best practices, supporting smarter and multi-disciplinary innovations (e.g. Energy, Climate, Health, Digital) with a great attractiveness for future generations. An important boundary condition is a financially sound basis for the operation of the infrastructure. Current-day models do not sufficiently account for the increasing costs imposed by measures in the field of, among others, security and waste handling, endangering access and availability the valuable infrastructures.
Deliverables:
Main deliverables are to ensure at any time the availability of research and training reactors, large (but also on a smaller scale) supporting experimental and validation infrastructures (existing facilities, upgraded or newly built), state-of-the-art computer codes and computational simulation platforms, and the whole fuel cycle related laboratories. They shall encompass opportunities provided by policy initiatives undertaken to improve them, to further support the coordination of transnational access and a more efficient use of infrastructures, with due consideration given to their long-term availability, as well as to opportunities of excellence in research and training provided by highly attractive e-infrastructures and e-learning platforms (e.g. supporting OECD/NEA and IAEA initiatives, and establishment of a virtual research reactor laboratory). Introduction of a

financial model that accounts for all costs of exploitation of the infrastructures to secure continued access and availability of the infrastructure.

Expected impact:

Improve safety Long Term Operations (LTO), performance upgrades and by new design
Improve efficiency of research by fulfilling RIs - technical and financial – priority needs
Improve EU (vs. national) safety culture and RIs standing visibility through mobility schemes
Share investments, align, prioritise, integrate and further support any coordination to key EU/MS RIs
Supporting innovations

KPIs:

A sound financial model for the exploitation of research infrastructure, based upon full cost recovery
Improve research effectiveness by fulfilling the needs of the research community, its objectives and EC/MS funding (research, university and industry, public and private) including central European Member States
Maximise benefits of better aligned, coordinated, and integrated RIs investments and programmes
Increase EU and International users (and end-users) mobility and access to key RIs
Enhance inter-disciplinary research together with existing (and new) research networks
Support to deployment of advanced Gen-IV systems

R&D investments / Costs: EUR 300 million / year (MS, 2014-21),

Timeline: 5 to 20 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations.

To ensure any availability of state-of-the-art research infrastructures, the Jules Horowitz Reactor is being built in Cadarache (FR). It will be a major infrastructure operated in the framework of an international cooperation and bilateral agreements. Present partners Research Institutes: CIEMAT (Spain); SCK (Belgium); CVR (Czech Republic); VTT (Finland); the French Atomic Energy Commission (CEA) (France); IAEC (Israel); DAE (India); NNL (United Kingdom); STUDSVIK (Sweden); Utilities and Industrial Partners: “Electricité de France” (EDF); FRAMATOME (ex AREVA-NP); TECHNICATOMEJHR first criticality is foreseen by 2021. Euratom could benefit from its access rights share. It will also be complemented by infrastructures in support of JHR.

The High Flux Reactor (HFR) in Petten (NL) is one of the most powerful multi-purpose materials testing reactors in the world. It is owned by the European Union's Joint Research Centre (JRC) and operated by the Dutch Nuclear Research and consultancy Group. The HFR is a tank in pool type light water-cooled and moderated reactor, operated at 45 MW. It offers a variety of irradiation facilities in the reactor core, in the reflector region and in the poolside facility. It is used for nuclear R&D and different commercial applications (e.g. supplying about 60% of Europe's and 30% of the world's supply of medical radio-isotopes (radiopharmaceutical products for millions of people with cancer and cardiovascular diseases being diagnosed and treated, 10 million examinations every year within the EU)), doping of silicon for manufacturing semiconductors, and. Examples for research carried out in the HFR are: Materials testing to ensure safe long term operation of existing nuclear power plants; Irradiation tests and qualifications of innovative fuels and functional/structural materials for use in next generation fission reactors with enhanced safety and performance; and R&D for Fusion Reactor technologies, e.g. first wall components.

PALLAS will replace the sixty years' old High Flux Reactor (HFR) in Petten. The Foundation Preparation PALLAS-reactor (PALLAS) has selected on 24 January 2018 the Argentinian-Dutch company ICHOS, (INVAP and the TBI companies Croonwolter&dros – Mobilis) for the design and construction of the state-of-the-art PALLAS-reactor. The project’s contract value amounts to up to EUR 40 million for the current preparation phase.

Early 2014, the Czech Republic obtained a EU ERDF funding support of EUR 85 million (total costs of EUR 100 million) towards their SUStainable ENergy project (SUSEN). Building such a research infrastructure extends their energy research possibilities with emphasis on nuclear technologies at the Research Center of Rez and at the Pilsen University of West Bohemia.

SAFIR, the Finnish Research Programme on Nuclear Power Plant, within th Finnish Nuclear Energy Act since 2004, is to ensure that should new matters related to the safe use of nuclear power plants arise, the authorities possess sufficient technical expertise and other competence required for rapidly determining the significance of the matters. High scientific quality is required of the research projects in the programme.

BR2 (Belgian Reactor 2) is amongst the most powerful and flexible research reactors in the world on nuclear fuel and materials research, production of radioisotopes, but also 15 to 25 tons of doped silicon for high energy electrical applications using high-grade semiconductors. Since its start-up in 1962 the reactor has operated on uranium with pressurised water as coolant and moderator. BR2 has undergone a thorough maintenance and modernisation operation in 2016 where various systems and components were replaced to guarantee a safe and efficient operation till 2026.

GUINEVERE (Generator of Uninterrupted Intense Neutron at the lead VEnus Reactor) project at SCK-CEN, in Belgium, plays an essential role in research into accelerator driven systems or ADSs, of which MYRRHA will be the first test and research reactor. With the construction of GUINEVERE as a scale model, SCK-CEN has made a significant step forward in the further development of MYRRHA. Experimental programmes are now running to validate measurement methods for determining the sub-criticality (an important safety parameter) of the system in different operating conditions. This will contribute to the safety of future ADSs which will, among other things, be capable of performing transmutation.

Implementation and monitoring:

- Jules Horowitz Reactor (JHR) Access Rights, progress reports, 2016-46
- JRC Open Access to JRC infrastructures, progress reports, 2014-18
- Security of supply of radio-isotopes (JHR, MYRRHA, PALLAS, others, full cost recovery, etc.), progress and final reports, and roadmap, 2017-2020
- HFR Supplementary Program (FR and NL), Fuels and materials testing, progress reports, 2016-19
- NL, PALLAS Design and licensing base, progress reports, 2012-19
- FR, Material Test Reactor JHR, Underground Laboratory MHM, progress reports, 2016-25
- CZ, SUSEN Sustainable Energy benefitted from ERDF Structural Funds, progress reports, 2017-25
- FI, Finnish research programme on nuclear power plant safety, SAFIR progress reports, 2017-20
- BE, BR2 upgrade and operations, progress reports, 2016-26
- BE, Heavy Liquid Metal infrastructures complex and GUINEVERE, progress reports, 2010-30
- UK, Virtual Engineering platform, progress reports, 2017-21
- UK, Thermal Hydraulics Capability, progress reports, 2017-21

KEC 6: INCO International cooperation

Scope: This includes an enhanced R&D cooperation between Member States in key areas, not only in multi-disciplinary R&D fields such as radiation protection and geological disposal, but also regarding development of new research infrastructures, waste facilities and advanced reactor systems; reinforced international cooperation with leading third countries, bilaterally or multilaterally, in key strategic areas. Enhancing and focusing EU international cooperation (e.g. CN, JP, KR, IN, RU, USA) in research and innovation calls for a strategic approach, filling the skills, competences and knowledge gap, promoting mobility, life-long learning, workforce training, national and international networks, industry involvement and partnerships.

Deliverables:

Main deliverables are related to provide a systematic and coherent identification of priorities for international cooperation. This underlines the importance of international cooperation and partnerships between Member States especially in areas related to development of advanced and innovative reactors, together with OECD/NEA, e.g. in the frame of Nuclear Innovation 2050 roadmap (NI2050), with IAEA, e.g. in the frame of International Project on Innovative Nuclear Reactors and Fuel Cycles for sustainable nuclear energy for the 21st century (INPRO), and with Generation-IV International Forum (GIF), which pursues R&D activities on six innovative nuclear energy systems. Towards 2050 the availability of innovative designs offering increased uranium resource efficiency and lower long-lived waste production may become attractive for utilities. In addition, in view of the increasing requirements for more flexible energy sources and non-fossil fuel process heat, small modular reactors (SMR) and co-generation plants may develop on a shorter timescale. The concurrent development in this sector and the market uptake of innovative solutions will be one of the main drivers in this field.

Expected impact:

Added value when International cooperation research and innovation capacities, synergies and complementarities can be created

Activities contributing to meeting EU's international commitments in energy, climate, health and Millennium Development Goals overall

Contribution towards scientific and technological excellence ensuring a new generation of European highly qualified experts in all nuclear sectors, a common nuclear safety and security culture world-wide

Opportunities for access to new or emerging markets promoting sustainable nuclear energy

KPIs:

Adequate legal and administrative frameworks in place to engage in cooperation, also including lessons learnt from previous cooperation

Priority setting process to be reflected in multi-annual roadmaps for international cooperation with its key partner countries and regions and International organisations, e.g. OECD/NEA, IAEA and GIF

Implementation of the strategy for international cooperation in research and innovation enabling skills development, competences and fulfilling knowledge gaps

R&D investments / Costs: EUR 10 million / year (MS, 2015-20),

Timeline: 5 to 20 years

Modality of implementation:

Increased cooperation between Member States, Public and Private investments involving industry, research centres, academia and technical safety organisations.

Implementation and monitoring:

- Support to the implementation of existing (or new) international agreements concluded by Euratom and Member States; participation to committees; fostering of better global cooperation towards research and innovation, where R&D needs and capabilities, safety enhancements and advanced nuclear activities, as well as education and training activities benefit from synergies and complementary experts groups evaluations, gap assessments, recommendations and roadmaps, progress and final reports, 2015-2030

- EC DEVCO (and further EEAS) Instrument for Nuclear Safety Cooperation (INSC) supporting a higher level of nuclear safety, radiation protection and the application of efficient and effective safeguards of nuclear materials in non-EU countries, progress and final reports, 2015-2030

Illustrative summary overviews are presented here below:

Figure 1: Implementation plan summary overview: **research roadmap on Generation II-III, waste and geological disposal, decommissioning, radiation protection and cross-cutting R&D activities**

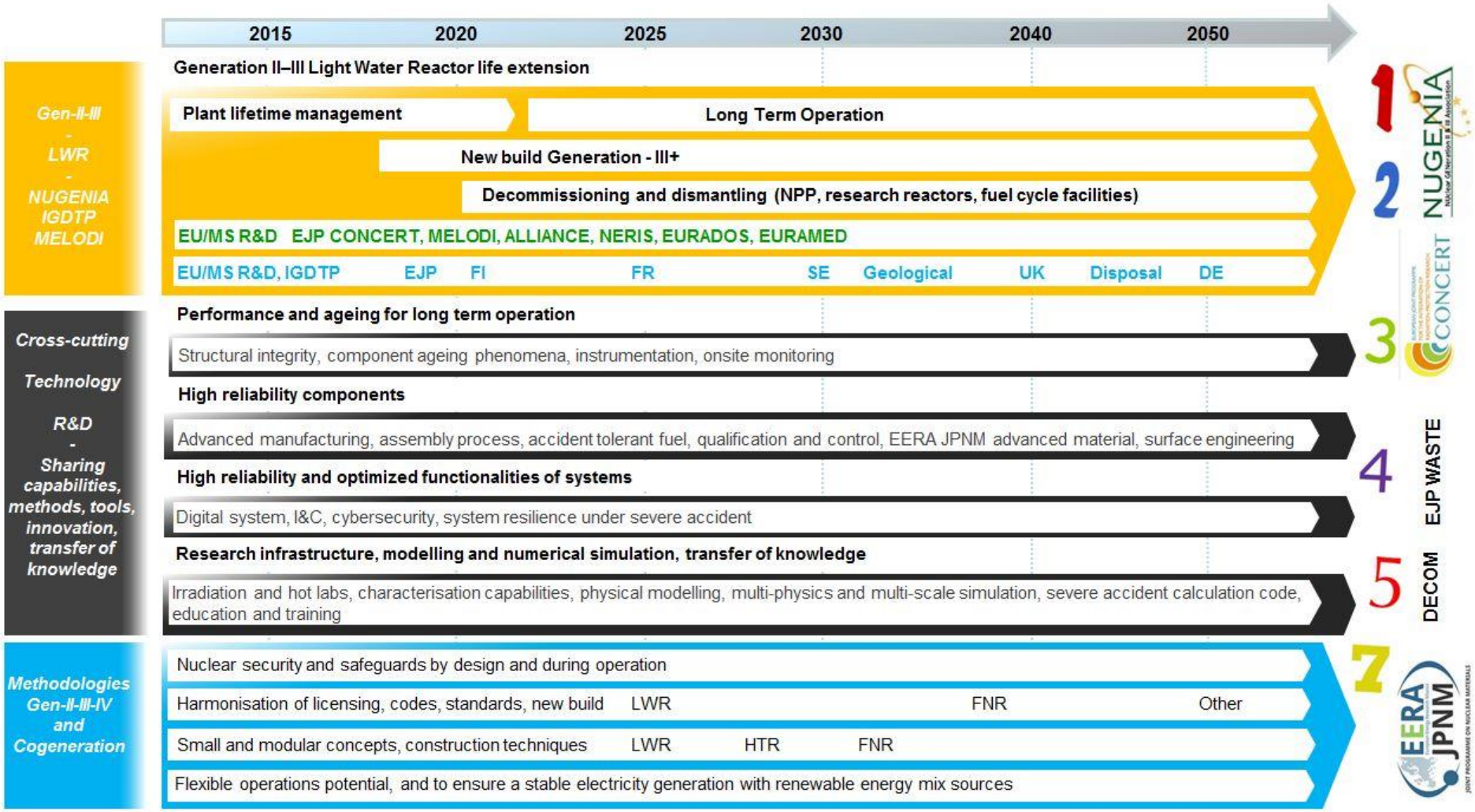


Figure 2: Implementation plan summary overview: **research roadmap, prototypes related to Generation-IV**

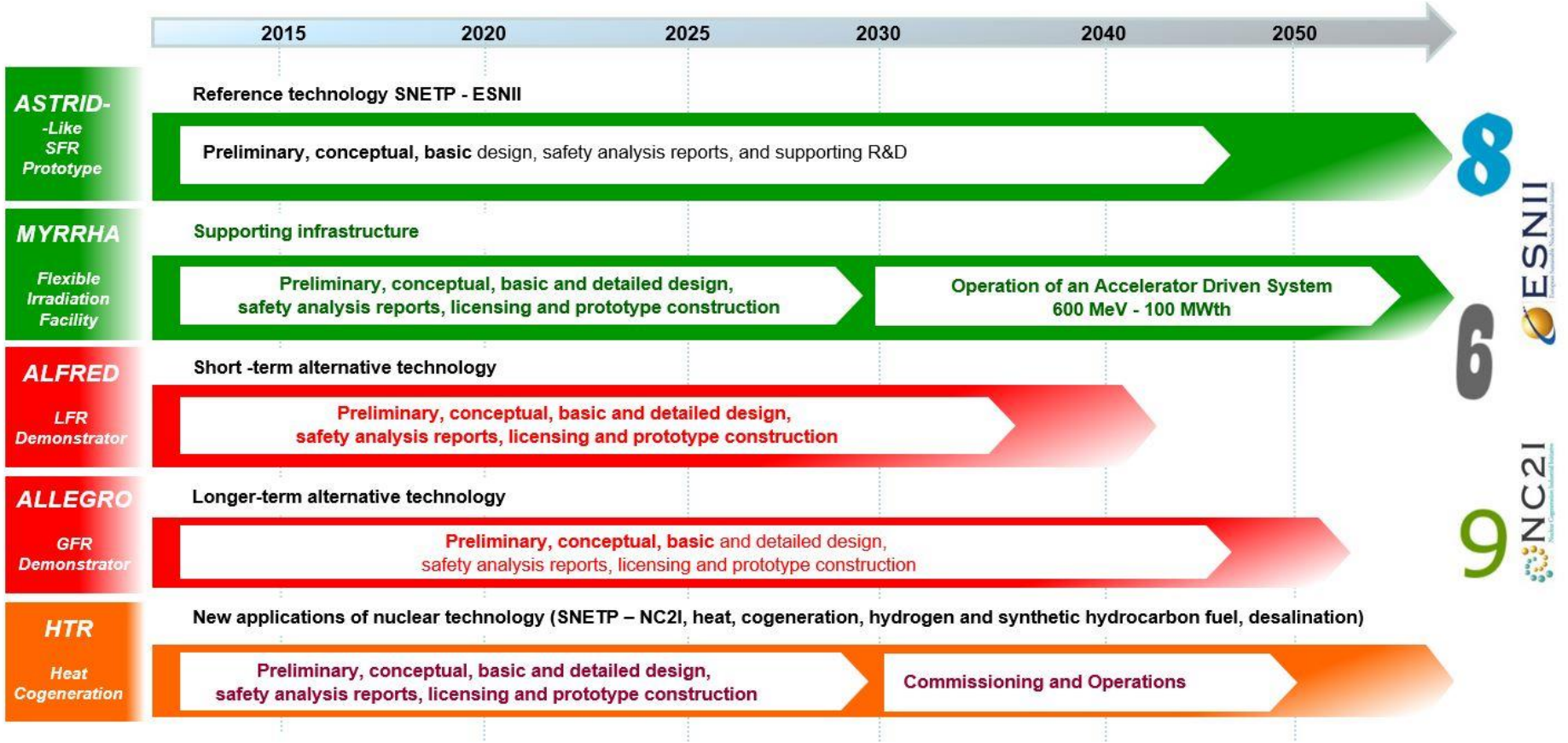


Figure 3: Implementation plan summary overview: **research roadmap on supporting infrastructures and cross-cutting activities**

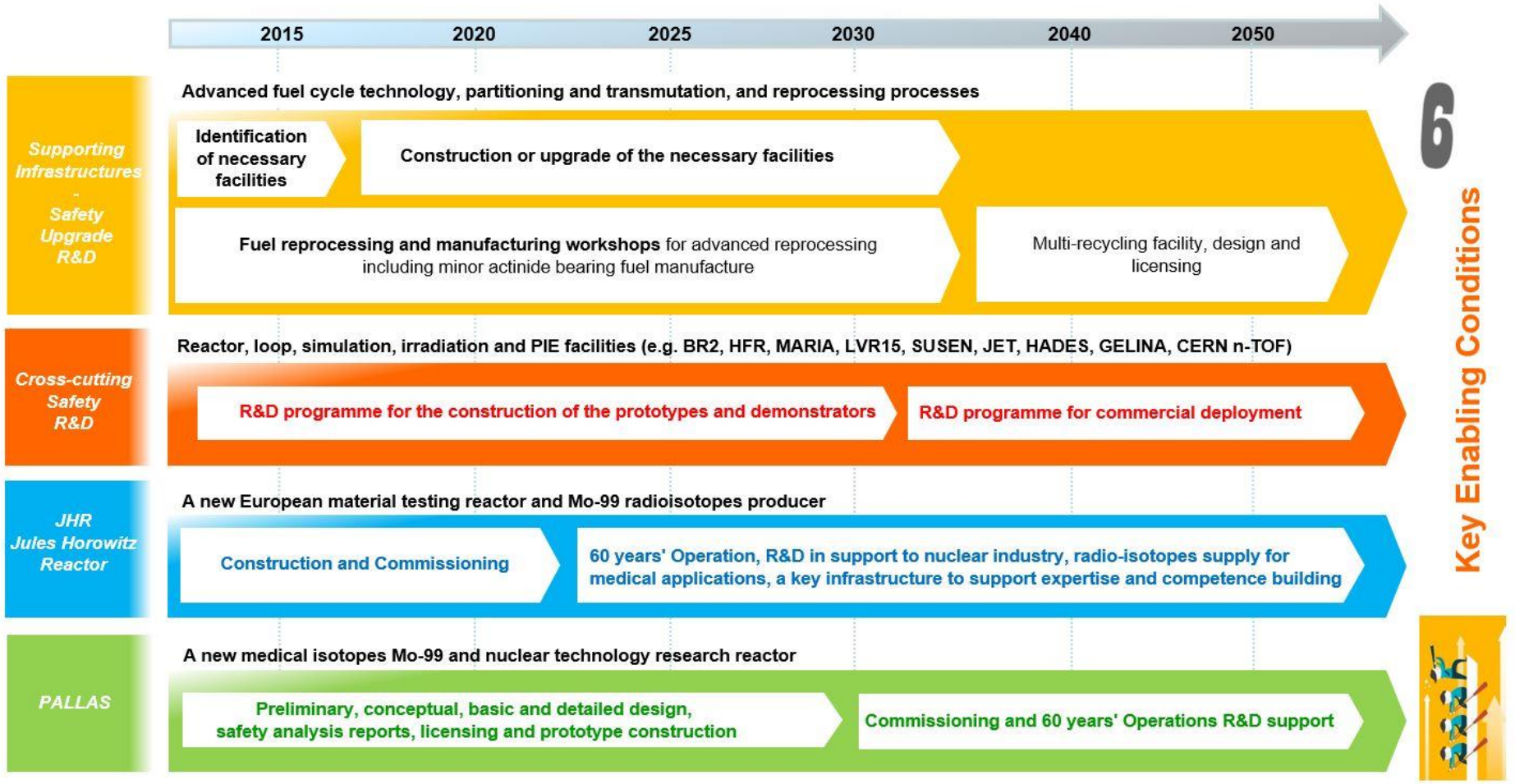


Figure 4: The road to fusion electricity: **European research roadmap to the realisation of Fusion Energy** (see for more details https://www.euro-fusion.org/eurofusion/roadmap/)

Three stages to design fusion power plants

Near term

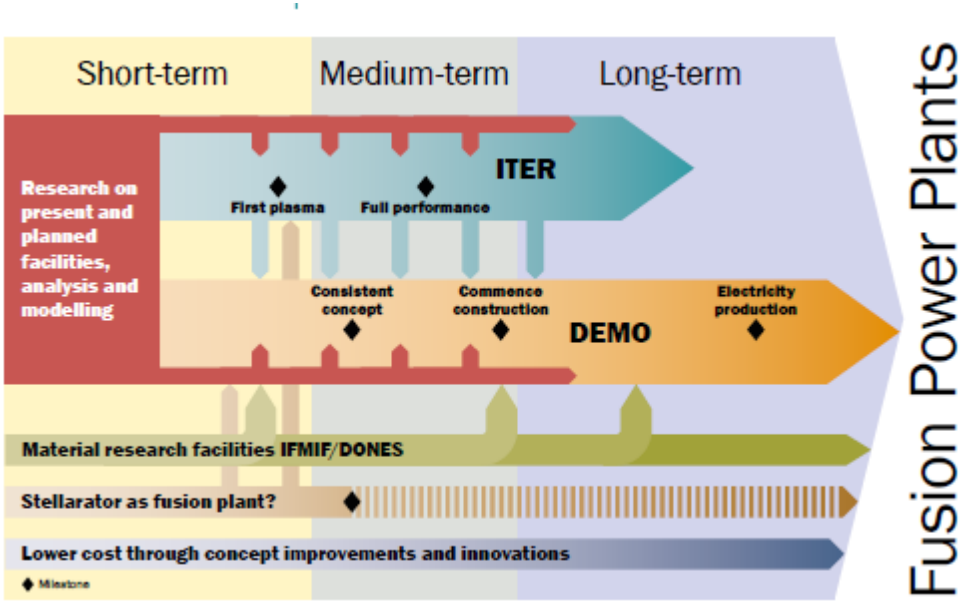
- Construction of ITER
- Research & Development in support of ITER
- Deuterium-tritium operation of JET
- Concept Design phase of DEMO
- Research & Development for DEMO
- Construction of a fusion materials testing facility, IFMIF-DONES
- Scientific and technological exploitation of the stellarator concept

Medium term

- First scientific and technological exploitation of ITER
- First exploitation of IFMIF-DONES
- Engineering Design phase of DEMO with industrial involvement
- Development of power plant materials and technologies
- Possible further development of the stellarator concept

Long term

- High performance and advanced technology results from ITER
- Qualify long-life materials for DEMO and power plants with IFMIF-DONES
- Finalisation of the design of DEMO
- Construction of DEMO
- Demonstration of electricity generation
- Commercialisation of technologies and materials
- Deployment of fusion together with industry



ANNEXES

Annex 1: References

Annex 2: List of abbreviations and acronyms

Annex 1: References (complementing annex 2 of the Declaration of Intent)

[1] European Energy Strategy: Secure, competitive, and sustainable energy
http://ec.europa.eu/energy/en/topics/energy-strategy
Building the Energy Union https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/building-energy-union
2020 Energy Strategy https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2020-energy-strategy
Energy Security Strategy https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/energy-security-strategy
Clean Energy for All Europeans https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
2030 Energy Strategy https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy
Governance of the Energy Union https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union
2050 Energy strategy https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy
PINC Nuclear Illustrative programme https://ec.europa.eu/energy/en/topics/nuclear-energy
PINC 2016-17 Update COM/2017/0237 final http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2017:237:FIN
PINC 2016 SWD/2017/0158 final http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1496064782666&uri=CELEX:52017SC0158

[2] EU/Euratom legislative framework http://ec.europa.eu/energy/en/topics/nuclear-energy
Nuclear safety https://ec.europa.eu/energy/en/topics/nuclear-energy/nuclear-safety
Radioactive waste and spent fuel https://ec.europa.eu/energy/en/topics/nuclear-energy/radioactive-waste-and-spent-fuel
Decommissioning of nuclear facilities https://ec.europa.eu/energy/en/topics/nuclear-energy/decommissioning-nuclear-facilities
Radiation protection https://ec.europa.eu/energy/en/topics/nuclear-energy/radiation-protection
Nuclear safeguards https://ec.europa.eu/energy/en/topics/nuclear-energy/safeguards-avoid-misuse
Radioactive waste and spent fuel, First implementation report dated 15 May 2017
COM/2017/0236 final, SWD/2017/0159 final, and SWD/2017/0161 final
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2017%3A236%3AFIN
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2017%3A159%3AFIN
http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1496670357597&uri=CELEX:52017SC0161

[3] The European Group on Ethics in Science and New Technologies, 'An ethical framework for assessing research, production and use of energy', Opinion No. 27, doi:10.2796/20644, 2013, https://ec.europa.eu/research/ege/index.cfm?pg=reports
Benefits and limitations of nuclear fission for a low-carbon economy, 2013 Symposium Proceedings, European Commission, 2013,
http://cordis.europa.eu/pub/fp7/docs/2013-symposium-proceedings_en.pdf

[4] Horizon 2020 European Research Framework Programme
http://ec.europa.eu/research/horizon2020/index_en.cfm
http://ec.europa.eu/programmes/horizon2020/h2020-sections
European Commission Departments (Directorates-General) and services
http://ec.europa.eu/about/ds_en.htm

Multi-Financial Framework Programme 2014-2020
http://ec.europa.eu/budget/mff/programmes/index_en.cfm
H2020 sub-heading http://ec.europa.eu/budget/mff/programmes/index_en.cfm#horizon2020

[5] JHR Jules Horowitz Reactor http://www-rjh.cea.fr/general-description.html

MYRRHA Multi-purpose hYbrid Research Reactor for High-tech Applications http://sckcen.be/en/Technology_future/MYRRHA
PALLAS http://www.pallasreactor.com/?lang=en
SUSEN Sustainable Energy Project http://susen2020.cz/en/

[6] Strategic Energy Technology Plan (SET-Plan)
http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm
SET-Plan Information System (SETIS) http://setis.ec.europa.eu/
SET-Plan Education & Training Roadmap http://setis.ec.europa.eu/setis-deliverables/education-training-roadmap
SET-Plan Materials roadmap https://setis.ec.europa.eu/setis-output/materials-roadmap
SET-Plan Technology mapping https://setis.ec.europa.eu/setis-output/technology-mapping
CORDIS, European Community Research and Development Information Service http://cordis.europa.eu/home_en.html and EU Participant Portal
http://ec.europa.eu/research/participants/portal/desktop/en/home.html

[7] EU Regional Policy, European Regional Development Fund ERDF http://ec.europa.eu/regional_policy/en/funding/erdf/
The Sustainable Energy Project (SUStainable ENergy, SUSEN) project http://susen2020.cz/en/
EC JRC Smart Specialisation Platform http://s3platform.jrc.ec.europa.eu/

[8] European Technology Platforms (ETPs) http://cordis.europa.eu/technology-platforms/
SNETP Sustainable Nuclear Energy Technology Platform http://www.snetp.eu/, and SNETP 3 pillars (NUGENIA, ESNII and NC2I)
NUGENIA Generation II III water cooled reactor technology http://nugenia.org/ and http://www.snetp.eu/nugenia-nuclear-generation-iiiii-association/
ESNII Generation IV fast reactors employing the closed fuel cycle http://www.snetp.eu/esnii/
NC2I Cogeneration of electricity and heat http://www.snetp.eu/nc2i/
IGDTP Implementing Geological Disposal of Radioactive Waste http://www.igdtp.eu/
MELODI Multi-disciplinary European Low Dose Initiative http://www.melodi-online.eu/
ENEN European Nuclear Education Network Association http://www.enen-assoc.org
FUSENET European Fusion Education Network http://www.fusenet.eu/
EUROfusion https://www.euro-fusion.org/, European Research Roadmap to the Realisation of Fusion Energy https://www.euro-fusion.org/eurofusion/roadmap/,
ITER http://www.iter.org/ and JET Tokamak http://www.ccfe.ac.uk/JET.aspx

[9] Independent authoritative expert body with regulatory backgrounds for the stress tests
ENSREG European Nuclear Safety Regulator Group
http://ec.europa.eu/energy/nuclear/ensreg/ensreg_en.htm
ETSON European Technical Safety Organisation Network
http://www.etson.eu/

ENEF European Nuclear Forum Energy
http://ec.europa.eu/energy/nuclear/forum/forum_en.htm

[10] OECD/NEA Nuclear Energy Agency http://www.oecd-nea.org/
IAEA International Atomic Energy Agency http://www.iaea.org/
GIF Generation-IV International Forum http://www.gen-4.org/
GIF Generation-IV International Forum Progress in Nuclear Energy, volume 77 http://www.sciencedirect.com/science/journal/01491970/77
GIF Annual reports https://www.gen-4.org/gif/jcms/c_44720/annual-reports

[11] 2010 Deloitte study on the funding of ESNII industrial initiative http://cordis.europa.eu/pub/fp7/euratom-fission/docs/deloitte-gen4-022010-full-report.pdf
European Investment Bank EIB http://www.eib.org/
EIB RSFF InnovFin http://www.eib.org/products/blending/innovfin/index.htm
EIB EFSI European Fund for Strategic Investments http://www.eib.org/efsi/

[12] EHRO-N, European Human Resources Observatory for the Nuclear sector, Perspective report
http://ehron.jrc.ec.europa.eu/sites/ehron/files/documents/public/ehro-n_putting_into_perspective_report_2012_05_25_0.pdf
Bologna Process in 1999
http://ec.europa.eu/education/policies/educ/bologna/bologna_en.html
Copenhagen Declaration in 2002
http://ec.europa.eu/education/lifelong-learning-policy/ecvet_en.htm
ECVET European Credit System for Vocational Education and Training
http://www.ecvet-team.eu/
EIT KIC InnoEnergy MSc EMINE – European Master in Nuclear Energy
http://www.innoenergy.com/education/master-school/msc-emine-european-master-in-nuclear-energy/

ERC European Research Council https://erc.europa.eu/ and FP7 Scientists create 'trophy molecule' that could revolutionise nuclear industry
http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=34791
DG EAC (Education, Audio-visual and Culture Executive Agency) ERASMUS+ http://ec.europa.eu/programmes/erasmus-plus/ and EUJEP-1and-2 projects Post-Fukushima European Japanese Exchange Project in Nuclear Education and Training http://www.enen-assoc.org/en/training/eujep-21/eujep-21.html

[13] EC Framework Programme on infrastructures (complementary to Euratom FP) http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=mapri
ESFRI roadmap, Pan-European research infrastructures roadmap of 2016 http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=mapri_european
http://www.esfri.eu/roadmap-2016
European Research Infrastructure Consortium (ERIC) legal framework http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=eric

Evaluation of pertinence and impact of the EU research infrastructure activity in FP7 https://ec.europa.eu/digital-single-market/en/news/evaluation-pertinence-and-impact-research-infrastructure-activity-fp7-epiria-smart-20120045

[14] EU Regional Policy, European Regional Development Fund ERDF http://ec.europa.eu/regional_policy/en/funding/erdf/
EC JRC Smart Specialisation Platform http://s3platform.jrc.ec.europa.eu/

[15] OECD/NEA (Nuclear Energy Agency) Research and Test Facilities Database (RTFDB), http://www.oecd-nea.org/rtfdb/
ADRIANA final report ftp://ftp.cordis.europa.eu/pub/fp7/euratom-fission/docs/adriana-final-report_en.pdf

IAEA Department of Nuclear Energy maintains over 20 Nuclear Energy Databases in its areas of activities.
http://www.iaea.org/OurWork/ST/NE/Main/databases.html
IEA/NEA International Energy Technology Map http://www.iea.org/topics/nuclear/
IEA Online Statistics http://www.iea.org/statistics/
EU Contribution to a reformed ITER project COM(2017) 319 final dated 14/06/2017
https://ec.europa.eu/energy/sites/ener/files/documents/eu_contribution_to_a_reformed_iter_project_en.pdf and SWD(2017) 232 final, staff working document
https://ec.europa.eu/energy/sites/ener/files/documents/commission_staff_working_documentiter_2017.pdf

Annex 2: List of abbreviations and acronyms

ABET	Accreditation Board for Engineering and Technology
ADRIANA	ADvanced Reactor Initiative And Network Arrangement
ADS	Accelerator-Driven System
AFCEN	Association Française pour les règles de Conception, de construction et de surveillance en exploitation des matériels des Chaudières Electro Nucléaires
ALFRED	Advanced Lead Fast Reactor European Demonstrator
ALLEGRO	European Gas-Cooled Fast Reactor Demonstrator
ALLIANCE	European Radioecology Alliance
ANENT	Asian Network for Education in Nuclear Technology
ASTM	American Society for Testing and Materials
ASTRID	Advanced Sodium Technological Reactor for Industrial Demonstration
ATF	Accident Tolerant Fuels
CANDU	Canada Deuterium-Uranium Reactor
CBRN	Chemical, Biological, Radiological and Nuclear
CCS	Carbon Capture and Storage
CEN	Comité Européen de Normalisation / European Committee for Standardization
CENELEC	Comité Européen de Normalisation Electrotechnique / European Committee for Electrotechnical Standardization
CERN	European Organization for Nuclear Research
CfD	Contract for Difference
CONCERT	European Joint Programme for the Integration of Radiation Protection Research
CSA	Coordination and Support Action
CSP	Concentrated Solar Power
CERN	European Organization for Nuclear Research
DEMO	DEMOnstration fusion Power Plant
DEVCO	EC Development and Cooperation Directorate General
D-T	Deuterium-Tritium
EC	European Commission
ECTS	European Credit Transfer System
ECVET	European Credit System for Vocational Education and Training
EEPR	European Energy Programme for Recovery
EERA	European Energy Research Association
EESC	European Economic and Social Committee

EFSI	European Fund for Strategic Investments
EFTS	Euratom Fission Training Scheme
EGE	European Group on Ethics in Science and New Technologies
EHRO-N	European Human Resources Observatory in the Nuclear Energy Sector
EIB	European Investment Bank
EII	European Industrial Initiative
EIT	European Institute of Technology
EJP	European Joint Programme
EMINE	European Master in Innovation in Nuclear Energy (KIC InnoEnergy)
EMSNE	European Master of Science in Nuclear Engineering
ENEF	European Nuclear Forum Energy
ENEN	European Nuclear Education Network Association
ENEF	European Nuclear Forum Energy
ENIQ	European Network for Inspection and Qualification
ENS	European Nuclear Society
ENSRA	European Nuclear Security Regulators' Association
ENSREG	European Nuclear Safety Regulators Group
EPR	European Pressurised Reactor
ERASMUS+	EU's programme to support education, training, youth and sport in Europe
ERC	EC European Research Council
ERDF	Cohesion Policy funds and European Development Regional Funds
ERIC	European Research Infrastructure Consortium
ESARDA	European Safeguards Research and Development Association
ESFRI	European Strategy Forum on Research Infrastructures
ESNII	European Sustainable Nuclear Industrial Initiative
ETKM	Education, Training and Knowledge Management
ETP	European Technology Platform
ETS	Emissions Trading System
ETSON	European Technical Safety Organisations Network
EU	European Union
EUA-EPEU	European University Association European Platform of Universities in Energy
EURADOS	European Radiation Dosimetry group on dosimetry research
EURAMED	European Alliance for Medical Radiation Protection Research

F4E	Fusion for Energy
FIIF	Fusion Industry Innovation Forum
FNR	Fast Neutron Reactor
FOAK	First Of A Kind
FORATOM	European Atomic Forum
FR	Fast Reactor
FUSENET	European Fusion Education Network
GFR	Gas-cooled Fast Reactor
GHG	Green House Gas
GIF	Generation-IV International Forum
H2020	Horizon 2020 - The EU Framework Programme for Research and Innovation
HERCA	Heads of the European Radiological Protection Competent Authorities
HEU	High Enriched Uranium
HLM	Heavy Liquid Metal
HTGR	High Temperature Gas-cooled Reactor
HTR	High Temperature Reactor
HTRR	High Temperature Research Reactor
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IGD-TP	Implementing Geological Disposal Technology Platform
InnovFin	H2020 Risk Sharing Finance Facility
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
INSC	Instrument for Nuclear Safety Cooperation
IP	Implementation Plan
ISO	International Organization for Standardization
ITER	means "The way" in Latin. ITER is an international project with the aim to demonstrate the scientific and technological feasibility of fusion energy being the first fusion experiment to produce net power
JET	Joint European Torus
JPNM	EERA Joint Programme on Nuclear Materials
JRC	European Commission’s Joint Research Centre
KIC Inno	Knowledge and Innovation Community InnoEnergy
KEC	Key enabling condition
LANENT	Latin American Network for Education in Nuclear Technology

LCEE	Low Carbon Energy and Efficiency
LEU	Low Enriched Uranium
LFR	Lead-cooled Fast Reactor
LLW	Low Level Waste
LTO	Long Term Operation
LWR	Light Water Reactor
MA	Minor Actinides
MELODI	Multidisciplinary European Low Dose Initiative
MFF	Multiannual Financial Framework
MMO	Man-Machine Organisations
MOU	Memorandum of Understanding
MOX	Mixed Oxide Fuel
MS	Member State
MSCA	EC Marie Skłodowska-Curie Actions
MSR	Molten Salt Reactor
MYRRHA	Multi-Purpose Hybrid Research Reactor for High-tech Applications
NC2I	Nuclear Cogeneration Industrial Initiative
NEA	OECD Nuclear Energy Agency
NERIS	European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery
NGNP	New Generation Nuclear Plant
NI2050	OECD/NEA Nuclear Innovation 2050 roadmap
NKM	Nuclear Knowledge Management
NPP	Nuclear Power Plant
NUGENIA	Nuclear Generation II and III Association
NURESIM	Nuclear Reactor Simulation Platform
OECD	Organisation for Economic Co-operation and Development
ODS	Oxide Dispersion-Strengthened
P&T	Partitioning and Transmutation
PIE	Post-Irradiation Examinations
PINC	Nuclear Illustrative Programme
PRPPWG	GIF Proliferation Resistance and Physical Protection Working Group
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor

Q	Fusion Energy Gain Factor
R&D	Research and Development
R&D&I	Research Development and Innovation
R&I	Research and Innovation
RCC-MRx	Règles de Conception et de Construction pour les Matériels mécaniques des structures à hautes températures et des Réacteurs expérimentaux et à fusion
RES	Renewable Energy Source
RI	Research Infrastructure
RSFF	Risk Sharing Finance Facility
RSWG	GIF Risk and Safety Working Group
RTD	EC Research and Innovation Directorate General
SAMG	Severe Accident Management Guidelines
SCWR	Supercritical Water-cooled Reactor
SET-Plan	Strategic Energy Technology Plan
SETIS	Strategic Energy Technology Information System
SFR	Sodium-cooled Fast Reactor
SIAP	Senior Industry Advisory Panel
SMR	Small Modular Reactor
SNETP	Sustainable Nuclear Energy Technology Platform
SRIA	Strategic Research and Innovation Agenda
STC	Euratom Scientific and Technical Committee
STEM	System for the Education and Training of Scientists and Engineers
TSO	Technical Safety Organisation
TWG	Temporary Working Group
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VHTR	Very High Temperature Reactor
WENRA	Western European Nuclear Regulators Association
WMO	Waste Management Organisation
WS64	Comité Européen de Normalisation Workshop 64