Joint Input Paper to SET-Plan Action 10 by SNETP and EERA/JPNM

April 2016

This document provides input to the European Commission, specifically on the **Issues Paper for Action #10** of the SET Plan on "*Maintaining a high level of safety of nuclear reactors and associated fuel cycles during operation and decommissioning, while improving their efficiency*".

It represents the consolidated views of the Sustainable Nuclear Energy Technology Platform (**SNETP**, including its three technology pillars NUGENIA, ESNII, NC2I) and of the Joint Programme on Nuclear Materials established under the European Energy Research Alliance (**EERA/JPNM**).

SNETP and its pillars gather more than 120 European stakeholders involved in the research and development, deployment and operation of nuclear fission reactors and fuel cycle facilities: industry, research centres, universities, technical safety organisations, service providers, non-governmental organisations. Despite industrial competition, SNETP has achieved efficient collaboration and consensus building between its stakeholders. It has developed a common vision on the future contribution of nuclear fission energy in Europe, with the publication of a *Vision Report*, a *Strategic Research & Innovation Agenda* and a *Deployment Strategy*.

www.snetp.eu

The **EERA's JP on Nuclear Materials** gathers 17 core partners and 29 associated partners representing energy materials research across Europe. Its objective is to improve safety and sustainability of nuclear energy by focusing on materials aspects: Better knowledge of materials behaviour under operating conditions, seeking predictive capability, to select the most suited materials and define safe design rules, especially allowing for radiation and temperature effects, while caring for compatibility with coolants; and Development of innovative materials with superior capabilities, resistant to high temperature and aggressive environments.

www.EERA/JPNM.eu

1. Introduction

1.1. Foreword

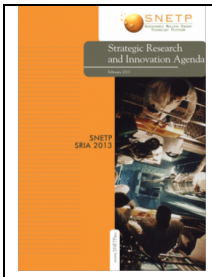
For sustainable prosperity, an affordable and secure energy supply with minimized environmental impact is a primary need, for Europe and beyond. Currently the major share of energy needs is covered by fossil fuel resources. With a growing world population and energy consumption per capita, fossil resources are becoming scarce, while global ecological impact from greenhouse gas emissions is increasing day by day. Increased geopolitical tensions, negative economic impact due to energy price volatility, and maintained imbalance in world population prosperity can be connected to this. It will be hard to change both the luxury of access to cheap energy, and the convenient way fossil fuels have provided it. The right answer is to replace the large share of energy generation by fossil fuels by a balanced mix of different low-carbon energy sources, whilst reducing energy usage as much as is reasonably achievable. The COP21 Paris Agreement to contain temperature rising, and Europe's ambitious decarbonisation targets will lead to a considerable increase in low-carbon electricity consumption. Therefore looking to massive electricity production by non-emitting sources like nuclear energy is a must.

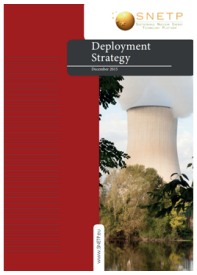
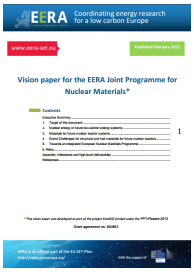
Nuclear energy has been a reliable energy source for decades, and provides a very significant share of current electricity supply. We believe this share should be maintained in Europe, as a responsible contribution to the EU's low-carbon energy mix. This is achieved by ensuring safe and reliable operation of the current (Generation II) fleet, supported by long term operation, maintenance programmes, and by pursuing nuclear the development of new build projects of Generation III nuclear plants. Furthermore, significant improvements in terms of resources, efficiency and waste production will be reached with the future deployment of Generation IV nuclear systems, which relies on fast neutron technology with a closed fuel cycle. Nuclear fission technology can also deliver cogeneration of heat and power, in particular for industrial purposes where the heat market is dominated by fossil fuels with no alternative from renewables, thus appearing as a game-changer in reducing the carbon footprint of energy-intensive industries.

Advanced materials are a key enabler for innovation in nuclear fission systems, both present and future, which is reflected in the cooperation between SNETP and the EERA JPNM. The needs addressed include both structural materials and nuclear fuel.

1.2. Reference documents

The vision and objectives of SNETP and the EERA JPNM are detailed in a number of strategic documents, all publicly available online:

	**SNETP Strategic Research & Innovation Agenda 2013** (download here) Updated from SNETP's initial SRA 2009, the SRIA 2013 addresses the short-, mid- and long-term challenges with respect to fission technologies, in line with the SET-Plans' objectives and long-term vision. The R&I objectives are structured along SNETP's technology pillars (NUGENIA, ESNII, NC2I) as well as cross-cutting topics.

	**SNETP's Deployment Strategy 2015** (download here) The Deployment Strategy complements the SRIA, and aims to prioritise the SNETP programme over the coming decades to make it fully aligned with the general context of electricity generation in Europe, which includes different energy sources, different national energy policies and societal challenges. Planning assumptions for the nuclear energy systems define the technical milestones to be reached.
	**EERA JPNM's Vision Paper 2015** (download here) This report presents the vision of the JPNM with respect to the need for future nuclear energy as a component of a resilient Energy Union with a forward-looking climate change policy; the key role of structural and fuel materials for the development of sustainable nuclear reactor systems; the Grand Challenges for such materials that need to be addressed; the establishment of an integrated European nuclear (structural and fuel) materials research programme. Additionally JPNM is currently developing a Strategic Research Agenda.

The priorities set out in the above documents are also aligned with the **SET-Plan Integrated Roadmap**, specifically its Heading 5 on "*Supporting Safe Operation of Nuclear Systems and Development of Sustainable Solutions for the Management of Radioactive Waste*"

1.3.Our common commitment

The ambitious targets proposed by the SET-plan in the *Issues Paper Nr. 10* cover implicitly in a generic way, for fission energy, the aspects already detailed in the strategic research & innovation agenda (SRIA) of the SNETP, as well as, for materials, in the draft SRA of the EERA JPNM. The actions connected to the achievement of those targets are thus aligned with the commitment of these platforms. SNETP and its three technology pillars are gathered in a single ETIP, and the EERA/JPNM is in the process to explicitly link with the ETIP via a Memorandum of Understanding currently under finalisation. As an anticipation of such structuration, the current document reflects the common commitment of SNETP, its pillars and EERA/JPNM to work jointly, with the support of the European Commission and the Member States, to achieve the targets defined in the Issues Paper. The support of MS and EC is actually key, because none of the targets can be approached without the political willingness of the MS and the integrating role of the EC.

SNETP and EERA/JPNM welcome the EC's initiative and offer their collaboration to the EC to provide a joint view from the main R&D&I actors in nuclear fission technologies for electricity or heat generation and other applications. SNETP and EERA/JPNM provide in this input paper very specific recommendations on the description, scope and timing of the targets and cross-cutting issues included in the EC's draft Issues Paper, and also suggests additional critical targets to

maintain the safety and competitiveness of nuclear electricity generation and to enhance its long-term sustainability.

SNETP and EERA/JPNM will also be willing to contribute along all the roadmap indicated in the "SET Plan Expected outcomes and process" towards a final preparation of the Issues Paper, the update of the SET-Plan and corresponding R&D&I programmes. In this context we would like to suggest the use of the recent SNETP Deployment Strategy (DS, Dec 2015), released after a large coordination effort with all major European nuclear fission actors, including the three industrial initiatives inside the SNETP (NUGENIA, ESNII and NC2I), that describes in detail our evaluation of the recommendations on prioritising R&D activities on those issues, identifying who are the best placed actors to implement the targets/priorities (industry, EU, Member States,…) and identify possible gaps/barriers & areas of cooperation on the priorities/targets proposed in the Issues Paper. This is complemented with an EERA/JPNM Annex to the present joint Input Paper summarising these elements from the specific perspective of the SRA in preparation (to be published within 2016). Both SNETP and EERA/JPNM are ready to provide any additional clarification or collaboration with the EC.

We believe that SNETP's and the JPNM's strategic priorities are overall properly reflected in the orientations of the proposed SET-Plan *Action 10 Issues Paper*, and provide here detailed input to the consultative process organised by the European Commission.

2. Input Paper

2.1. Comments to the "Targets" section of the draft Issues Paper / Action No. 10

SNETP and EERA/JPNM welcome the EC initiative to prepare the Issues Paper Action No. 10 and the invitation to comment this paper and contribute to reach an agreement of the nuclear stakeholders on the appropriate targets/priorities.

SNETP and EERA/JPNM share most of the targets of the Issues Paper and their formulation, however we would like to propose some comments for clarification of the scope and ambitions and in some cases, to be efficient and specific, we propose alternative formulations for specific targets. In addition, some new targets are suggested that we understand would be critical to maintain the safety and competitiveness of the nuclear electricity generation and to enhance its long-term sustainability:

- *Comments to Target 1. Maintaining a high level of safety and security*
  - Second bullet: Some of the targets proposed in the second bullet, like accident-tolerant fuel, might be too difficult to reach conclusive findings by 2020; still with adequate funding it is possible to advance significantly on crucial aspects of LTO by focusing on specific materials and components, so it might be better to split the bullet and to indicate a later date (2025 or 2030) for some of the sub-targets.
  - Bullet 4: "optimisation of NPP operation as a function of predicted demand, and integration with more intermittent suppliers in evolving electricity grids" could be referred to present reactors and to new concepts. So although it can be

considered at this point it might be better to make it a differentiated target in relation to innovative reactors and, in any case, we understand that it is important to make clear that the optimizations include the technical and economical capability of NPP operation in those conditions.

- It might be also appropriated to consider adding a bullet for: "identification, by 2020, of technologies to handle obsolescence of equipment of plants in operation and to adapt the technological culture of future operators to plants built some decades ago".
- Finally, although availability of trained workforce is recognized as an important cross cutting requirement, it could be useful to stress that a clear definition of the tools to guarantee the availability of sufficient workforce with the required training level is particularly critical for this target 1.

- *Comments to Target 2. Radioactive waste management and decommissioning*
  - We would like to suggest a new bullet added for: "Validation, by 2020, of the safety, feasibility and technologies for different extended storage of irradiated fuel as interim solutions for, at least, the next 50 years. Demonstration that the solutions are adapted to provide the time buffer from waste generation until disposal or recycling, and are prepared to properly handle any possible evolution of the national energy policy."

- ***Comments to Target 3. Advanced and innovative fission reactors***

  In the draft received this target mixes several concepts and could induce confusion. It can be misleading to assemble together, in the same paragraph, the GEN IV reactors which offer "…uranium resource efficiency and lower long-lived waste production..." and the "…SMR and co-generation plants..." which can provide "... more flexible energy sources...". The attractiveness as well as the Technology Readiness Levels (TRL) are different. So we suggest that this target could be better described by splitting it into 3 targets and we propose the following formulation:

- *Target 3a: Innovative reactors designs for long-term sustainable fuel cycle*

  Towards 2050 the availability of demonstrated designs offering increased resource efficiency and lower long-lived waste production may become attractive for utilities, as well as for the general public in the frame of minimizing long term environmental impacts. This requires targets by 2030:
  - At least one Generation-IV demonstrator fast reactor operating in Europe by 2030, including associated facilities for the closed fuel cycle (pilot fuel fabrication and processing plants). The availability of qualified innovative nuclear materials and fuels, suitable for the expected operational conditions, is crucial for this target.
  - Long-term sustainable closed fuel cycle can also be implemented based on Small Modular Reactors designs based on fast spectrum coolant technologies. Should the balance of economics, sustainability and market need favour development of fast spectrum SMRs, the target should be to develop a demonstrator of such a system by 2030.

- *Target 3b: Increase nuclear competitiveness and flexibility*

  Several elements should be considered: on one side the reduction of NPP capital costs; and on the other hand adapting NPP to the increasing requirement for more flexible energy sources including the optimisation of NPP operation as a function of predicted demand, and integration within evolving electricity grids including intermittent power from renewable energy sources.

  - Development by 2030 of methodologies and technologies allowing significant reduction of NPP capital costs: construction schedule reduction, simplification of design, standardisation and construction in series, certification at EU level and licensing harmonization...
  - Development of Small Modular Reactors (SMR). SMRs can be either based on current Light-Water Reactors (LWR) technology or innovative coolant technology. The TRL of SMR based on LWR technology should allow putting one such SMR into operation by 2030. Such a reactor should demonstrate the added value of modularity, larger flexibility of load follow up and passive safety. The flexibility of SMRs to replace existing fossil plants, including different power requirements and geographical distributions should also be validated. The research and development of licensing practises for SMRs and specific material research to accommodate the demand following performance are prerequisites for this target.

- *Target 3c: Nuclear cogeneration*

  Nuclear heat and electricity cogeneration is a low-carbon alternative to fossil fuels in industrial heat generation. Therefore it is necessary to progress with its implementation having in mind challenging goals of energy independence and emission reduction. Providing low cost industrial heat is also important for ensuring competitiveness of European industry. Thus, the target should be:

  - Developing at least one high temperature cogeneration plant by 2030, and demonstrating the efficiency and safety of the coupling to the heat consumer industrial plant. The availability of qualified innovative nuclear materials and fuels suitable for the expected system conditions are crucial prerequisites for some of the reactor designs considered for cogeneration plants.

- *No comments on Target 4: Fusion* (outside the scope of SNETP)

- *We propose to introduce a new Target 5: Irradiation facilities*

  During the last decades, irradiation services for material and fuel irradiations services for present and future fission reactors and for fusion reactors as well as for the production of radio-isotopes for medical and industrial applications, were mainly secured by HFR (NL), BR2 (BE), OSIRIS (FR) and MARIA (PL). The last one needs to be upgraded, while the others reactors are scheduled to be replaced by PALLAS (NL) MYRRHA (BE) and JHR (FR). So the following specific targets should be considered:

  - JHR experimental reactor for material and fuel testing commissioned by 2020,
  - Commissioning of MYRRHA as a fast spectrum irradiation facility and ADS concept demonstrator by 2030,

- Those experimental reactors should be complemented on a commercial basis with PALLAS to secure the radio-isotope production.

- *We also propose to introduce Target 6: Nuclear generation capacity and cost of electricity*

  Nuclear fission reactors have the potentiality of providing a large share of the electricity generation and for contributing to the EU's security of energy supply, with very low CO_2 emissions and competitive generation costs compared with other low CO_2 sources of energy. The following specific targets should be considered:
  - Deployment of 100 GWe new-build capacity, mainly Generation-III LWR, to be connected to the grid in the period 2015-2050
  - To maintain competitive levelised cost of electricity (LCOE) of the latest generation of Light-Water Reactors from new-build Generation-III and LTO Generation-II, in line with recent forecasts:
    a) For the first of a kind new-build twin reactor project on a brownfield site: EUR(2012) 48/MWh to 84/MWh (falling to EUR(2012) 43/MWh to 75/MWh for a series build) (with discount rate assumption of respectively 5% and 10% real);
    b) Following refurbishment for long term operation (LTO, 10 to 20 years on average) of the existing Gen-II nuclear power plants: EUR (2012) 23/MWh to 26/MWh (with discount rate assumption of respectively 5% and 10% real).

2.2. Comments to the "Cross-cutting challenges" part of the draft Issues Paper / Action No. 10

SNETP and EERA/JPNM agree with all the items included in the proposed list of cross-cutting challenges required to achieve the previous targets and to maintain the contribution of nuclear energy to a safe, competitive and low-carbon electricity generation. We would like, however, to propose some clarifying comments to better describe their scope and required ambition, as well as to remind other cross-cutting challenges that we consider also very important:

- Bullet 3: For clarity of the messages we suggest to split this bullet in two challenges:
  - The availability of a well-defined system for the education and training of scientists, engineers and other skilled workers, e.g. benefitting from ERC, MSCA and/or ERASMUS+ grants;
  - The availability and mobility at EU level of the required trained workforce, e.g. benefitting from a European Credit System for Vocational Education and Training (ECVET).
- Bullet 6: In order to avoid confusion for the meaning of "reactor codes" we suggest to use "Reactor Codes and Standards".
- Bullet 8: We agree that "availability of state-of-the-art research infrastructures is needed for materials research", but we would like to stress that it is also important, "for safety, basic data and models, and fuel research" and that the availability is "stable and

predictable". We suggest to also indicating in this bullet that "Support is essential for the development of computational tools for improved accuracy and fast execution using modern massively parallel computing technology, covering all aspects, from neutronics and materials behaviour to accident evolution".

- Bullet 9. The availability of all potential EU funding options, towards the MS that made the choice to develop new research infrastructure, deserves the highest priority since this is the main path to achieve and maintain "… technological leadership in the nuclear domain..." as reported in the Energy Union Communication mentioned in the Introduction. Moreover, the erection of Demonstration Reactors has to benefit as well.

- We propose to add a new bullet (just after the first bullet) with: "Development of modular construction technique for any reactor coolant technology (light water, liquid metal, molten salt and gas) that will allow progressive and lower initial capital investment with fast return on investment, and delocalized production of energy".

SNETP, JPNM/EERA and other technological platforms are contributing to structure, at EU level, the Fission Energy R&D&I program, proposing comprehensive strategic research and innovation agendas (SRIA) and deployment strategies (DS), compatible between themselves and with the SET-Plan Integrated Roadmap (Heading 5). This framework provides favourable conditions to support the joint programing of this research. Such instrument could be used in several areas of the Fission R&D&I, to leverage earmarked MS funding in support of pan-European coordinated efforts towards a long-term sustainable nuclear energy.

As a final remark, it is important to remind that Europe can only retain leadership in these areas, given the increase in nuclear generating capacity in the rest of the world, by maintaining a vibrant EU nuclear industry and a corresponding innovative, comprehensive and well-funded EU nuclear research capability.

3. Contact

SNETP and EERA/JPNM are happy to provide any clarification or additional information on the above input paper.

Questions may be channelled to:

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