SNETP

Sustainable Nuclear Energy Technology Platform

SNETP REPORT

SNETP FORUM 2022 - Proceedings

SNETP Association

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The SNETP FORUM 2022 Proceedings report was prepared by the SNETP Association.

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Executive Summary

The SNETP FORUM 2022 was held on 2 June 2022 in Lyon, France. Over 300 participants from all European countries were actively involved in this 2022 edition.

The programme was designed with the help of the moderators of the SNETP FORUM:

- ✓ Abderrahim Al Mazouzi (EDF)
- ✓ Anthony Banford (NNL)
- ✓ Michael Fütterer (EC-JRC)
- ✓ Elisabeth Guillaut (ORANO)
- ✓ Erika Holt (VTT)
- ✓ Pavel Kral (UJV)
- ✓ Petri Kinnunen (VTT)
- ✓ Oliver Martin (JRC)
- ✓ Ferry Roelofs (NRG)
- ✓ Christophe Schneidesch (Tractebel)
- ✓ Ronald Schram (NRG)
- ✓ Eero Vesaoja (Fortum)
- ✓ Jozef Sobolewski (NCBJ)

And the organisation committee:

- ✓ Abderrahim Al Mazouzi (EDF)
- ✓ Gilles Quénéhervé (LGI)
- ✓ Clara Demange (LGI)

1. The challenges of nuclear energy in Europe

During the FISA 2022 & EURADWASTE'22 conferences, just before the SNETP Forum 2022, the SNETP president, **Bernard Salha**, delivered the following keynote speech featured here:

SNETP[1] is an international association (AISBL) composed of around 120 members from 25 countries, gathering nuclear power plant operators, research centers, nuclear industry, and technical support organizations. The association has been supporting the creation and the implementation of R&D programmes since 2007.

European Technology Platforms (ETPs), such as SNETP, are industry-led stakeholder fora recognised by the European Commission as key players in driving innovation, knowledge transfer and European competitiveness in support of the SET Plan Implementation. Among their numerous activities, they develop research and innovation agendas supported by private and public funding for an implementation at the EU but also at national levels.

SNETP members believe that continuous technological innovation is fundamental to maintaining a high level of safety and competitiveness and requires the establishment of a coordinated R&D&I programme at European level in close collaboration with international partners to continuously make the European nuclear sector more competitive and safer, in a context of climate change and global competition within which nuclear energy can play a significant role in meeting climate objectives as a near zero-greenhouse gas emissions source.

During the Covid pandemic, our sector has demonstrated a high-level of resilience thanks to the highly skilled competences available in Europe[2]. Today, we are facing an unprecedentedly complicated situation in the energy sector with the need to ensure a smooth and affordable transition to a decarbonised economy in 2050. All low-carbon technologies will be needed, and many member states have confirmed that nuclear will be an essential part of their energy mix.

Recently, the European Commission has approved the complementary delegated act (CDA) on the taxonomy regulation and nuclear technology has been included, even though with drastic limitations[3]. Nuclear can indeed help the EU tackle the current energy challenges, providing a positive contribution to the security of supply, the stability of power prices and the achievement of the decarbonisation goals. Therefore, there is a growing relevance of R&D&I to reduce the EU dependence on unreliable sources and to provide more diversified and affordable energy.

New innovative solutions are needed to ensure competitive costs compared with other production technologies and short time construction and implementation in the local systems. It is also important to cover the needs of industry and transport with very low-carbon supply of industrial heat and hydrogen at large scale. In addition to the operating nuclear power reactors and those that are under construction or ready to be launched, Europe needs to broaden the available reactor offer to meet national/local specificities. The development of various ***SMRs, based either on LWR technology or others*** *offers the possibility to deploy flexible options for electricity and non-electricity applications. R&D&I must support the*

[1] http://www.snetp.eu/

[2] https://op.europa.eu/en/publication-detail/-/publication/08f1e63d-a8cf-11ec-83e1-01aa75ed71a1/language-en?pk_campaign=ENER%20Newsletter%20APRIL%202022

[3] https://snetp.eu/2022/01/24/snetp-reacts-to-the-draft-of-the-complementary-delegated-act-of-the-eu-taxonomy-regulation/

*development of SMRs to make them **safe and competitive** with other production means within a global strategy of deployment within next decades.*

*In this context, SNETP, thanks to its members, has been working hard to **streamline and foster collaboration in the technological sectors** that are critical for our field based on the updated **SNETP SRIA** and on the visions of its pillars (**NUGENIA vision**, **ESNII vision**, **NC2I vision**). Moreover, SNETP has taken a leading role on the co-creation of the **EU SMR partnership preparation**, together with other institutions (FORATOM renamed recently "**NUCLEAREUROPE**", the European Commission and ENSREG) and stakeholders, gathering our best efforts to make Europe play its part in the development of this very promising technology for power generation and non-electric applications.*

It has become increasingly clear – and widely documented – that achieving the 2°C target and complete carbon-neutrality by 2050 cannot be achieved without nuclear power. Thus, large light water reactors and SMRs based on various technologies are complementary with renewables to meet this objective. This is also related to the expected massive electrification of buildings, transport and industry in the future:

- ***Growing demand of electricity and capacity to supply it at a stable price through nuclear power***

Several recent studies from the European Commission[4], the IPCC[5] and various stakeholders[6] have explored the potential for increased ambition for the decarbonisation of the power sector: These studies suggest a growing role of electricity, from circa 20% of the European final energy consumption in 2015 to more than 40% to 50% by 2050 through electrification of transport, heating and cooling and industrial processes.

Nuclear energy also contributes to improving the dimension of energy security (i.e., to ensure that energy, including electricity, is available to all when needed) since:

- *fuel and operating costs are relatively low and stable: about 15% of the Kwh produced by a nuclear power plan (the remaining 85% are related to the construction and dismantling);*
- *it can generate electricity continuously for extended periods; and*
- *it can make a positive contribution to the stable functioning of electricity systems*

Thus, nuclear, together with renewables, can play an important role in reducing the dependence on fossil fuel energy imports in Europe and produce industrially a large quantity of decarbonised electricity at affordable and stable price.

- ***Decarbonization of energy intensive industry at a stable price through nuclear energy***

Demand for non-electric forms of energy is also growing and will be decisive for the success of re-industrialization in the EU and for the security of supply. This concerns mainly process heat and the production of hydrogen or its derivatives, for instance syngas, synthetic hydrocarbon fuels or ammonia. These are not only used as energy carriers but as feedstock for many industrial products. Because they can be easily stored, they can also facilitate the interfacing of nuclear with variable renewables.

- ***Industrial autonomy and security of supply of the EU thanks to nuclear energy***

The European nuclear industry is robust and experienced, it can ensure the independence and the autonomy of the EU covering the entire life cycle from design to construction and safe exploitation of nuclear power plants:

[4] 2030 Impact assessment (2020), 2050 EU Energy roadmap (2018), EU Reference scenario 2013, 2016, PINC
[5] IPCC: Global Warming of 1.5C, October 2018 (3)
[6] World Energy Outlook (IEA, 2020)

- *In 2019, the nuclear industry sustains more than 1.1 million jobs throughout the European Union, out of which more than half a million are staffed with highly skilled professionals, among them 15000 researchers[7].*
- *Today, 104 reactors are in operation across the union, still several industrial units are operating for the fabrication and the recycling of fuels (France, Germany, Netherlands) including Uranium chemical treatment and enrichment*
- *The EU has developed over decades, a consistent and well qualified supply chain starting from the beginning of the process cycle, these are raw material suppliers, fabricators, sub-component suppliers, original equipment manufacturers, system integrators and technology vendors, including within the member states that have decided the phase-out (Italy, Germany)*
- *The nuclear research in Europe encompasses multiple layers of local and centralized initiatives and programs (including Euratom) using high quality research infrastructures (even though scarce and ageing) that allows the strengthening and the maintenance of the EU leadership;*
- *Important capacities, although ageing, for the production and the recycling of fuel quasi-exclusively for light water reactor technology*
- *The EU has the most advanced legally binding and enforceable regional framework for nuclear safety in the world and, despite diverging views among Member States on nuclear generated electricity, there is a shared recognition of the need to ensure the highest possible standards for the safe and responsible use of nuclear power and to protect citizens and environment from radiation.*
- *Disposal facilities for high level radioactive waste are under construction in Finland, Sweden and France and many other facilities for intermediate storage are being operated across almost the entire Union.*

- ***Strategic approach for value and growth***

To keep the pace and to take stoke of the experience gained, the challenges of the European nuclear industry should be addressed along two paths:

- *Contribute to achieving carbon neutrality in Europe by 2050: to ensure this objective only the technology of industrially mature water reactors grants a sufficient capacity by this horizon to contribute significantly. The means to achieve this are:*

  - *To maintain a high level of safety for existing and future reactors - Operate existing reactors in the long term up to their technical limit, extend the lifetime beyond 60 years whenever aging analyzes permit it, avoid premature closures (case of Belgium that decided to maintain 2 reactors, the case of Germany that decided to close the last 3 running reactors).*

  - *To build new large-scale reactors (EPR2 in France, call for tenders in the Czech Republic, announcements from the British PM) where the sites and the electrical transmission network allow it. They will be based on existing technologies (no development of new large models in the Western world today), either French (EPR2), American (AP1000) or Korean (APR1400) by maximizing the European local share in these last two cases.*

  - *To develop and build SMR/AMR in Europe (see European Partnership on SMR). These will be new models because this technology is not currently deployed on an industrial scale. Water-based SMR technology is the most promising to rapidly play a significant role*

[7] FORATOM | Economic and Social Impact Report, 2019

alongside large reactors as they are based on proven technology. SMR/AMR could also foster the use of nuclear energy for other application than electricity (e.g., industrial high temperature heat, hydrogen production…) contributing to the net zero objective.

- ➢ *To sustain by modernizing and adapting them to the needs of the production, operation and recycling of fuel for light water reactors*

- *Ensure the sustainability of nuclear power in the long term by reducing the volume of long-lived waste products, in particular actinides, and limiting the dependence on natural uranium through closed fuel cycle. To this end, it is necessary to:*
    - ➢ *Develop Generation IV reactors, specifically Advanced Modular Reactors (AMR), with first demonstrators operating by 2035 at the soonest to support a fully established commercial deployment by 2050.*
    - ➢ *Develop associated fuel industrial offer (including recycling) based on existing know-how on light water reactor technology;*
    - ➢ *Take advantage of the European approach of the SMR partnership to produce these developments at the European level and pool efforts on reactors that still are not industrially mature;*
    - ➢ *Bring together players working on similar technologies (sodium, lead, molten salts, high temperature) to build critical mass of skills and competences with the needed infrastructures.*

- ***SMR-partnership initiative***

The above-described strategic approach is well aligned with the initiative "SMR-partnership" launched in June 2021 under the auspice of the European commission. It is an opportunity to develop cross-sectorial synergies and to deploy modern and innovative technologies in the nuclear sector. It is also an opportunity to strengthen EU research and industrial nuclear capabilities on SMR/AMR which may lag behind a number of other countries.

Key attributes of the SMR partnership can be synthetized as follows

- *SMRs are small-scale reactors, factory constructed in series, whose deployment must be based on the same model produced identically in several countries to maximize the series effect. The European partnership is therefore a necessity to ensure the economic and industrial viability of these reactors.*
- *Supported by the European Commission, Foratom (European association of nuclear industry), SNETP (European nuclear research platform), ENSREG (association of European nuclear regulators), it brings together all the European players in the sector.*
- *It is based on five streams and working groups:*
    1. *Exploration of market conditions and in particular the use of SMR for the production of electricity but also of hydrogen or high temperature heat;*
    2. *Harmonisation of safety rules to limit regulatory changes for reactors built in different European countries and thus maximize the series effect;*
    3. *Adoption of favourable financing and support mechanisms;*
    4. *Mobilization of the European industrial supply chain to become the backbone of the industrial deployment of SMRs from manufacturing to maintenance of the needed equipment of these reactors;*

5. *Mobilization of the European research network and its experimental facilities to validate the innovative concepts of these reactors and train new engineers.*

The SMR partnership should lead to the selection of 3 to 5 future SMR reactor designs (for LWR) or reactor technologies (for AMR) on which the above working groups will focus. These models will be selected based on the support they receive from member states and European utilities and the principles of autonomy and independence of the European Union concerning the manufacturing capabilities and intellectual property rights.

Most of these will be water reactors, but also of generation IV design. Several models with a strong European content will thus emerge, facilitating the deployment of SMRs in Europe on mid-long term scales. Furthermore, this will allow the identification of the appropriate fuel management systems for generation IV type designs.

- ***Conditions for success***

The success of this industrial approach requires a favorable regulatory context and financing mechanisms reconciling revenue visibility and stable costs for customers:

- *The European nuclear taxonomy is being finalized: the European Supplementary Delegated Act should be voted on in parliament at the beginning of July and come into force at the beginning of 2023 if it is approved.*
- *Nuclear power plants (and recycling facilities) are long-term investments (from launch to construction, followed by an operating period of ~60 years). Their financing requires mechanisms to give investors visibility on revenues beyond short-term energy prices. In return, customers must benefit from stable and competitive energy prices over a long period of time*

- ***Additional Cross sectorial benefits***

Nuclear is a cutting-edge R&D&I.

- *Nuclear R&D&I develops cutting-edge knowledge that may be beneficial to several other sectors, such as health, aerospace, digital, …*
- *Vice-versa other cutting-edge technologies such as artificial intelligence for example could be used in nuclear technology, for example for design and maintenance of nuclear facilities.*
- *SNETP intends to promote those cross-sectorial benefits in its R&D&I programme.*
- *Cross-sectorial industrial cooperation between electricity, heat, hydrogen generation and energy intensive sectors will be a key element to drive success*

2. SNETP Forum programme

SNETP FORUM TECHNICAL SESSIONS – 2 June 2022				
#	Room 1	Room 2	Room 3	Room 4
	TS1: SMRs **Moderators: Ferry Roelofs (NRG), Jozef Sobolewski (NCBJ)**	**TS4: R&D&I facilities** **Moderators: Pavel Kral (UJV), Petri Kinnunen (VTT)**	**TS2: Nuclear codes & standards & supply chain** **Moderators: Oliver Martin (JRC)**	**TS6: Nuclear to mitigate climate change including non-electricity applications** **Moderators: Ronald Schram (NRG), Michael Fütterer (JRC)**
11:00	**P1:** SMR-partnership, **Yves Desbazeille (Foratom)** **P2:** Market analysis, **Bernard Dereeper** **P3:** Supply Chain, **Roberto Adinolfi (Ansaldo)**	**P1**: OFFERR project, **Charles Toulemonde (EDF)** **P2**: Setting up the "European User Facility Network", **Jiri Zdarek (UJV)** **P3**: RJH, **Petri Kinnunen (VTT)**	**P1:** Comparison of component integrity concepts for LWRs and activities of CEN Workshop 64 Prospective Group 1, **Bruno Autrusson (nuclear consultant), Manuela Triay (Framatome)** **P2:** Ongoing development activities on RCC-MRx and its enlargement to different Gen IV systems, **Karl-Fredrik Nilsson (JRC), Cecile Petesch (CEA)** **P3:** The NUCOBAM project – Incorporation of additive manufacturing into nuclear codes & standards, **Oliver Martin (JRC)**	**P1**: EU's energy sector integration and hydrogen strategies, **Andrei Goicea (Foratom)** **P2**: Introductory Scene Setter (new Euratom projects, NEA, GIF, IAEA), **Michael Fütterer (JRC)** **P3**: The European chemical industry on the path to climate neutrality, **Nicola Rega (CEFIC)** **P4**: Deployment of nuclear energy in deep decarbonization of the energy system, **Andre Faaij (TNO)** **P5**: Integrated Energy Systems and the pathway to Net Zero by 2050 (a UK context), **Paul Newitt (NNL, 10min video)**
12:00	**P4:** R&D&I - **Sylvain Takenouti** **P5:** Core and Fuel - **Eric Hanus (CEA)** **P6:** Non-electricity (power) applications, **Ville Tulkki (VTT)**	**P4**: NEA task Force on Nuclear Safety Research support facilities for existing and advanced reactors, **François Barré (IRSN)** **P5**: Possibilities of the BR2 reactor as a support facility to materials and fuels R&D, **Joris Van den Bosch (SCK.CEN)** **P6**: PKL/SACO, **Simon Schollenberger (Fra-G)**	**P4:** R&D challenges in improving civil structures design rules for sustainable nuclear energy technology, **Etienne Gallitre (nuclear consultant), Pekka Valikangas (STUK), Tadeusz Szczesiak (ENSI), Alexis Courtois (EDF)** **P5:** Qualification of electrical equipment according to RCC-E **Benedict-John Willey (AFCEN)** **P6:** High-quality European industrial grade items guidelines: **Andrei Goicea (Foratom), Natalia Amosova (Apollo+)**	**P6**: Summary of the Polish national project: GOSPOSTRATEG-HTR, **Agnieska Boettcher (NCBJ)** **P7**: NOMATEN Centre of Excellence in Multifunctional Materials for Industrial and Medical Applications, **Jacek Jagielski (NCBJ)** **P8**: Exploring the deployment of advanced reactor systems for decarbonization of future energy generation: **Geert-Jan de Haas (NRG)** Wrap-up by **Ronald Schram (NRG)**
13:00	**Lunch Break**			
	TS1: SMRs **Moderators: Ferry Roelofs (NRG), Jozef Sobolewski (NCBJ)**	**TS4: R&D&I facilities** **Moderators: Pavel Kral (UJV), Petri Kinnunen (VTT)**	**TS3: Digital & Robotics** **Moderators: Eero Vesaoja (FORTUM), Christophe Schneidesch (Tractebel), Elisabeth Guillaut (ORANO)**	**TS5: Waste minimization and fuel cycle** **Moderators: Erika Holt (VTT), Anthony Banford (NNL)**
14:00	**P7:** NSSS **Oliver Martin (JRC)** **P8:** Passive systems **F. Mascari** **P9:** Severe Accidents, **P. Dejardin** **P10:** Modularity, **M. Marconi (Ansaldo)**	**P7** : Source Term Experimental Research - IPRESCA and OECD/NEA THEMIS Projects, **Sanjeev Gupta (Becker Technologies GmbH)** **P8**: COSMOS-H, **Stephan Gabriel (KIT)** **P9**: HFR / Pallas, **Ronald Schram (NRG)**	**P1:** The Nuclear Digital Nuclear Initiative, **Benoît Levesque/Chai Koren – EDF** **P2:** Combination between Digital Twin and AI for anomaly detection for industrial processes, **Aurélien Schwartz - Métroscope, EDF group** **P3:** Data based solutions & performance in the nuclear sector, **Vincent Champain – Framatome**	**P1:** Euratom introductory address, **Seif Ben Hadj Hassine (EC)** **P2**: Fuel Handling and Waste issues for Molten Salt Reactors, **Jiri Krepel (PSI)** **P3**: Plutonium management in GENIV reactors, **Francisco Alvarez Velarde (CIEMAT)**
15:00	**P11:** Energy Well – Czech molten salt SMR concept, **David Harut – CVR** **P12**: Conceptual design of EUHTER (Polish experimental HTGR), **prof. Mariusz Dąbrowski**	**P10**: Czech research infrastructure for supporting the implementation of the SNETP strategic research agenda, **Marek Mikloš (CVR)** **P11**: Open access of research infrastructures, **Rachel Eloirdi (JRC)**	**P4:** Utilization of artificial intelligence in the analysis of nuclear power plant requirements, **Santeri Myllynen – FORTUM** **P5:** Digital Solution Projects, **A. Duchêne – Tractebel**	**P4:** Waste minimization /recycle through whole fuel cycle, **Luke O'Brien (NNL)**
15:40	**Coffee Break**			
		TS4: R&D&I facilities **Moderators: Pavel Kral (UJV), Petri Kinnunen (VTT)**	**TS3: Digital & Robotics** **Moderators: Eero Vesaoja (FORTUM), Christophe Schneidesch (Tractebel), Elisabeth Guillaut (ORANO)**	**TS5: Waste minimization and fuel cycle** **Moderators: Erika Holt (VTT), Anthony Banford (NNL)**
16:00		**P12**: Education and training and facilities, **Leon Cizelj (IJS)**	**P6:** Modelling and simulation-assisted engineering of cyber-physical systems throughout their life cycle, **T. Ngugen – IAEA consultant** **P7:** Robotics and drone program, **Anders Wik – Vattenfall** **P8:** AERACCESS, **Jean-Luc AYRAL**	**P6:** Advanced Separation for the Optimum management of spent Fuel – portioning, fuel fabrication, secondary waste streams, **Christophe Bruggeman (SCK CEN)** **P7a:** Unique for SMR spent fuel and waste management, **Timothy Schatz (VTT)** **P7b:** Towards harmonised practices, regulations and standards in waste management and decommissioning (EU-HARPERS), **Réka Szőke (IFE)** **P8:** SRA documentation development from projects SHARE and PREDIS, **Anthony Banford (NNL) and Erika Holt (VTT)**
17:00			**P9:** Robotics in VVER SG inspection/cleaning, **Ville Lestinen - Fortum**	Guided Discussion: going forward topics and plan (future collaboration ideas) **– chairpersons**

3. Technical session #1 – Small Modular Reactors (SMR)

This technical session was moderated by J. Sobolewski (NCBJ) and F. Roelofs (NRG). A zip file containing the presentations is available for download here.

3.1 Scope

New innovative solutions are needed to ensure cost competitiveness with other power generation technologies, as well as speed of construction and implementation in local systems. In addition to the nuclear reactors in operation and those under construction, Europe needs to expand the range of reactors technologies available to meet national/local specificities. The development of different SMRs, based on most matured technologies or on other advanced technologies, offers the possibility to deploy flexible options for both power and non-power applications and contribute to decarbonization. R&D&I should support the development of SMRs to make them safe and competitive with other means of production as part of a global deployment strategy over the coming decades.

3.2 Summary

EU SMR-partnership, Yves Desbazeille (Foratom)

A short introduction was provided on the preparations of an EU SMR partnership. The preparations are divided in 5 workstreams, some of which were presented in follow-up presentations. Since SNETP is responsible for work stream 5 on R&D and Innovation, this work stream was explained by the various topics in subsequent presentations.

Work Stream 1 - Market Analysis, Andrea Goicea (Foratom)

Work stream 1 focuses on the market analysis for SMR deployment in Europe. Future needs in Europe are being identified with respect to the various product streams, i.e., electric power, heat, and hydrogen production through literature review and surveys. After that the technical/economical capabilities of SMRs and the market potential for SMR deployment will be analyzed. The analysis should be ready by the end of 2022.

Work Stream 5 – R&D and Innovation, Sylvain Takenouti (EDF)

The objective of work stream 5 is to define a roadmap for SMR R&D&I consistent with market needs and licensing requirements. The work stream is divided in 7 technical topics: Core/fuel (1), NSSS Integrated vessel and its internals (2), Passive systems (3), Severe Accidents (4), Modularity (5), Human Factors and autonomy (6), Uses beyond electricity (7). All technical topics consider and distinguish where needed between small modular light water reactors (SMRs) as well as advanced modular reactors (AMRs).

Work Stream 5 Topic 1 - Reactor Core and Fuel, Eric Hanus (CEA)

Main directions identified for SMRs are the design of smaller cores with high neutron leakage, design with non-soluble boron, adaptability to ATF and HA-LEU, thermal-hydraulic aspects, fuel limits for cogeneration modes, core instrumentation and monitoring, and multi-scale / multi-physics modelling tools to reduce conservatisms and costs. For AMRs, the main directions are fuel characterization, fuel qualification, fuel manufacturing, fuel reprocessing techniques, quality control techniques, fission product behavior, validation of analysis tools, passive shutdown systems, and multi-scale / multi-physics modelling tools for analysis of AMR cores.

R&D Needs for Non-power Uses of Nuclear Energy, Ville Tulkki (VTT)

Specific R&D gaps include the coupling between a nuclear heat source and a heat use facility, the analysis of the requirements for electric power, heat, and hydrogen production, the operability, maneuverability, and flexibility of SMRs and AMRs and their economic, impact, public acceptance and safety analysis, and the development of tools.

Work Stream 5 Topic 2 - R&D Needs & Technical Issues of the Nuclear Steam Supply Systems, Oliver Martin (JRC)

The R&D&I gaps for the nuclear steam supply systems can be found in the regulatory framework (varying levels of harmonization), applicability of nuclear codes & standards, reactor internal hydraulics (incl. vibrations), reactor structural materials and coolant chemistry control (especially for LFRs), specific reactor components (e.g., compact and/or high temperature component designs like pumps or heat exchangers), advanced manufacturing, and in-service inspection.

Work Stream 5 Topic 3 - Passive Systems, Fulvio Mascari (ENEA)

The main needs for development and implementation of passive systems are summarized as the further development of an experimental assessment database, modelling approaches and numerical tools, system reliability, and system designs and engineering process.

Work Stream 5 Topic 4 - Severe Accidents, Philippe. Dejardin (Tractebel ENGIE)

SMRs and AMRs should include inherent safety features to drastically reduce the likelihood of severe accidents. Two high level needs are identified: the identification of potential and postulated severe accident scenarios, and the associated needs with respect to vessel and containment integrity and emergency planning zones. For SMRs, the main direction is to investigate the possibility of crediting applicability of large reactor knowledge. For AMRs, a prerequisite is to determine the definition of a severe accident and subsequently to investigate the scenarios.

Energy Well Project, Mathieu Reungoat (CVR)

The Energy Well project was presented. Energy well is a micro-SMR with a power of about 20 MWth (8 MWe) for local production of electricity and/or heat based on a molten salt cooled technology and using TRISO fuel. Currently, work is ongoing to realise a non-nuclear demonstrator by 2024.

Conceptual Design of EUHTER (Polish Experimental HTGR), Mariusz Dąbrowski (NCBJ)

The current plans for deployment of HTR technology for cogeneration of electricity and heat in Poland are explained. A prototype is planned in the early 30’s, while commercialization is aimed at in the 40’s. A pre-conceptual design for a 40 MWth prototype under the name TeResa was completed within the Polish national program. A strategic partnership has been established with JAEA in Japan for the transfer of knowledge, experience and support.

Some important questions were raised during the many discussions that took place. The first one was whether the EU SMR partnership should aim at the deployment of an SMR in Europe or at the development of a European SMR design. The steering group of the partnership should discuss this and take a position. Related to this, a question was raised about the market for SMR/AMR deployment in Europe. And another question raised during the discussions was the focus of the partnership on light water reactor designs and/or AMRs and especially the involvement of the AMR experts in the various work streams and technical topics.

4. Technical session #2 – Nuclear codes & standards & supply chain

This session was moderated by Oliver Martin (JRC). A zip file containing the presentations is available for download here.

4.1 Scope

Safety-related structures, systems and components (SSCs) of nuclear power plants are normally designed and produced according to stringent nuclear codes & standards (NC&S). Supplying such SSCs normally requires companies to establish and maintain a quite costly nuclear quality-assurance (QA) programme. In response to growing supply chain challenges, European NPP operators started looking into greater deployment of high-quality non-nuclear industry standard components and equipment for safety-related SSCs of NPPs (i.e., commercial-grade dedication) and launched corresponding pilot projects with approval of their regulators. This is supported by European and international nuclear organisations like Foratom and the IAEA by providing guidance in this area. The further development of NC&S remains high on the agenda. Novel materials, manufacturing methods and technologies need to be included in NC&S before being allowed to be used for safety-related SCCs. This and also NC&S development for advanced reactors (SMRs, Gen IV) require significant R&D&I efforts. In this session ongoing NC&S development activities and needs and supply chain related activities and challenges for the current reactor fleet and advanced reactors will be presented and discussed.

4.2 Summary of the technical session

Technical session 2 "Nuclear codes & Standards and Supply Chain" of the SNETP Forum 2022 covered six presentations, with four of them on the ongoing project CEN Workshop 64 on the further evolution of the AFCEN codes (= French nuclear codes & standards (NC&S)), one on the ongoing Euratom project NUCOBAM and the remaining one on the recently published European commercial-grade dedication guidelines by Foratom.

P1: ***Component Integrity Concepts for LWRs and Activities of CEN Workshop 64 Prospective Group 1*, Bruno Autrusson (nuclear consultant), Manuela Triay (Framatome), Oliver Martin (EC-JRC)**

P1 was a summary of recent activities of CEN WS64 PG1 whose scope are the AFCEN codes RCC-M design rules for mechanical components of LWRs and RSE-M rules for maintenance and in-service inspection of LWRs. In Phase 2 of the CEN WS64 (2014-2018) PG1 performed a qualitative study to investigate to what extent known degradation mechanisms of mechanical components of LWRs and their possible effects are accounted for in these codes. In Phase 3 (2019 – 2022) PG1 looked into pipe integrity concepts and defect assessment procedures and approaches.

P2*: Ongoing Development Activities for RCC-MRx and its Enlargement to Different Gen IV Systems*, Karl-Fredrik Nilsson (EC-JRC), Cecile Petesch (CEA)

P2 was a summary of recent activities of the CEN WS64 PG2 whose scope is the AFCEN code RCC-MRx design and construction rules for mechanical components of high-temperature reactors. Being initially introduced to provide design & construction rules for mechanical components of SFRs, PG2 made considerable efforts to enlarge RCC-MRx to LFRs, which have peculiar degradation mechanisms like liquid metal embrittlement and erosion. Thus, there has been and still is a strong interaction with the European LFR community and associated Euratom project consortia (e.g., Matter, Gemma). Introduction of novel materials mechanical characterization tests (e.g., small punch test) and additive manufacturing in RCC-MRx are also high on PG2's agenda.

P3: ***The NUCOBAM Project – Incorporation of Additive Manufacturing into Nuclear Codes & Standards*, Oliver Martin (EC-JRC)**

P3 was on the ongoing Euratom project NUCOBAM on additive manufacturing of reactor components. The main aim of the project is the development of a methodology to qualify additive manufactured components for use in safety-classified structures and components, essentially to ensure that they meet the requirements of NC&S. The main focus of the presentation was the qualification methodology, which is already available in draft form.

P4: ***R&D Challenges in Improving Civil Structures Design Rules for Sustainable Nuclear Energy Technology*, Etienne Gallitre (nuclear consultant), Pekka Valikangas (STUK)**

The focus of P4 was on the technical challenges and R&D needs of the further evolution of RCC-CW, the AFCEN design rules for containments and civil structures of NPPs, which is the scope of PG3 of the CEN WS64. The technical challenges and R&D needs identified by PG3 are liners for both NPP containments and spent nuclear fuel pools, robustness of civil NPP structures against events for which they have not been explicitly designed, impact of aircraft crashes into containments and computational analyses of such processes, shear in reinforced concrete structures and ageing management of concrete structures.

P5: ***Qualification of Electrical Equipment According to RCC-E*, Benedict-John Willey (AFCEN)**

P5 was an introduction into RCC-E, the AFCEN codes for electrical and I&C equipment and systems of nuclear islands, which is the scope of PG4 of the CEN WS64. Besides a few general words on RCC-E, the focus of the presentation was on the qualification of electrical and I&C equipment and maintaining such qualifications over time, e.g., in view of LTO. The presentation was intended for non-experts on the field.

P6: ***Quality Assurance Guidelines for Procuring High-quality Industrial-grade Items Aimed at Supporting Safety Functions in Nuclear Facilities*, Andrei Goicea (Foratom)**

P6 was dedicated to the quality assurance guidelines for procuring high-quality non-nuclear industry grade items (often referred to as commercial-grade items) for safety-related SSCs in nuclear facilities recently published by Foratom. Increased use of such items in safety-related SSC of nuclear facilities is a way to solve supply chain challenges currently facing European utilities, such as SSC obsolescence and difficulty of finding new suppliers. The available guidance on using such items in safety related SSCs of nuclear facilities originates from the U.S. and as a consequence is primarily tailored to U.S. nuclear industry needs and regulation. The Foratom guidelines are targeting mainly European utilities that are more versatile to cope with different nuclear regulations of EU MS or European countries in general. The publication of the Foratom guidelines is a milestone and use of high-quality non-nuclear industry grade items for safety related SSCs in nuclear facilities is becoming more widespread in Europe.

Overall TS2 contained interesting presentations and there were fruitful discussions after each presentation despite the limited attendance of the session overall due to the sessions on SMRs and research infrastructures running in parallel. TS2 emphasised the need of NC&S development, to turn R&D results into design and construction rules for SSCs, so that they can be used by end-users, mainly vendors and suppliers and utilities. All PGs of the CEN WS64 are currently completing Phase 3 and preparing Phase4, whose main focus will most likely be SMRs. In this sense, having a similar session like TS2 in a SNETP Forum in couple of years, would be highly beneficial. NUCOBAM paves the way to allow production of reactor components via additive manufacturing. Similar R&D projects for other advanced manufacturing techniques (e.g., electron beam welding) are required. The publication of the Foratom guidelines enables more widespread use of high-quality non-nuclear industry grade items for safety related SSCs in nuclear facilities. Although primarily intended for currently operating NPPs, the guidelines are also relevant for new-build and advanced reactors / SMRs and offer the possibility to organize supply chains of safety-related SSCs of such reactors differently straight from the beginning and thus avoid to some extent the supply chain challenges of the current fleet.

5. Technical session #3 – Digital & Robotics

This session was moderated by Elisabeth Guillaut (ORANO), Eero Vesaoja (FORTUM), Christophe Schneidesch (TRACTEBEL). A zip file containing the presentations is available for download here.

5.1 Scope

Digital and robotics technologies are innovative tools developed for a safe and optimal plant management, while improving the security of workers. As part of the SNETP annual forum, two consecutive sessions were dedicated several innovations developed on those topics. The digital transformation and the use of robotics have become cross-cutting trends to all industrial sectors and nuclear is no exception to this: the European Commission considers that the climate transition should be coupled with a digital transition. Therefore, it is essential to build a European digital integration bench to achieve digital twins such as a Digital Nuclear Reactor. Moreover, robots limit exposure to radioactivity and support maintenance tasks that would otherwise be impossible, thus significantly extending the lifetime of reactors.

The presentations cover a wide range of IR&D developments already supporting practical applications with a clear benefit to nuclear activities and operational processes efficiency.

5.2 Summary of the technical session

Digital

- **The Nuclear Digital Nuclear Initiative, Cécile Clarenc-Mace -EDF**
    - Project developed with 8 partners over 4 years starting in 2020, to provide Operators as well as Engineering Design Offices with two products based on a continuum of models in reactor physics. The outcome will be digital twins of a nuclear reactor comprising a platform to perform advanced studies relying on Multi-Physics / Multi-Scale couplings and a full scale training simulator, the two supported by visualization tools and all services accessible by a single web portal. Current results match the objectives on practical test cases and demonstrate the operability of the two products. Work is on-going to optimize or include missing peripheral functionalities.
- **Combination between Digital Twin and AI for Anomaly Detection for Industrial Processes, Aurélien Schwartz - Métroscope, EDF group**
    - To monitor and diagnostic plants through confronting deviations from the measured plant data and from the expected behavior of a digital twin. The software is used to capture and understand root causes for abnormal behaviors of the installation. 300 active users worldwide (whole nuclear EDF fleet is equipped). Used at site, engineering, corporate levels. A practical example illustrates the analysis performed for a PWR in operation and highlights the benefit of the software for a plant Operator, which from the diagnostic, was capable to optimize maintenance activities and recover missing power.
- **Data Based Solutions & Performance in the Nuclear Sector, Vincent Champain – Framatome**

  - The Nuclear sector is characterized by a huge amount of data and limited value creation from it. Framatome is investing to valorize those data with the deployment of a wide portfolio of specific data acquisition technologies, covering e.g. inspection/ND testing, measurement/capture, monitoring/analysis, remote inspection, product certification/quality and product integrity. Each value creation was illustrated by typical examples of dedicated software application, e.g. forecast how manufacturing can help to avoid problems (Graphsight using NLP to extract references to make engineers safe). However, if the Nuclear sector can benefit from advances from the non-nuclear industry, it still faces some inherent challenges and barriers to be tackled well before taking full advantage of the various innovative solutions in development.

- **Utilization of Artificial Intelligence in the Analysis of Nuclear Power Plant Requirements, Santeri Myllynen – FORTUM**
  - The requirement text is filled in into a language model and converted into a feature vector. AI can clearly be utilized in requirement engineering, can save time and money. The current tools show that it reduces manual errors in rather monotonic and time-consuming processes, but important work still remains in developing further dedicated algorithms may be further developed for, e.g., recognizing and potentially combining similar requirements or assessing the fulfillment of requirements.
- **Digital Solution Projects, Arnaud Duchêne – Tractebel**
  - Tractebel implementation of digital twin functionalities for dismantling activities. The developments cover BIM (virtual reality / Augmented reality/ system engineering) complemented by digital models for simulations and asset management. Dismantling digital twins are used either for design of new waste management facilities or modification of existing installations. They bring together digital capabilities to predict the waste quantities, perform simulation for the characterization. The interoperability and integration of data, models as well as functionalities between the different components of the application are illustrated by practical applications. The platform however calls for further improvements in its functionalities.
- **Modelling and Simulation-assisted Engineering of Cyber-physical Systems Throughout their Life Cycle, T. Nguyen – IAEA consultant (ex EDF)**
  - Developed a method called BASAALT (behavioral simulation) helping maintenance of the engineering and safety knowledge. The issue is that too many requirements are poorly engineered and inadequate, mainly because of a lack of understanding the full picture and wrong assumptions; from there a need to have tool to support the engineering: BASAALT was developed with as main characteristics: modularity, tracking progress, enabling coordination.

Robotics

- **Robotics and Drone Program, Anders Wik – Vattenfall**
  - Drone inspection in BWR NPP 2021 (esp. in radioprotection area) – developed internally Birdflapper and mini solar boat for autonomous inspections. Many floor/air/water robots (generally commercially available) are used with different type of sensors. They are deployed for example in inspection of the dome liner. Future applications cover creation of radiations maps, regular inspection tours in NPP, surveillance of work progress, which could be combined with AI for image recognition. A strong validation process is required for nuclear sector applications. Security of the information transmission is a major issue.

- **Foldable Oranef UAV for High Radiation Zone Inspection in Nuclear Plants, Jean-Luc Ayral – AERACCESS**
  - Programme developed with Orano, under the European RIMA programme and the French recovery plan (Factories of tomorrow project) to improve navigation and compensation of the drifts (acoustic ranging and use of elevation). The Oranef UAV has a unique architecture embarking 4K camera for vision and peripheral sensors on 3-axis and capable to carry payloads such as ultrasonic (NDT) or dosimetric sensors SLAM (simultaneous localization and mapping) navigation based on stereoscopic vision is foreseen to address different types of requirements (mapping of HRZ cells, fusion of the 3D mapping and control of the trajectory according to obstacles).
- **Robotics in VVER SG Inspection/Cleaning, Ville Lestinen**
  - Project started in 2019 for and inspection and cleaning robot of steam generators of Lovissa as part of the regulatory requirement to clean every 4 year the steam generator. The work presents high radiation doses and other occupational health and safety risks. A first version of a robot was tested in outage of Loviisa NPP in September 2020 and its feedback led to consider a second robot version focusing on more flexible inspection capacities. The testings proved how present and future robots can operate in hazardous and dangerous places. First business cases could be around inspection of pools, containers and all other waterways

Concerted RD&I work is essential to make progress in terms of multi-physics modelling and simulation, High Performance Computing, data analysis and analytics, visualization, Virtual Reality, advanced instrumentation (e.g., Internet Of things) and I&C.

6. Technical session #4 – R&D&I facilities

This session was moderated by Pavel Kral (UJV) and Petri Kinnunen (VTT). A zip file containing the presentations is available for download here.

6.1 Scope

Several R&D facilities have been shut down in the EU over the last decade. Therefore, loss of critical research infrastructure (i.e., facilities, capabilities and expertise) remains a concern to all SNETP stakeholders and the nuclear community as a whole. SNETP and some of its members decided to set up the “OFFERR” project that aims to support the European nuclear R&D community, and to establish an operational scheme facilitating access for R&D experts to key nuclear science through the channeling of financial grants provided by the Euratom programme. The goal is to construct a sustainable “User facility network (UFN)”.

This session discussed the way this network should be built and provided the current status of research facilities that support the implementation of the SNETP Strategic Research Agenda (2021) and beyond.

6.2 Summary of the technical session

The following presentations were given in the meeting:

- **Charles Toulemonde: The OFFERR Project**
- **Jiri Zdarek: Setting up the European User Facility Network (presented by C. Toulemonde)**
- **Leon Cizelj: Education Training and Research Facilities**
- **P. Kinnunen: JHR**

- **F. Barre:** **NEA Task Force on Nuclear Safety Research Support Facilities for Existing and Advanced Reactors**
- **J. Van den Bosch:** **Possibilities of the BR2 Reactor as a Support Facility to Materials and Fuels R&D**
- **Sanjeev Gupta:** **Source Term Experimental Research - IPRESCA and OECD/NEA THEMIS Projects**
- **Ronald Schram:** **HFR and Pallas**
- **Marek Miklos:** **Czech Research Infrastructure for Supporting the Implementation of the SNETP SRA**
- **Rachel Eloirdi:** **JRC Open Access of Research Infrastructures**

The meeting started with the two presentations related to the OFFERR project. The aim of this project is to create a European user facility network - list and synergies with 17 partners and a budget of 9 M€ of which 7 M€ to R&D facilities. OECD NEA is the latest member. In OFFERR there will be different tracks available for obtaining the funding and the network will be increased during the course of the project. Two other presentations were connected to the OFFERR presentation: J. Zdarek's and L. Cizelj's which both reflected the willingness to focus the European efforts on research and competence creation. This OFFERR "entity" raised many discussions as the audience commended quite widely the plans and the use of budget. It was concluded to be a little bit disappointing that the OFFER can give in maximum 300 k€ support as that amount does not help too much with the expensive irradiation tests. In addition, several listeners asked how will the OFFERR try to benefit of the existing roadmaps and infra listings etc.

L. Cizelj presented good statistics on the ENEN+ project outcome. In the future ENEN+ project will aim at moving 1000 persons (i.e. ~100 person years) as it has been observed that this kind of scientist mobility is of great value. Zdarek's presentation focused mainly on the first contact with PNNl & EPRI (USA) initial collaboration involving information exchange.

F. Barre described in his presentation (“NEA task force on nuclear safety research support facilities for existing and advanced reactors”) the structure of OECD/NEA and relevant activities, mostly organized in CSNI and WGAMA. Objectives of the cooperation with partner-countries through joint safety research projects are as follows: maintain key experimental facilities and key competencies and support the operating agents, address a wide range of high priority safety issues, facilitate cooperation between countries, anticipate needs for future technologies, preserve and disseminate high quality data. The contribution of Senior Expert Group on Safety Research (SESAR) was also discussed. In the end, the short term and long-term recommendations related to preservation of experimental infrastructures for nuclear safety were summarized.

In the topic “Source term experimental research - IPRESCA and OECD/NEA THEMIS projects” given by Sanjeev Gupta. SNETP/NUGENIA IPRESCA is an in-kind project and aims to promote integration of international research activities related to pool scrubbing by providing support in experimental research and modelling work. OECD/NEA THEMIS project focuses on combustible gases and source term issues to support analysis and further improvement of Severe Accident Management measures. Both projects are cross-cutting between Nugenia TA1 and TA2.

The group of existing and future reactor capacities handled presentations of BR" 8 in Belgium), LVR-15 (Czech) and JHR (France), HFR and PALLAS (Netherlands) as well as a description of the JRC open access to the research infra. The reactor presentation was very interesting giving the views from the history up today and described thoroughly what kind of irradiation capabilities and laboratories are available in the current fleet of research reactors and in the future reactors (JHR, Pallas). It is obvious that the current fleet will be needed still for many years and the reactors have been renewed to answer the current and foreseen challenges in the near future. BR2 is the most versatile available reactor at the moment, LVR-15 has excellent laboratories for many purposes and is an important tool among others for future technologies, HFR is a multipurpose reactor - old reactor but working well. The JHR is delayed and the plans for Pallas are such that it should start in the early 2030's like the JHR.

JRC open access of research infrastructures is the key tool for the EC to optimise the use of the existing JRC facilities. Altogether JRC has a total 56 research infrastructures of which 20 are for nuclear. JRC open access has granted more than 40 accesses but the covid has delayed the use of them.

In addition to these presentations, one presentation was sent as a video (S. Schollenberger: Experimental programs at the PKL test facility). Unfortunately, we did not have time to watch it during the meeting as there were many discussions on other presentations.

The last presentation from the original Programme – the presentation of Stephan Gabriel on COSMOS-H thermohydraulic test facility – was cancelled as the presenter asked for withdrawal of his contribution due to his illness.

7. Technical session #5 – Waste minimisation and fuel cycle

This session was moderated by Erika Holt (VTT) and Anthony Banford (NNL). A zip file containing the presentations is available for download here.

7.1 Scope

The current and projected fleet of plants consists largely of water-cooled, water-moderated reactors. These reactors have over time achieved a high degree of maturity in terms of economic performance and safety. To achieve major steps in terms of sustainability (reduced high-level waste production, better use of resources and higher thermal efficiencies) and to open the way for high-temperature non-electricity applications, new types of reactors based on other coolant technologies should be envisaged combined with more advanced fuel cycles. The use of fast reactors in a closed fuel cycle approach will allow a large decrease in natural resource (uranium) consumption, allowing therefore a more sustainable implementation of nuclear energy. One of the major concerns of society regarding the implementation of nuclear energy is also the high-level nuclear waste. Fast spectrum reactors with closed fuel cycles will allow a significant reduction in high-level nuclear waste radiotoxicity and volume. Advanced reprocessing and fuel manufacturing techniques are needed to recycle the minor actinides. This session discusses how sustainability in terms of resource utilisation and high-level waste minimisation can be gradually increased.

7.2 Summary of the technical session

This technical session was developed to bring together thinking on future reactor concepts, fuel cycles and waste management, in the interest of developing a lifecycle approach to minimise waste and enhance system sustainability. The discussions will feed into the Strategic Research Agendas (SRAs) currently under development. *The session was attended by over 40 delegates from a range of countries and the IAEA.*

Seif Ben Hadj Hassine (EC) opened the session with an **Introduction to EC Programmes on Radioactive Waste Management and the Linkages with the Complimentary Decommissioning Projects**. The presentation stressed the importance of adopting a whole cycle approach, from reactors and fuel through to pre-disposal waste processing and final disposal.

Jiri Krepel (PSI) presented on **Fuel Handling and Waste Issues for Molten Salt Reactors**, including indications of impacts of solid and liquid fuel in these salt systems, and the impacts on operation, safeguards, criticality safety, and waste management. The ongoing benchmark work for burn up and design issues within the European SAMOFAR project (http://samofar.eu/) is to be published soon.

Francisco Alvarez Velarde (CIEMAT) – highlighted work on **Plutonium Management in GENIV Reactors** (PUMMA project, https://pumma-h2020.eu/), with particular respect to the importance of assessing the impacts on to whole cycle including fuel recycle and plutonium management.

Luke O'Brien (NNL) described how a range of innovative tools have been applied in the **UK Advanced Fuel Cycle Programme to Apply the Waste Hierarchy during the Development of Future Fuel Cycles**. The project outputs have demonstrated the potential benefits of applying these techniques to optimise concept flow sheets at the earliest opportunity.

Christophe Bruggeman (SCK CEN) moved the discussions onto **Advanced Separation for the Optimum Management of Spent Fuel (ASOF)**. The ASOF project is linked to the MYRRHA demonstrator transmutation facility, and includes evaluating the contribution of actinides and fission product impact on the radiotoxicity of the final waste and their impact on disposability.

Timothy Schatz (VTT) presented on **SMR Spent Fuel and Waste Management**, setting the scene using Finland as an example of the demand and prospects for SMR deployment and showed results with case studies for spent fuel, waste management (including interim storage, ownership responsibility) and disposal.

Reka Szoke (IFE) **introduced the new HARPERS project** which will focus on opportunities for harmonised practices, regulations and standards in waste management and decommissioning. The coordinators encouraged SNETP members and delegates to get involved in the stakeholder discussions and feedback to help prioritise activities.

Anthony Banford (NNL) gave an overview of the **SHARE project** highlighting the development of the decommissioning Strategic Research Agenda and Roadmap of R&D needs, and also the **ongoing PREDIS project** that is updating the future R&D needs in pre-disposal radwaste management. The objective of sharing this was to encourage discussion and identification of priority areas for future R&D (needs) within the SNETP community and member states. Further information on the SRAs is available https://share-h2020.eu/ and https://predis-h2020.eu/

Discussion

The questions and discussion in the session all reinforced the importance of adopting a holistic lifecycle approach to fuel cycle optimisation, and waste minimisation in both legacy and future systems. Specific examples raised for potential collaboration include,

- Legacy waste optimisation with the goal of waste minimisation, which is common to SNETP objectives and to the PREDIS and EURAD SRAs.
- Future reactor system (SMR, AMR & Gen IV) and associated fuel cycle waste management.
- Challenges and linkage (cross-border solutions for treatment, disposal, techniques).
- Treatment options for problematic waste streams without existing treatment routes
- Social acceptability of waste systems.

8. Technical session #6 – Nuclear to mitigate climate change including non-electricity applications

This session was moderated by Ronald Schram (NRG) and M. Fütterer (JRC). A zip file containing the presentations is available for download here.

8.1 Scope

With increased awareness of climate change in recent years, nuclear energy has received renewed attention. Nuclear energy can make a significant contribution to reducing greenhouse gas emissions (GHGs) worldwide, while at the same time meeting the increasing demand for energy of a growing world population and supporting global sustainable development. Nuclear energy has considerable potential to meet the challenge of climate change mitigation by providing a secured supply of electricity, district heating and high temperature heat for industrial processes while producing almost no GHGs.

This session will focus on the different possible uses of nuclear to contribute to the EU decarbonisation strategy.

8.2 Summary of the technical session

In this session, moderated by Ronald Schram (NRG) and Michael Fütterer (JRC), a broader view of nuclear was provided, from different angles: Industry's perspective, energy-mix perspective, and R&D perspective.

Scene Setter

Michael Fütterer (JRC) provided a short introduction and recalled that successful decarbonization and energy security require not only large new capacity of low-carbon electricity generation, but also the replacement of fossil hydrocarbons for industrial process heat and, importantly, as feedstock and reactants in the chemical and steel industry. Several new projects from Euratom, OECD/NEA, the Generation IV International Forum and at the IAEA are addressing this challenge.

Industry

Andrei Goicea (FORATOM) spoke about **EU's Energy Sector Integration and Hydrogen Strategies**. FORATOM promotes the capabilities of nuclear beyond electricity considering hydrogen as one of the main vectors of the energy sector because of its versatility for storage and use. The hydrogen position paper states i.a. that from 2025 to 2030, hydrogen needs to become an intrinsic part of our integrated energy system. The current plan at EU level is to build by then at least 40 GWe of renewable hydrogen electrolyser capacity and the production of up to 10 million tonnes of renewable hydrogen in the EU, which is equivalent to the current annual consumption. In this context, nuclear energy can help achieve these goals more easily than with renewables alone.

Nicola Rega (European Chemical Industry Council - CEFIC) provided a talk on **the European Chemical Industry on the Path to Climate Neutrality**. CEFIC launched the iC2050 project: a model representing the EU27 chemical industry to identify potential pathways to climate neutrality. The model identifies four different scenarios to achieve neutrality for the chemical industry. All simulations run so far assume a strong electrification of processes and thus confirm a substantial increase in electricity consumption. The question is to what extent the nuclear industry can support the electrification of the chemical industry, including through the delivery of process heat, for instance in the form of steam.

Energy mix

Andre Faaij (Utrecht University, The Netherlands) provided **a pre-recorded presentation on Deployment of Nuclear Energy in Deep Decarbonization of the Energy System**. Recent analyses on global, European and national level were presented with specific attention for the situation in the Netherlands, on how nuclear energy may or may not fit in reaching the GHG emission reduction targets set by the Paris Agreement. Very recent system and scenario analyses shed light on the interaction of nuclear energy units in an energy system with a rapidly increasing role for solar and wind energy, with detailed attention for overall system costs, flexibility (also to use nuclear energy for generation of heat and hydrogen) and cost projections for different technologies.

Paul Nevitt (National Nuclear Laboratory, UK) provided a pre-recorded presentation on **Integrated Energy Systems and the Pathway to Net Zero by 2050 (a UK Context).** (This presentation was too long for the available time but will be provided to the participants of the session). The UK Government has committed to net zero greenhouse gas emissions by 2050, demanding an integrated approach to ensuring an optimum low-cost, low carbon energy system. As part of its recent Energy Security Strategy, it also set out a clear role for nuclear, committing to up to 24 GW of new nuclear by 2050; supporting development of large, small, and advanced nuclear across all sectors, not just electricity. Nuclear, for example, is included in the 'Industrial Decarbonisation' and 'Hydrogen' strategies recently published. To understand better future scenarios and the role of nuclear, NNL published a groundbreaking new modelling report demonstrating the role nuclear can play in delivering the UK's net zero goals.

R&D

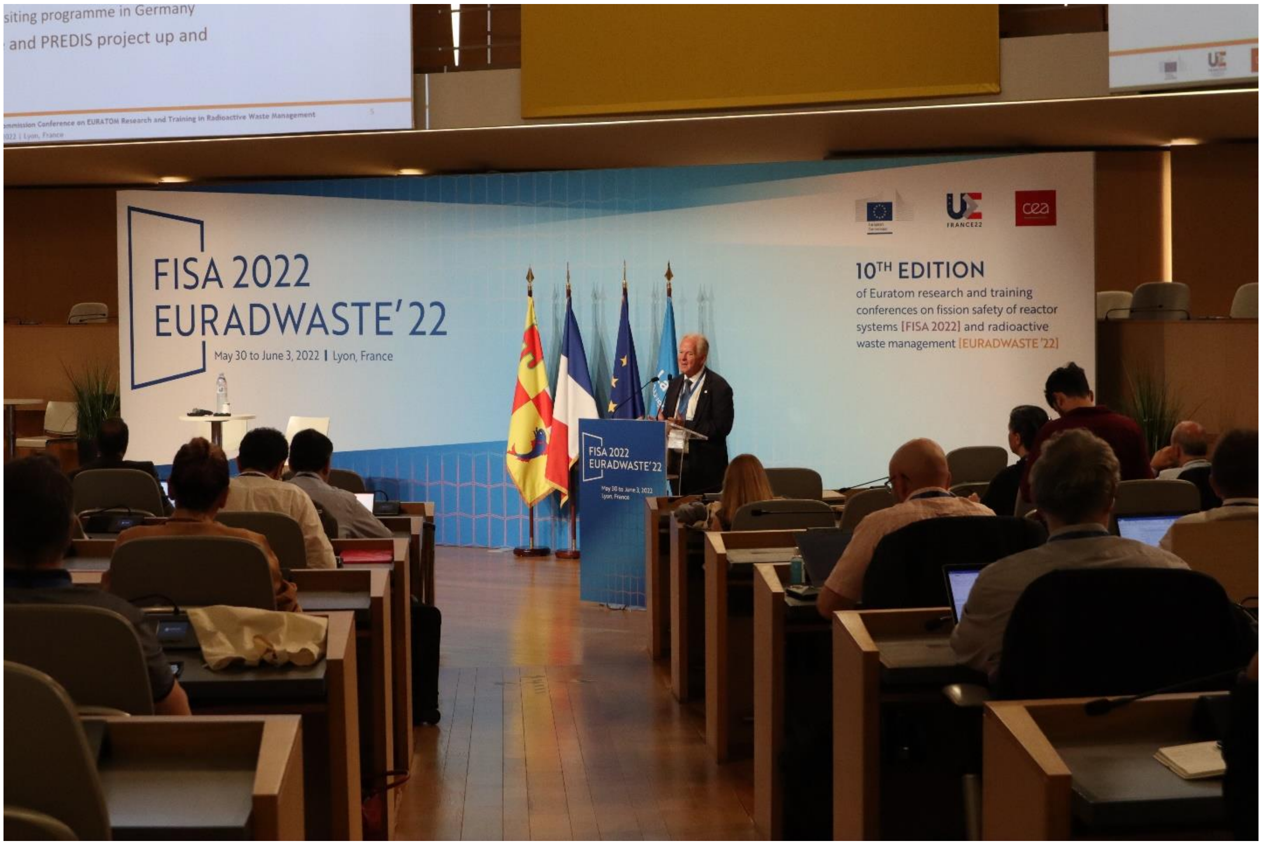
Agnieska Boettcher (National Centre for Nuclear Research, Poland) presented a **Summary of the Polish National Project: gospostrateg-htr**.

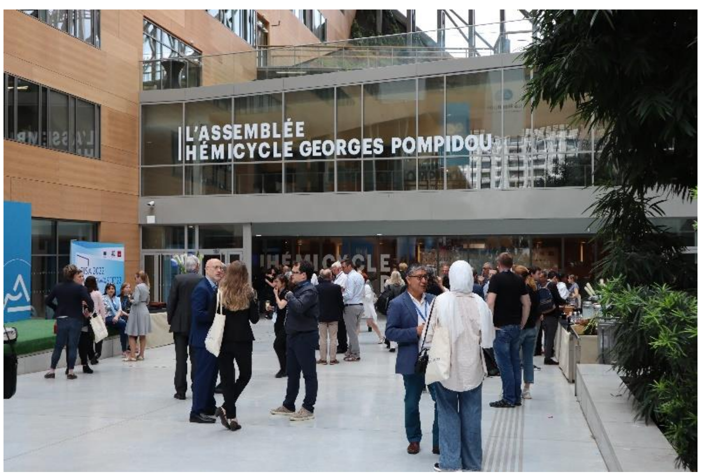
GOSPOSTRATEG-HTR is a national project under the strategic Polish program of scientific research and development for the preparation of legal, organizational and technical instruments for HTR demonstration and deployment in Poland. The GOSPOSTRATEG-HTR project was divided into two phases. The first phase of the project includes research work, the second phase included the implementation of the developed procedures and strategies. The key objectives were presented: Preparation to the licensing process, Material tests, and the legal, societal, economic and industrial aspects of the project.

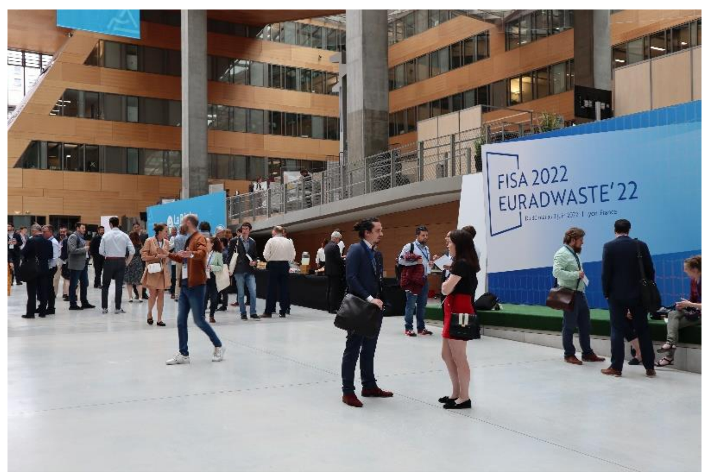
Jacek Jagielski (National Centre for Nuclear Research, Poland) presented **the Nomaten Centre of Excellence in Multifunctional Materials for Industrial and Medical Applications**. One of the main goals of the newly created NOMATEN Center of Excellence is to conduct research on materials for extreme applications, defined as high temperature, radiation and corrosion. As such, the project supports the Polish HTR demonstration and deployment efforts. NOMATEN should be regarded as a tool for initiation of a broad cooperation network on materials for harsh environments.

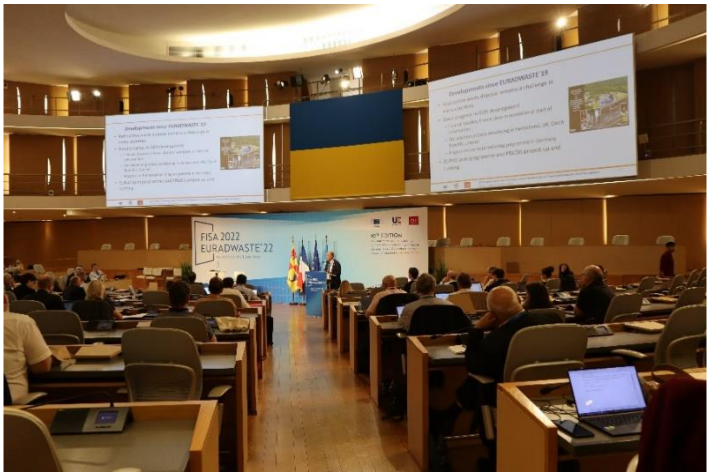
Geert-Jan de Haas (NRG, The Netherlands) spoke about **Exploring the Deployment of Advanced Reactor Systems for Decarbonization of Future Energy Generation**. The view of the Dutch nuclear stakeholders on current and future nuclear energy generation was outlined. Their nuclear development roadmap was presented and explained. In addition, it was demonstrated how the Dutch PIONEER R&D program has been tailored towards this roadmap with emphasis on the support for the advancement of molten salt, gas and liquid metal cooled reactor technology towards demonstration and deployment.

Appendix 1: Photos





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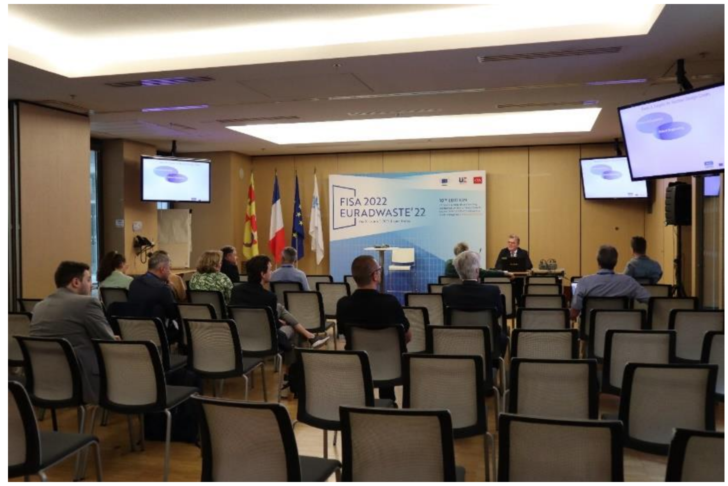
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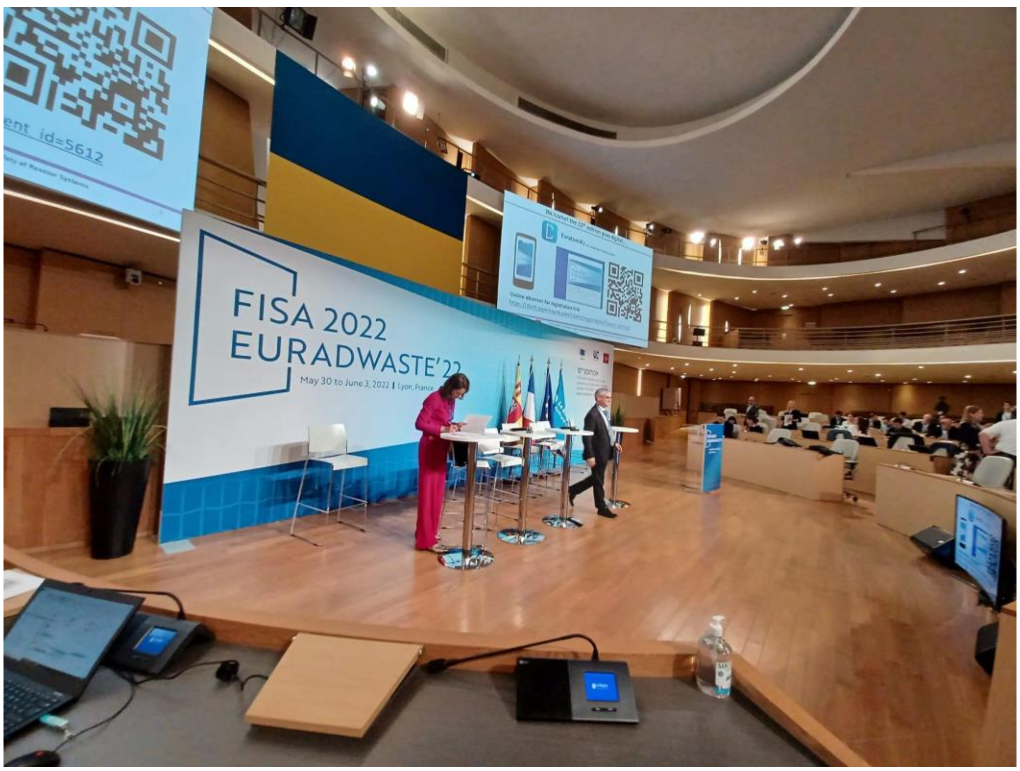
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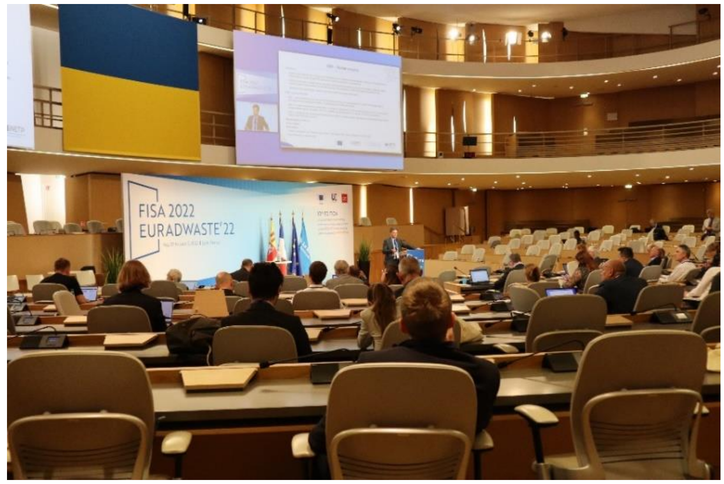
HÉMICYCLE GEORGES POMPIDOU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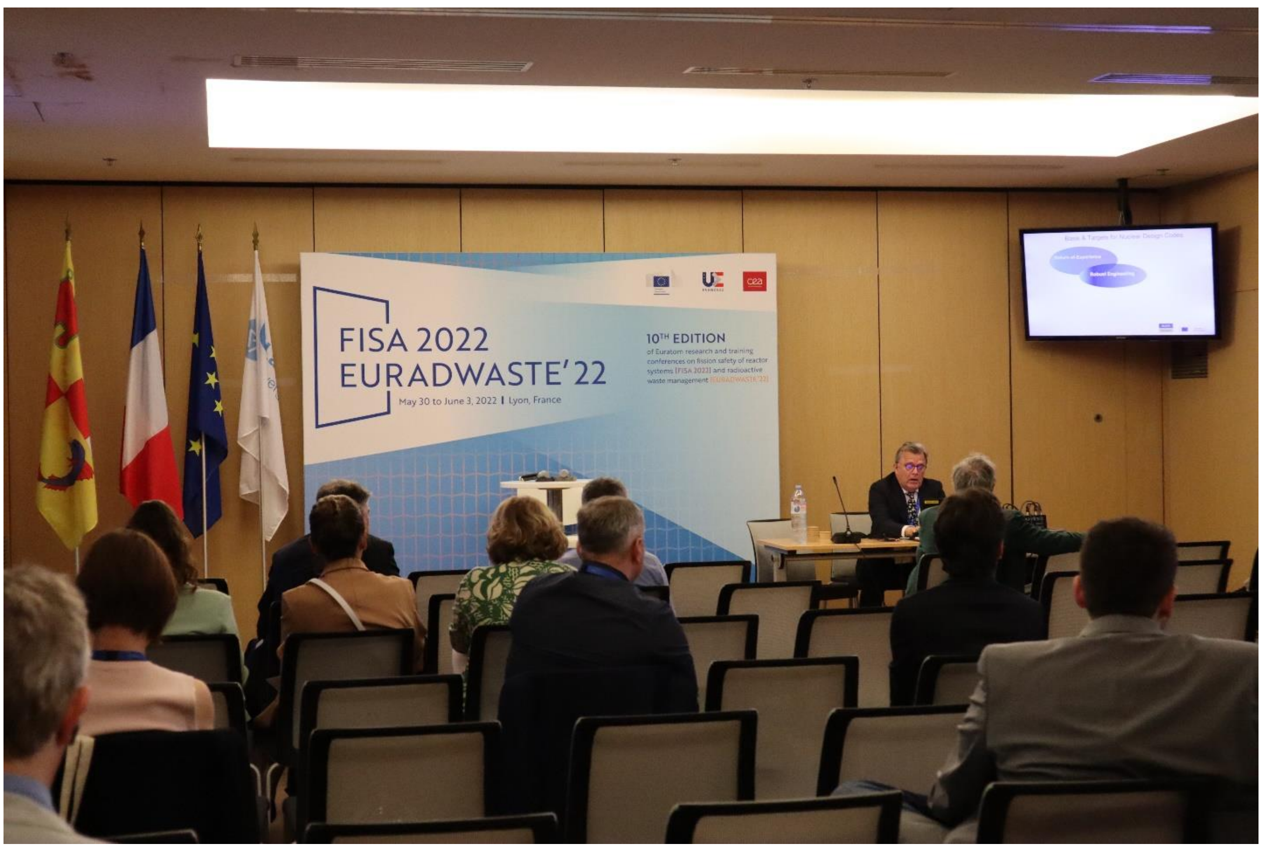
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SNETP
Sustainable Nuclear Energy Technology Platform

ABOUT SNETP

The Sustainable Nuclear Energy Technology Platform (SNETP) was established in September 2007 as a R&D&I platform **to support technological development for enhancing safe and competitive nuclear fission in a climate-neutral and sustainable energy mix.** Since May 2019, SNETP has been operating as an international non-profit association (INPA) under the Belgian law pursuing a networking and scientific goals. It is recognised as a European Technology and Innovation Platform (ETIP) by the European Commission.

The international membership base of the platform includes industrial actors, research and development organisations, academia, technical and safety organisations, SMEs as well as non-governmental bodies.

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