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D5.41 Strategic Orientations for Transatlantic Cooperation for Nuclear Cogeneration

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Summary

This report describes the strategic orientations for the transatlantic cooperation between the European Nuclear Cogeneration Industrial Initiative and the NGNP Industry Alliance in the USA.

The NC2I and the NIA are following up nearly identical objectives in different regions and therefore have started years ago to collaborate and to assist each other in a large transatlantic cooperation.

Today our joint GEMINI Initiative strengthens the NC2I efforts which are aiming at the design and regulatory work required for a modern HTGR demonstration plant.

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Strategic Orientations of Transatlantic Cooperation for Nuclear Cogeneration

1 Background

From the beginning of the NC2I-R project as a part of the European Nuclear Cogeneration activities, the objectives (in particular with respect – but not limited – to communication) have put a special emphasis onto the interaction with the US programme. The corresponding present US activities are managed by the NGNP Industry Alliance (NIA) which was incorporated in 2009 in the frame of DOE's Next Generation Nuclear Plant (NGNP) project.

Today the NGNP Industry Alliance is an international consortium headquartered in the USA with member organizations aligned to promote HTGR technology. The Alliance has been growing since 2010 and is currently comprised of industry-leading membership including potential end users, owner operators, industrial suppliers and nuclear technology companies including: the Advanced Research Center (ARC), AREVA, ConocoPhillips, Dow Chemical Company, Entergy Corporation, Graftech International Ltd., Mersen, Petroleum Technology Alliance Canada, Savannah River Site Community Reuse Organization (SRSCRO), SGL Group, Technology Insights, Toyo Tanso Co. Ltd., Ultra Safe Nuclear Corporation, Manufacturing Excellence Consulting, Inc., Westinghouse Electric Company and the state of Wyoming.

Within the NGNP Project which had been started in 2006, the US government has spent more than 500 M$ US for investigations in design R&D and for licensing questions of HTGRs. Considering the links between European and US nuclear industries, the NIA represents an obvious and maybe even natural correspondent for NC2I in the US. The corresponding partnership and collaboration between NC2I and the NIA is as old as the NGNP project /01/.

End users of the HTGR technology can and will be found on both sides of the Atlantic Ocean, as indicated by the situation in Asia, where end users have already been identified, such as in China and recently in Indonesia, and the HTGR implementation process is in progress.

This brief report is to describe the present interaction between NC2I-R and the US programme, to recapitulate the results of the joint workshops between the NIA and the NC2I and to assess further possible cooperation schemes between them.

2 Strategic Aspects of Cooperation

2.1 Shared Convictions

The discussions on HTGRs and cogeneration in US and Europe so far have resulted in a common understanding with respect to the following points:

- Cogeneration based on HTGR technology can pave a way for the reduction of greenhouse gas emissions and hence will profit from reasonable policies, which are anticipated and partly already visible: In Europe, the SET-Plan has fixed ambitious targets for reducing CO_2 emissions by 40% until 2030 (basis: 1990). In the US there is the Clean Power Plan with the EPA emission goals, (from June 2014) which require a reduction by 30% until 2030. Moreover, US President Obama declared in March, 2014, that the US will cut their greenhouse gas emissions by 26% to 28 % until 2025.
- Modernity and maturity of technology: The HTGR technology is a Gen IV technology thereby underlining the global understanding that it is able to produce its energy safely, reliably and sustainably. Moreover from all Gen IV systems, the HTGR is the closest to large scale industrial implementation and can already look back onto a significant operation experience.

- Intrinsic safety: HTGRs can be built in such a way that even for a complete loss of active core cooling along with a loss-of-coolant accident, radioactive releases at medium and large scale can be definitely excluded by design. For sake of clarity it should be stated that such a « release-proof » design limits by itself the maximum possible fuel temperatures during all reasonably imaginable accident courses to values where fission products together with residual fissile material remain safely enclosed in the fuel elements (at temperatures far below melting temperature). Such a conservative plant design is the first barrier for any defense-in-depth consideration and it should not be compromised. For UO_2 fuel in TRISO particles in a modular HTGR, this means that the plant must be designed in such a way that without any active operation of any engineered safety system, accidents can definitely be excluded where the fuel would experience temperatures in excess of about 1600°C. At the same time the fuel's retention capacity is the most reliable contribution to the mitigation of accident consequences. This is the basis of the so-called and bluntly spoken « walk-away safety » /03/.
- Modularity: In order to satisfy requirements for higher outputs on the basis of a medium power HTGR reactor, a plant will ideally host several identical reactor modules of medium size.
- Interactions between nuclear and conventional plant parts: Have to be minimized beyond the fact that the conventional plants will consume the process heat from the nuclear plants.
- Funding: In Europe as well as in US, we are convinced that the financial effort still needed until realization of a detailed design and a demonstration plant is too large to be borne by industry alone. Significant public funding is considered necessary on both sides of the Atlantic.

2.2 Mutual Completion

Important aspects of possible mutual completion between NC2I and NIA are as follows:

- Sharing efforts needed to promote HTGR based cogeneration.
- Converging as much as possible the designs on both sides of the Ocean, possible residual differences having to be justified only by different regulatory requirements or customers' needs.
- Mutualizing as much as possible residual technology developments and material and component qualification needs (which will be facilitated if designs are close to each other)
- Mutualizing manufacturing capabilities for the components of the demonstration plant
- Possibility to build in parallel HTGRs in Europe and in the US testing different design options (possibly prismatic core and pebble bed core).

2.3 Specific Challenges on both Sides of the Atlantic

Unfortunately and in addition to common challenges for new nuclear projects, there are individual other constraints on each side of the Atlantic Ocean:

- Low prizes for gas and oil in the US. The resulting low electricity generating costs are presently effective show stoppers for all nuclear new build activities in the States.
- Political anti-nuclear positions in parts of Europe which show a certain tendency to leave national boundaries and rise up to European level. See e.g. the protests against the British plans for electricity prize guarantees to be given by the UK government (and to be approved by the concerned European bodies) to the investors before start of construction of 2 new power reactors at Hinkley Point.
- While in the US, nuclear is largely recognized as an appropriate means when thinking of the decrease of greenhouse gas emissions (and while the low prizes of fossil fuels can be considered the largest obstacle on this way) the situation is a bit different in Europe where we are far from such a homogeneous acceptance of nuclear energy.

3 The GEMINI Initiative

3.1 MoU between NIA and NC2I

Building on the basis described above, the NC2I and the NIA have signed on June 24, 2014 a memorandum of understanding within which we have jointly declared that we intend to collaborate on the promotion, development, demonstration and commercialization of HTGR technology[1] for process heat/steam applications, hydrogen production, and electricity generation. Specific objectives of this collaboration include:

- Information exchange on HTGR systems technologies, safety and their applications to electricity generation, process heat application and hydrogen production, including economical models of such systems.
- Collaboration in establishing an international licensing framework for HTGR commercialization and proximate siting to industrial end users.
- Collaboration in enhancing public and government acceptance of and support for HTGR systems.
- Collaboration to promote and advance the concept of and the design and design certification for parallel or "sister" HTGR projects in North America and the European Union.
- Collaboration in demonstration, commercialization and deployment of HTGR systems.
- Joint research and support of materials, standards, and infrastructure assets that is beneficial to world-wide commercialization.
- Other areas that have commercial and regulatory benefit, as mutually agreed upon.

3.2 The GEMINI Vision

The cooperation framework between NC2I and the NIA was called "GEMINI Initiative". In December 2014 a vision document /04/ was issued which condenses the joint strategy of NC2I and the NIA.

The GEMINI Initiative calls for a simple, transparent, accountable and strong agreement between the U.S. and EU partners to work with their governments under an international agreement framework to carry out the design and regulatory work for a modern HTGR demonstration plant.

The vision document explains that the GEMINI Initiative builds on a shared vision of the assets and challenges for HTGR industrial deployment. An important idea behind the GEMINI Initiative is to come to a certain convergence of designs between Europe and the US (even if some residual differences will persist in order to maintain the flexibility needed to address different market needs and regulatory requirements). The main actors of the GEMINI Initiative include nuclear vendors, research centers, governments and investors. The main outputs of this Initiative shall cover a certified design, an identified supply chain, qualified components, the identification of sites for demonstration in the US and in Europe and an operator/end-users partnership for construction and operation.

In practice, the Initiative aims at definition of reactor specifications, design and licensing-relevant documentation and, through these efforts, to strengthen the confidence needed for investments among both, private sides and governments. Vice versa, this anticipated investment will pave the way for the realization of HTGR demonstration projects in U.S.A. and Europe and thereby will push wider utilization and commercialization of HTGR technology covering domestic markets as well as export.

For the completion of the development of modern HTGRs, the GEMINI Initiative provides chances to share engineering costs and risks and pool best engineering resources and richest HTGR experience from two continents. It aims at raising public understanding and acceptance of the HTGR technology and increasing its attractiveness for investors and industry.

While final site selections, licensing, and construction of FOAK prototypes are clearly outside the scope of the GEMINI Initiative, the identification (and involvement) of possible sites is deemed important in order to fuel the process and the discussions needed to be kicked off among people, governments and other stakeholders.

The complete GEMINI vision document /04/ is appended at the end of this report.

[1] In this context, HTGR technology is meant to cover the technology for so called VHTGRs (Very High Temperature Gas Cooled Reactors)

The GEMINI Initiative has already been presented at an international level at the conferences HTR 2014 /05/ and ICAPP 2015 /06/ as well as in the GIF VHTR System Steering Committee with the particular remark that the NIA/NC2I cooperation is open to other parties.

4 Recent and Present Directions of Collaboration

4.1 Joint Workshops in Washington and Brussels

After launch of NC2I-R, two transatlantic workshops among the NC2I and the NIA were organized at Washington D.C. (March 5-7, 2014) and Brussels (June 24-26, 2014). These workshops gave rise to the GEMINI Initiative described above. The first meeting was held at the Nuclear Energy Institute in Washington D.C. The discussions were focused on opportunities for collaboration between the NIA and the NC2I. Information was exchanged on HTGR-related news in North America and Europe including technical, political and commercial boundary conditions. Funding options for nuclear cogeneration installations were reviewed. The participants discussed possibilities for future collaboration and started to work on a Memorandum of Understanding between the NIA and the NC2I (see Sec. 3.1). This MoU was finalized and signed during a return visit of NIA representatives to Brussels. There the ideas for the GEMINI Vision Document (see Sec. 3.2) were developed and pushed forward.

4.2 The TWINS Proposal

In summer 2014, NC2I and the NGNP Industry Alliance members prepared together a joint proposal for a project in the Euratom Horizon 2020 Call for Proposals. A substantial NIA share of works was defined thereby underlining the US commitment for collaboration.

The project was called TWINS (Transatlantic Working partnership for Intrinsic Nuclear Safety) and had the following key objectives:

- Selection of the main design options of a HTGR cogeneration system with the following objectives:
    - maximum competitiveness
    - enhanced safety and
    - maximum possible convergence between the designs of NC2I and NIA.
- Definition of a safety-oriented approach for licensing of the system and review by Technical Support Organizations (TSO) of European Regulators.
- Identification of a roadmap for the GEMINI Initiative.
- Elaboration of the technical and funding basis for starting the design and licensing of the prototype plant jointly in the US and in Europe.

The proposal was submitted in September 2014. Although the quality of the proposal was rated high by the EU, it was rejected as some other proposals had received even better scoring and the funding budget was limited.

4.3 Piketon

A GEMINI meeting was organized at Piketon on April 16-17, 2015.

Piketon, Ohio (approx. 2200 inhabitants) is best known for its 15 km^2-large “Portsmouth Gaseous Diffusion Plant” for Uranium Enrichment which was constructed in the 1950ies, run by the DOE and shut down in 2001. The present site activities are decontamination and decommissioning. Hence the site has brownfield character. As a legacy from its high season, it provides conditions which make it ideally suited as a candidate for an HTGR-based cogeneration plant:

- There is an excellent infrastructure in terms of an industrial electricity supply, transport, availability of cooling water and other.
- There is a very high degree of acceptance for a new nuclear use of the site as the local population is used to nuclear and has internalized through decades that the nuclear branch provides well paid jobs.

- The local authorities are familiar with nuclear business and willing to attract new industrial investments.

The NIA has started to talk to the site management (Fluor-B&W) and in the near future will address the DOE for their inclusion into all discussions.

As presently there is no significant industrial end user for process heat in Piketon, a local HTGR demo plant might have to be used for electricity production alone at least in the beginning. Subsequent attraction of further industry can be assumed.

Piketon shows that there are well suited sites with high acceptance from the sides of population and administration: Sites for HTGRs can be found.

4.4 Evolving Boundary Conditions

Conditions of living are not static even if generally the speed of change is not fast. But approaches for changes do exist and it is up to us to recognize them early and to take them into account for our activities.

Two examples:

The crisis/war in the Ukraine is changing the boundary conditions of the European energy supply: the replacement of Russian gas for heat production becomes crucial for energy independence of Europe or at least for certain countries in Europe. While in the US, the fossil fuel prizes have been lowering and do not favour the development of nuclear technologies, the Ukraine crisis could shift the conditions pro nuclear in Europe.

The EU Energy Union /07/ is a strategic political effort (and a central political EU priority) aiming at security of the energy supply all over Europe, at an integrated European energy market, lower energy prices and, among others, at a clean, low carbon, environment-friendly economy with a modern energy infrastructure. It is neutral with respect to nuclear and it could prove – even against the resistance of presently anti-nuclear European countries – beneficial for nuclear and in particular for HTGR technology.

Elements like these ones are, in small steps, making changes to the context. These context changes need to be recognized and occasionally they will allow steps into the right direction, i.e. they need to be monitored and respected when aiming at the deployment of our new energy technology.

It is important for the NC2I and the NIA to keep track cautiously of political processes.

5 Conclusions

The European Nuclear Cogeneration Industrial Initiative and the US NGNP Industry Alliance are following up similar objectives in different regions and therefore have started years ago to collaborate and to assist each other in a large transatlantic cooperation.

Today our joint GEMINI Initiative strengthens the NC2I efforts which are aiming at the design and regulatory work required for a modern HTGR demonstration plant. HTGR technology is one of the most mature Gen. IV reactor technologies and it has the proven potential to reduce the Carbon footprint of large industrial economies.

6 References

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7 Annex: GEMINI Vision Document

See following pages.

NC2I Nuclear Cogeneration Industrial Initiative

NGNP Industry Alliance
Clean, Sustainable Energy for the 21st Century

The GEMINI Initiative

A Trans-Atlantic Partnership to Accelerate the Development of Improved, Intrinsically Safe and Versatile Nuclear Energy Technology

Vision Document

December 2014

This document has been established by the U.S. NGNP Industry alliance and the European Nuclear Cogeneration Industrial Initiative NC2I

SUMMARY

No other technology other than the HTGR can, in the relatively near term and with such a high level of safety, address such a broad spectrum of energy challenges – electric power, process heat and hydrogen production for industrial and transportation purposes. The GEMINI Initiative provides a means for addressing and meeting the financial challenges and regulatory compliance work required to successfully deploy this technology. Upon successful implementation, the GEMINI Initiative will strengthen each partner's technology and economic base, increase energy security and significantly advance the protection of our environment.

VISION

The GEMINI Initiative calls for U.S. and EU partners to work with their governments under a simple, transparent, and accountable arrangement to facilitate the design and regulatory work for the first modern commercial HTGR. The scope of GEMINI includes the definition of HTGR specifications for both the U.S. and EU, design and the completion of regulatory documentation for the review and approval by the appropriate regulatory authority – the NRC in the U.S. and the appropriate authority in the presumed EU host country. Such an arrangement will help provide the confidence necessary to inspire private sector and Government investment to support the successful implementation of the GEMINI Initiative. In turn this will provide the framework for the construction of "sister" or "twin" prototype projects in both the U.S. and EU, and the ultimate widespread commercialization and utilization of this intrinsically safe and versatile nuclear technology.

The GEMINI Initiative:

- Reduces each partner's cost of design and licensing – a notional targeted funding model relies on 1/3 funding each by the U.S. and EU governments[2] and the private sector;
- Combines the best engineering talents from both the U.S. and EU;
- Fully utilizes completed and ongoing research and development work performed in the U.S. and the EU, by government programs and the private sector;
- Strengthens the attractiveness of the HTGR to potential investors by strengthening stability of government investment, lowering costs, and greatly increasing market opportunities;
- Relies on existing design experience and technology, adapts them to the present regulatory frameworks and benefits from new technology developments, particularly in the fields of fuel and graphite;
- Is driven by a financially incentivized U.S. / EU industrial team in partnership with the EU and U.S. governments;
- Enhances public understanding and acceptance of HTGR technology;
- Facilitates an international dialogue with end-user industries, many of them global players;
- Will create jobs and benefit the industrial economy of the partner nations;
- Enables each partner to move forward through its own means to complete construction of a first of a kind modern HTGR by the year 2027;
- Positions each partner to construct and potentially export subsequent modern HTGR plants; and
- Makes significant contributions to the energy security and environmental quality and obligations of both the U.S. and EU.

NC2I and the NGNP Industry Alliance are currently developing an overall project structure and are in discussions with possible sites in the EU and U.S. Both NC2I and the NGNP Industry Alliance encourage the U.S. and EU governments to work together with their respective industries to determine how best to structure their partnership and participation. GEMINI Initiative costs and schedule will be optimized for all involved by an early agreement on the most simple and effective structure possible. Work performed should satisfy the regulatory requirements of both the U.S. and the anticipated host country in the EU.

Final site selection, licensing, and construction of FOAK prototype(s) is left to the partner nations and are outside the scope of GEMINI per se. However, it is important that potential U.S. and EU sites for construction be identified early and involved in each phase. GEMINI Initiative private sector participants will be heavily incentivized to make a return on their investment and hence will work hard with the governments and other stakeholders to ensure the project is a success.

[2] EU governments are understood as European Union as well as National and Regional Governments.

Context and Background

Nearly 80% of the world's energy demand is consumed in the industrial and transportation sectors, and nearly all of this energy is supplied from the **burning of fossil fuels**. Additionally, approximately 70% of electric power is produced from the burning **fossil fuels**.

High Temperature Gas Cooled Reactors (HTGRs) can be strategically deployed in the relatively near term to play a significant role in reducing the world's very heavy reliance on fossil fuels. The need to address this heavy reliance is particularly acute in the EU and Eastern Europe where alternatives to Russian natural gas are desperately needed in both the near and longer-term time frames.

The high temperature capability (750°C presently and higher projections for the future) of HTGRs provides a viable alternative for reducing the massive amounts of natural gas and/or other fossil fuel used in industry, and assisting in the carbon-free synthesis of liquid transportation fuels and hydrogen. Depending on the use, the energy from each 100MW of HTGR-produced heat can eliminate the consumption of 72 millions of cubic meters of natural gas (2.5 million MMBtu) annually. From an environmental perspective, this translates to a reduction of 140 000 tons of CO2 emissions per year when replacing natural gas usage and almost double that amount when replacing coal usage. A 600 MWth reactor would **avoid approximately 1 million tons of CO2 emissions per year**.

Having evaluated the worst-case scenarios, the HTGR's simple design provides an **intrinsic safety feature** that precludes the potential of any significant fuel failure scenario that would result in significant release of radioactive material. Because they require no emergency power sources, cooling water or operator intervention to prevent core damage and significant radioactivity release, HTGRs are immune to extreme natural disasters or other events such as, earthquakes, tsunamis or complete station blackouts. They are "walk away safe", meaning that in a worst-case scenario, no human intervention or response is required to ensure the safety of the public or the surrounding area. Indeed, the safety zone surrounding an HTGR is only a few hundred meters as opposed to two or more miles for a large light water reactor. As a result, no evacuation zone would be required around HTGR. Recent research and development work in the U.S. and EU has further established the unparalleled safety case for these reactors.

Their intrinsic safety features and high outlet temperatures make HTGRs **uniquely versatile**: they can be co-located within new or existing industrial facilities to substitute for fossil fuels for the production of electricity, process heat and steam. Intrinsic safety is a pre-requisite for direct colocation with industrial facilities, and HTGR is considered as the reference nuclear technology for addressing this requirement. In addition, their high efficiency in electric power production allows them to be located in arid areas with very limited supplies of cooling water.

Of all of the next generation reactor technologies on the horizon, HTGRs are the most developed and have the highest potential for commercialization in the **relatively near term**. Their intrinsic safety features also make them more attractive to a safety conscious public. Currently, HTGR test reactors are operating in Japan and China: both the U.S. and EU have together hosted and operated a total of five HTGRs in the past. Moreover, China is currently building a 2-unit HTGR first-of-a-kind (250 MWth / unit), and preparing for deployment of a commercial HTGR program.

Despite their very low safety risk, the commercial development of modern nuclear reactors represents a difficult undertaking from the financial perspective: the up-front costs are large, timeframes for obtaining regulatory approvals can be long and difficult to predict; additionally, the time for return on investment can be in the range of 15 to 20 years. The costs of preparing regulatory documentation, completing facility and infrastructure design, infrastructure development and obtaining regulatory approvals for HTGR in the U.S. or EU is expected to be approximately $1.5 Billion (€1.1 billion) over 7 years[3]. Therefore, as with any new nuclear energy technology, government support is necessary for design and licensing of HTGRs, particularly in the early phase of development.

The subsequent construction phase of a first-of-a-kind industrial prototype is expected to last 4 years and also cost approximately $1.5 Billion. However the construction phase is expected to require substantially less government

[3] Based on U.S. estimates

support – possibly none depending on market conditions - as the primary up-front and regulatory risks will have been addressed.

Proposed GEMINI Initiative Timeline

2014 –2015: NC2I and NGNP Industry Alliance work with potential demonstration sites in the U.S. and EU to develop a proposed development partnership. In addition, initial discussions begin with the U.S. and EU governments on how to move forward will be taking place.

End of 2015 – mid-2016: Project structure and partners largely determined. Substantial non-government cost share will have been determined.

End of 2016 – Agreement with U.S. and EU governments on cost sharing and moving forward on project scope.

January, 2017: Necessary contracts implemented, project oversight mechanisms in place and work begins.

January, 2023: Completion of design and licensing requirements in both the U.S. and EU.

Beyond GEMINI: 2023 – 2027 – Construction of HTGR prototype(s) in the U.S. and EU.

Mid-2027 – First operation

Organizational Background

About the NGNP Industry Alliance

The NGNP Industry Alliance is an international consortium headquartered in the United States of America with member organization aligned to promote HTGR technology. In 2012, The Alliance identified and selected the HTGR technology that fits industry needs and has implemented a plan to move it forward. The Alliance has continued to grow since 2010 and is currently comprised of industry-leading membership including potential end users, owner operators, industrial suppliers and nuclear technology companies including: Savannah River Site Community Reuse Organization (SRSCRO) and the Advanced Research Center (ARC), AREVA, ConocoPhillips, Dow Chemical Company, Entergy Corporation, Graftech International Ltd., Mersen, Petroleum Technology Alliance Canada, SGL Group, Technology Insights, Toyo Tanso Co. Ltd., Manufacturing Excellence Consulting, Inc., Westinghouse Electric Company and Wyoming. For more see: www.ngnpalliance.org

2014 Alliance Members

About the NC2I

The European Nuclear Cogeneration Industrial Initiative (NC2I) was officially created in 2011 as one of three pillars of the European Sustainable Nuclear Energy Technology Platform (SNETP). The objective of the Initiative is to demonstrate an innovative and competitive energy solution for the low-carbon cogeneration of heat and electricity based on nuclear energy. The targeted outcome is the commissioning within 10 years of a nuclear cogeneration prototype to deploy this low-carbon energy technology in several energy-intensive industries. NC2I builds on the EUROPAIRS (see: www.europairs.eu) project that identified possible operating windows for the combined system of a very (V)HTR connected to industrial processes. Today NC2I counts eight full members and is supported by the NC2I-R (Research) European project, which is structuring the European public and private capabilities for preparing a nuclear cogeneration demonstrator program. NC2I is currently setting up a Business Group designed to structure the dialogue with energy-intensive industry and market actors. For more see: www.nc2i.eu