GEMINI+

NEWSLETTER N°2

In collaboration with the Nuclear Cogeneration Industrial Initiative (NC2I)

Word from the GEMINI+ Technical Coordinator

The GEMINI+ project is nearing completion by the end of August 2020, which is a good opportunity for the project team to issue this newsletter. The present edition highlights the most recent achievements along with some favourable new developments for demonstration and deployment of nuclear cogeneration with High Temperature Gas-cooled Reactors (HTGRs). One of them is that Prof. Grzegorz Wrochna, GEMINI+ Coordinator and Chairman of the European Nuclear Cogeneration Industrial Initiative (NC2I), was appointed by the end of 2019 Under Secretary of State at the Polish Ministry of Science and Higher Education. We thank Grzegorz for more than four years of visionary leadership and practical guidance. With his well-known energy and enthusiasm, he will contribute in his new function to the achievement of a Polish HTGR project, for which the international GEMINI+ team is wishing him lots of success.

Head of the Deterministic Analysis Team at NCBJ, **Janusz Malesa replaces Grzegorz as GEMINI+ Coordinator.** The entire GEMINI+ team is happy to support Janusz towards the successful completion of the project from a technical and managerial point of view.

On the other hand, **Prof. Józef Sobolewski,** currently Director at Polska Grupa Energetyczna (PGE) and former Director of the Nuclear Energy Department at the Polish Ministry of Energy, **will succeed Grzegorz as Chair of NC2I,** the organisation which initiated GEMINI+. Józef has remarkable experience at international level in technology, business and politics. He will ensure coordinated NC2I actions, promote nuclear cogeneration with inherently safe HTR and will strive to have the Green Deal energy policy relevance of this technology properly acknowledged, prioritised and implemented by European member states, organisations, investors and utilities.

In other parts of the world, 2020 will likely be **an auspicious year for HTR development.** In China, commissioning of HTR-PM (the first industrial scale modular HTR), should be completed. In Japan, the HTTR is expected to restart for safety demonstrations and coupling to an hydrogen production facility – HTTR had remained shut down after the Fukushima accident for relicensing. In the US, the Department of Defense is funding three competing micro-reactor projects based on TRISO fuel, and the NRC is preparing for licensing of advanced reactors including HTR. In Canada, a micro HTR prototype project is launched on the Chalk River site of Canadian Nuclear Laboratories in view of providing such a system on a commercial basis to power off-grid arctic communities and isolated mines.

The latest news on technology and projects internationally will be shared at **the upcoming HTR conference** which will take place in Yogyakarta (Indonesia) on 6-8 October 2020. Indonesia is a relatively young country interested in HTR. This conference is the only such event with focus on HTR technologies and related applications. NC2I was at the origin of this biannual conference series (2002 in Petten, Netherlands) with several experts from NC2I and GEMINI+ being actively involved in the organisation and presentation of their scientific technical results.

Coming back to Europe and GEMINI+, I am pleased to announce that the project will organise **a wrap-up event in Brussels in the upcoming months.** Time and venue will be confirmed shortly on the GEMINI+ website, so please mark your calendar for this event. During this workshop, the main outcomes of GEMINI+ will be of course presented, that's to say the design of an HTGR demonstrator for nuclear cogeneration and a business perspective towards industrial deployment. But our main objective is to raise stronger awareness and support from public and private European stakeholders, about the role nuclear cogeneration can play in Europe for economic prosperity, energy independence and protection of the environment. So, stay tuned! ● **Dominique Hittner**

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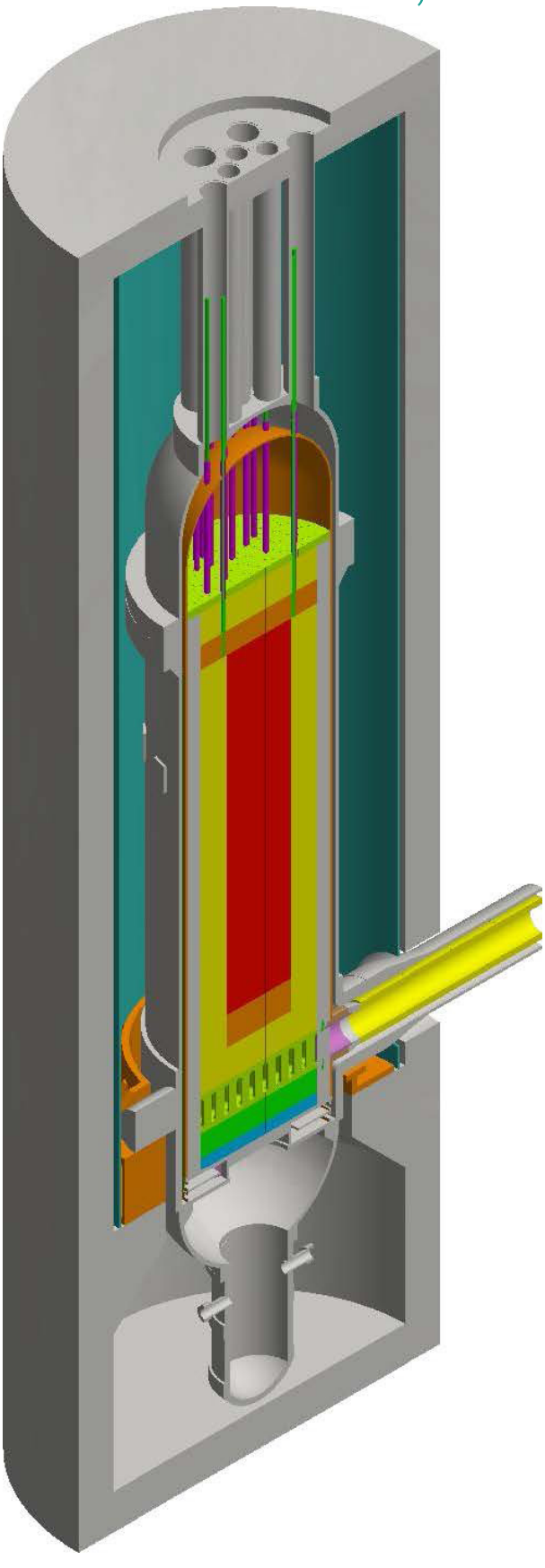

Presently, the GEMINI+ project is nearly completion and all the research activities carried out are close to delivering their main results. This 36-month project started on the basis of collaboration with the US Next Genration Nuclear Plant (NGNP) Industrial Alliance, relying on its reference design: the SC-HTGR (600 MWth). Then, considering that the most serious opportunity for early demonstration of nuclear high temperature industrial cogeneration is presently in Poland, GEMINI+ aligned its design on the needs of Polish and, more generally, European industries, which require much smaller reactors. A power of 180 MWth was selected, with a reactor operating only as boiler.

FLEXIBILITY & ADAPTATION

The system should be flexible enough to adapt to many industrial sites, which requires having components compact enough to be transportable by road, as well as being able to adapt to any energy sharing between steam and electricity, and to accommodate load variations of an industrial site. The GEMINI+ project proposed a system configuration with a block type reactor. The nuclear system delivers only steam to the customer, who distributes it to its processes, and if needed to a turbo generator.

It has been shown that the proposed standard configuration is very flexible. In particular, with a cylindrical core, the reactor vessel diameter is limited to about 4,5 m, which is compatible with road transportation. The compactness of the reactor is nevertheless challenging for designing the control system and for keeping the temperature of the fuel in a Depressurised Loss-of-Forced Circulation Accident acceptable, but the project has shown that solutions exist.

SAFETY & HYBRIDITY

The safety approach and licensing issues associated with a European construction site have also been addressed. According to the Euratom licensing obligations, the IAEA and WENRA (Western European Nuclear Regulators Association) guidelines were analysed for an HTGR and were found mostly applicable.

On the other hand, it has been shown that chemical process innovations can extend the market of such system (in particular for the production of hydrogen and synthetic transport fuel) and that, by means of its flexibility, a HTGR cogeneration system is very well suited to operate in a hybrid energy system environment. ●

Dominique Hittner
Technical Coordinator of the GEMINI+ Project

GEMINI+

How Its Features and Design Basis are in Line With the UK Interests

Modular High Temperature Gas-cooled Reactors (HTGRs) capable of shop manufacturing and application are of growing interest in a number of countries in Europe and over the world. Led by Poland, the GEMINI+ project is providing a pathway for early deployment of industrial nuclear cogeneration in Europe via HTGR technology.

In addition to traditional electricity market requirements, industrial process heat is a new market for nuclear energy with needs of up to 200 MWth (or possibly higher) and so the GEMINI+ design at 165 MWth is compliant with such a need. For example, in the world, three small HTGR designs for different applications are currently under CNSC Vendor Design Reviews (VDR) for addressing the energy needs of remote isolated sites in the North of Canada.

TOWARDS SHARED OBJECTIVES

In the UK, the Department for Business, Energy & Industrial Strategy (BEIS) is to invest up to £44 million (around €52 million) in the Advanced Modular Reactor (AMR) Feasibility and Development (F&D) project. Objectives are many: generating low-cost electricity, increasing flexibility in delivering electricity to the grid, finding alternative applications (production of hydrogen for instance), and generating additional revenue or economic growth. Therefore, these objectives are entirely consistent with the GEMINI+ project and its two major goals. The first one is the development of a design basis of a nuclear plant for process heat needs of Polish and European industry competitive with fossil-fuel power plants in terms of CO_2 emissions. The second one is the preparation of a full-scale demonstration in Poland.

FORESEEABLE POLYGENERATION

One market targeted by GEMINI+ is those sites equipped with existing steam distribution networks. In this case, the GEMINI+ system would operate as a boiler, providing only steam to end users, not electricity. Another application, is the integration of the GEMINI+ system with an electric grid with a large fraction of variable renewables. This would stabilise the grid, thanks to the system's thermal inertia and its potential for polygeneration, while keeping the reactors operating at full power. Looking further ahead, hydrogen production with a GEMINI+ system is feasible for penetration in an industrial market requiring hydrogen. ●

John Lillington
Chief Technologist Nuclear Reactors at Wood & GEMINI+ Partner

IN BRIEF

GEMINI+ at the 2020 Edition of HTR in Indonesia

From 6-8 October 2020, in Yogyakarta (Indonesia), the GEMINI+ partners and members of the European Nuclear Cogeneration Industrial Initiative (NC2I) will contribute to several strategic and technical contributions to the 10th international conference on High Temperature Reactor Technology (HTR 2020). Both professionals are trackleaders and part of the HTR international organising committee.

Organised in collaboration with the Indonesian Nuclear Society (HIMNI), the National Nuclear Energy Agency of Indonesia (BATAN) and Gadjah Mada University (UGM), HTR2020 is the only international event focusing on High Temperature gas-cooled Reactors (HTGRs) and process heat application technology. Moreover, it provides a comprehensive networking and exchange forum for professionals in R&D and industry, as well as for decision-makers from governments, utilities, end-user industries and vendors.

Launched in 2002 by the European High Temperature Reactor Technology Network (HTR-TN) in Petten (Netherlands), the HTR meetings were held then in China (2004), South Africa (2006), USA (2008), Czech Republic (2010), Japan (2012), China (2014) USA (2016) and Poland (2018). ●

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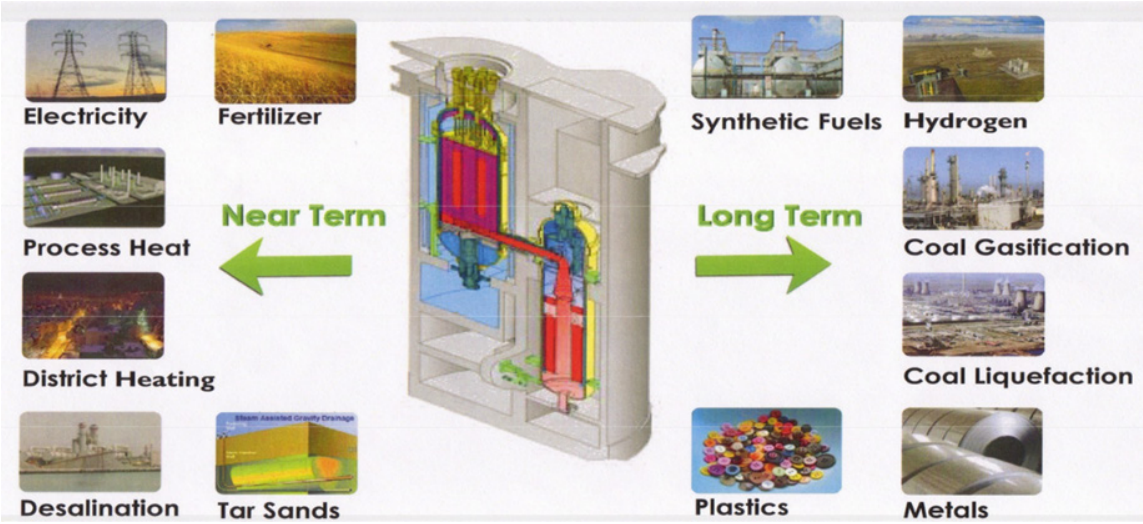
New High-Impact Options to Decarbonise Industry



The main objetive of the GEMINI+ project is to support the industrial demonstration of a cogeneration High Temperature Gas-cooled Reactor (HTGR) power plant. This should help de-risk further projects and accelerate deployment. Recently, the Polish government has reconfirmed its interest, in particular to reduce the country's carbon footprint and its dependence on natural gas imports, which are used both for heating purposes and as feedstock for chemical products.

WHAT CAN BRING GEMINI+?

Cogeneration is the conversion of a primary energy source into at least two different forms of secondary energy. This greatly increases thermal efficiency. The most common example is cogeneration of electricity and process heat, which can be carried in the form of a hot fluid from a power plant to many industrial applications ranging from seawater desalination to large-scale bulk hydrogen production.

Still too little noticed by policymakers and the public, cogeneration represents a very large market in Europe and globally, and is almost entirely dependent on fossil fuel today. GEMINI+ is looking into options to replace this fossil fuel by nuclear energy thus helping decarbonise industry as part of the European Green Deal.

FOR WHICH APPLICATIONS?

GEMINI+ is performing several studies about applications of nuclear process heat from an HTGR for a number of industrial purposes:

- large-scale hydrogen production
- nitrogen-based fertilisers and chemical commodity products
- hydrocarbon synthesis (for instance plastics or synthetic jet fuel)
- dry reforming of methane with CO_2 to produce syngas as a feedstock for numerous chemicals
- integration of nuclear energy in hybrid energy systems with variable renewables

Most of these processes rely on hydrogen to replace natural gas as a feedstock. These processes are of strategic interest for industrialised countries, and several of them are key to integrating nuclear power into hybrid energy systems with variable renewables. An overview of these studies will be presented at HTR 2020 and be completed with an impact analysis by evaluating the market and CO_2 savings potential.

Michael Fütterer
Deputy Head of Unit for Nuclear Safety at the Directorate General Joint Research Center (JRC) & GEMINI+ Partner

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Making the HTGR Technology Happen

One major goal of the GEMINI+ project is to prove the industrial feasibility of nuclear high temperature cogeneration by supporting a full-scale demonstration project. Poland has shown strong interest in such a project which requires ensuring the investor's confidence. The heat produced by a High Temperature Gas-cooled Reactor (HTGR) thanks to the fission of uranium atoms is perfectly aligned with the production of electricity and heat for a large array of industrial applications, which are today fully dependent on fossil fuel firing.

The main job of HTGR is to create heat through splitting atoms as other nuclear reactors do. But powering the grid is only one of the capabilities of this versatile reactor, because it operates at much higher temperature than present industrial reactors. Once in operation, it can provide carbon-free heat for a large array of industrial applications: electricity generation, district heating, process heat, hydrogen generation for clean fuels, seawater desalination to produce clean water... In addition, HTGRs can be built with robust inherent safety features. This reduces the perimeter of the Emergency Planning Zone (EPZ), hence allowing the collocation of HTGRs close to industrial sites.

Regarding economic aspects, the challenge for innovative nuclear technologies lies in the uncertainty of the Overnight Capital Costs (OCC) of a new reactor, especially for a first-of kind (FOAK). Additionally, a FOAK can appear as technically and financially risky for investors, especially regarding the demonstration costs. Therefore, GEMINI+ endeavours to arouse stakeholder engagement and analysed funding schemes in parallel with the ongoing GEMINI+ design and research activities.

HTGR DEMONSTRATION IN POLAND

Whatever the business model, the governmental support and the strong involvement of the Polish National Centre for Nuclear Research (NCBJ) are favourable conditions to make an HTGR demonstration in Poland happen. NCBJ will lead the design effort in partnership with private companies and nuclear research centres from across the globe. Mobilising initial public funding for the preliminary design phase will de-risk private investments in this game changer technology and help clarify the economic performance of such a reactor.

TRIGGERING PUBLIC-PRIVATE PARTNERSHIPS

Applying for any important financial instruments such as the European structural funds or for investments from private companies, a full description of the project in the form of a detailed business plan needs to be prepared. It should include at least a brief design description, a detailed financial analysis, an environmental impact assessment considering emission benefits and radioactive waste management aspects.

A COLLABORATIVE APPROACH TO SOLVE CHALLENGES

Apart from finding the right financing mechanism, which represents the greatest challenge, demonstration of the HTGR in Poland faces hedges on its road which can be tackled by taking early actions and changing some of the usual practices in nuclear energy.

A difficulty for nuclear cogeneration with HTGR is indeed the difference with Light Water Reactors (LWRs) dedicated to electricity generation, because both the reactor technology and the applications are different. This requires an evolution of the safety approach that should be acceptable by the regulator.

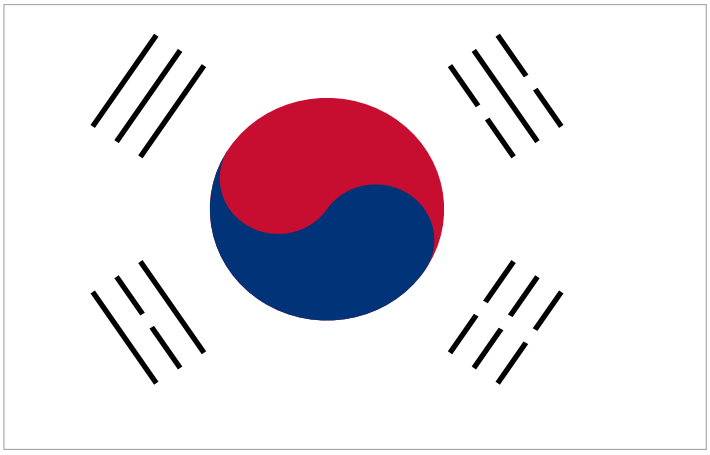
Another challenge lies in the need to develop national human resources and supply chain capability. The European expertise and the experience of international vendors will be useful to support the new Polish nuclear programme.

Any other obstacles can however be overcome by an effective project management and an early dialogue between stakeholders including lawmakers, potential investors, nuclear experts, international HTGR developers, and regulators. ●

Sertaç Erim
Nuclear Energy Analyst at LGI & GEMINI+ Partner

HTGR

Focus on South Korea and its Shift to Hydrogen-Powered Technologies



As part of the GEMINI+ partners, KAERI (Korea Atomic Energy Research Institute) has been developing a Very High Temperature Reactor (VHTR) technologies since 2006, based on a long-term national plan for future nuclear system. The purpose of VHTR development in Korea is primarily dedicated to the hydrogen production. In early 2019, the Korean government announced its plan for becoming an hydrogen economy by encouraging mass-manufacturing of hydrogen fuel cell vehicles (FCVs) and the use of hydrogen as an energy source to supply electricity.

ONE NATIONAL PLAN, ROADMAP & TEST REACTOR

In order to support and execute the national hydrogen plan, the Korean government released a dedicated roadmap in which nuclear hydrogen production using VHTR is considered as one of the future carbon-free hydrogen production technologies. It is indicated in the roadmap that the development of such technology requires a test reactor to validate the very high temperature heat supply up to 950°C and the production of hydrogen.

FOSTERING INTERNATIONAL COLLABORATION

As the development and demonstration of VHTR requires various design and engineering technologies that KAERI can't achieve alone, international cooperation and collaboration are essential. Thus, KAERI participates in several international cooperation initiatives, including the Generation IV International Forum (GIF) and the GEMINI+ project. Thanks to its research activities on cogeneration capability for electricity production and high pressure steam, the GEMINI+ project is a first step for an international effort to deploy HTGR technologies at a large-scale. Indeed, the HTGR technology developed in GEMINI+ will be a stepping stone for future advancements in the design and demonstration of VHTR.

COGENERATION & RENEWABLE: A WINNING DUO

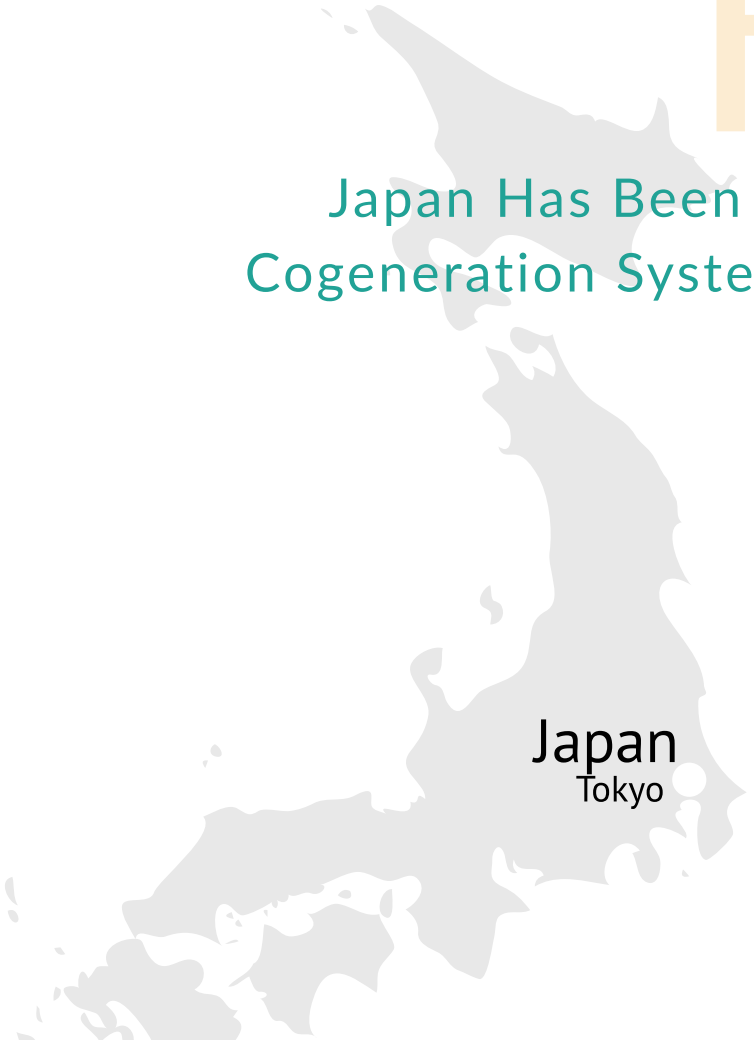
As the use of renewable energy is increasing around the world, a nuclear energy system based on cogeneration is becoming an essential choice that will open up new economic perspectives. Thus, the future R&D planning in Korea is more focused on a small or micro reactor technology and multiple heat applications including gas turbine, hydrogen production, and heat storage.

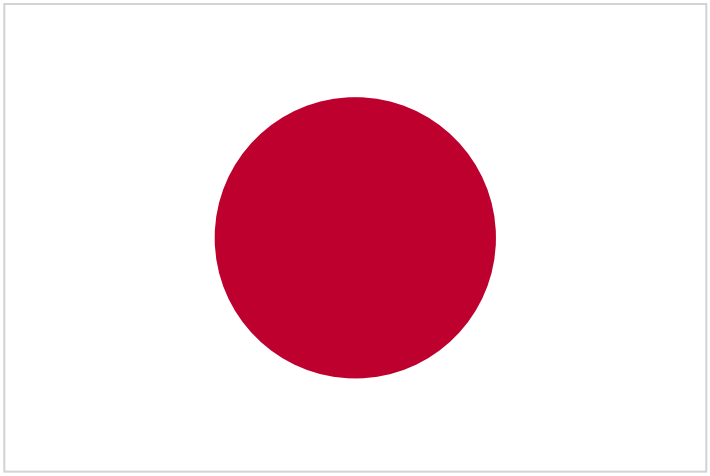
Considering the Korean hydrogen roadmap, cogeneration of electricity and hydrogen will be the best option for establishing a nuclear energy system coexisting with renewables. Among hydrogen production methods, High Temperature Steam Electrolysis (HTSE) operated under small VHTR or HTGR is considered as more advantageous than sulfur-iodine (SI) thermochemical process. Accordingly, new R&D activities on HTSE are under preparation in KAERI. ●

Minhwan Kim
Project Manager at KEARI & GEMINI+ Partner

HTGR

Japan Has Been Closely Looking at Nuclear Cogeneration Systems for More Than 50 Years





Since the 1960's and heat utilisation technologies such as helium gas turbine power generation and hydrogen production stem from water by sulfur-iodine (SI) thermochemical process, the Japan Atomic Energy Agency (JAEA) is developing HTGR technology using Japanese prismatic HTGR test reactor also called High Temperature Engineering Test Reactor (HTTR).

NUCLEAR HYDROGEN PRODUCTION

HTTR can achieve reactor outlet coolant temperature of 950°C at full power of 30MWth, and deliver the high temperature heat stably from the primary helium to the secondary helium thorough intermediate heat exchanger. This shows capability of high temperature heat utilisation, such cogeneration for instance.

In R&D of hydrogen production, the results of 30L/h and 150h continuous hydrogen production using the SI process and industrial material components had been reached in 2019. This is a significant achievement for the practical use of nuclear hydrogen production.

A LICENSING FRAMEWORK

JAEA is also performing a design of several HTGR cogeneration systems: cogeneration of electricity by steam turbine and high temperature steam, district heating up to 750°C as developed in the GEMINI+ project, and cogeneration of electricity by helium gas turbine and hydrogen employing 950°C HTGR.

One of the challenges of nuclear cogeneration is a licensing framework to build and operate heat utilisation facility coupled with nuclear reactor as non-nuclear facility. JAEA drafted the safety requirements for nuclear cogeneration system and opened discussions under both the research committee of the Atomic Energy Society of Japan and the IAEA Coordinated Research Project (CRP).

It is planned to connect helium gas turbine and hydrogen production system with HTTR to demonstrate the licensing and operationnal dimension of nuclear cogeneration leading to electricity and hydrogen production via HTTR (commonly called HTTR-GT/H2).

DIRECT LINK WITH GEMINI+

JAEA is contributing to the GEMINI+ project throught all these different HTGR cogeneration technologies. The final objective is the early deployment of the GEMINI+ nuclear cogeneration system of electricity by steam turbine and high temperature steam supply for chemical industry or district heating.

Hirofumi Ohashi
Group Leader HTGR Systems at JAEA & GEMINI+ Partner

NC2I

Nuclear Cogeneration Industrial Initiative

The European Nuclear Cogeneration Industrial Initiative (NC2I) is one of the three SNETP pillars. It aims at demonstrating 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.

SNETP and NC2I are supported by the SPRINT project which has received funding from the Euratom research & training programme 2014-2018 under Grant Agreement n°662149.

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The research and development activities performed in the GEMINI+ project aim to support the GEMINI Initiative, a transatlantic collaboration between the European Nuclear Cogeneration Industrial Initiative (NC2I) and the American Next Generation Nuclear Plant (NGNP) Industry Alliance

During 36 months, GEMINI+ partners will work together towards the demonstration of high temperature nuclear cogeneration with a High Temperature Gas-cooled Reactor (HTGR).

Launched in September 2017, this European Horizon 2020 project funded under the Euratom programme will provide a conceptual design of a high temperature nuclear cogeneration system that supplies process steam to industry, a licensing framework for this system and a business plan for a full scale demonstration.

Coordinated by the National Centre for Nuclear Research (NCBJ), in Poland, the GEMINI+ consortium gathers 26 partners from accross Europe and includes partners in Japan, South Korea and the United States.

The GEMINI+ project has received funding from the Euratom research and training programme 2014-2018 under Grant Agreement n°755478. The content of this newsletter reflects only the author's view. The European Commission is not responsible for any use that may be made of the information it contains.

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