Gemini Plus

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Preliminary requirements, assumptions and constraints for GEMINI + high temperature nuclear cogeneration system

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Summary

The report presents the preliminary requirements compiled from information given by the members of the consortium and sets out the tasks to be undertaken next.

Approval

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Abbreviations

EC DG RTD	European Commission – Directorate General for Research and Innovation
PQP	Project Quality Plan
DoA	Description of Action
WP	Work package
WPL	Work package leader
GB	Governing Board
CMB	CORTEX Management Board
PAR	Periodic activity report
PMR	Periodic management report
PR	Periodic report
QA	Quality assurance
PMO	Project Management Office
AEUG	Advisory End User Group
ECCP	Electronic Collaborative Content Platform

Summary

The report presents the preliminary requirements compiled from information given by the members of the consortium and sets out the tasks to be undertaken next.

1 Introduction

The objective of the project is to detail the requirements, assumptions and constraints of the GEMINI project as well as their rationale. These include:

- Safety and licensing requirements defined by WP1, including the definition of a set of envelope conditions for potential sites regarding environmental conditions, external events, etc.
- End-user requirements identified by the customer or in previous industrial research, Euratom and international projects (EUROPAIRS, ARCHER. NC2I-R and NGNP) and possibly complemented by end-users involved in WP4.
- Operator requirements expressed by utilities participating in the Project (FORTUM and US Utilities, which will provide information through the NIA) and by enquiry of other utilities.
- Additional assumptions and constraints related to strategic or technical decisions (e.g. working towards convergence of configuration with NIA, minimizing technology risk by giving preference to proven solutions, ease of manufacturing, maximizing workshop manufacturing, etc.).

The project is divided in several steps and will ultimately lead to a final report on the requirements, assumptions and constraints for GEMINI. This preliminary report is the first deliverable of the project and compiles the first set of requirements developed within this task. The objectives of the report are to:

- To ensure all parties involved in the project understand the rationale of the requirements and intend to take them into account;
- To seek feedback and encourage discussion regarding the list of requirement compiled, their rationale and relative priority.
- To highlight the requirements where details are lacking.

<u>Methodology</u>

First, a matrix was devised to classify the requirements, assumptions and constraints according to category (regulatory, end-user, project), nuclear lifecycle stage and source of information. Then information from members of the consortium was compiled based on their knowledge, experience and expertise, in particular with a view to developing requirements for the Polish demonstration project. Requirements were recorded using JIRA management tool.

The requirements compiled are presented below for each life-cycle stage they are associated with:

- Siting;
- Design;
- Construction and commissioning;
- Operation and maintenance;
- Decommissioning and waste management.

They are given a unique identification number provided by JIRA management tool.

2 Siting requirements

The requirements for the siting of the plant are:

GEM-31: Infrastructure availability

For each potential site, the availability of nearby infrastructure shall be considered. That includes grid impacts, also power lines capable of transmitting the plant's maximum electrical power output; water resources sufficient for the plant operation and heat consumption of would-be consumers for the high temperature steam produced.

The site shall have a water source able to sustain the plant's water needs in its vicinity. In addition, the site shall be located near the facilities of would-be customers. Finally, to limit the costs of the project, it should be easy and inexpensive to connect the plant to the electrical grid.

GEM-34: Workforce availability

A workforce sufficient to build the plant shall be able to come to the site and work on the construction.

GEM-12: Seismic requirements

The earthquake hazard shall be considered for potential sites. The peak ground acceleration for the design basis seismic event should be lower than 0.3g.

This would limit the amount of reinforcement and seismic defences the plant design requires and make the site licence process easier.

GEM-33: Easiness of permitting

The site shall be chosen to ease the permit process (e.g. small environmental impact, limited external hazards, etc.).

GEM-32: Nuclear licensing readiness

The plant should be capable of development to a high Technical Readiness Level (TRL) in the relatively near term in readiness for licensing.

3 Design requirements

3.1 End-user requirements

GEM-50: Characteristics of steam produced

The plant shall provide steam at 540℃, 13.6MPa which is what the Polish Chemical Industry requires.

GEM-51: Thermal power requirement

The plant shall provide a thermal power of 165MWth. This is the standard thermal power generated by industrial boilers in Polish chemical sites.

GEM-52: Load-transient requirements

The plant shall be able to follow the maximum load-transients required by Polish chemical sites. The specific power transient required needs to be researched.

GEM-36: Coupling to the industrial process

The coupling should ensure adequate separation between the nuclear licensed reactor side and the industrial process (steam) plant. Several design proposals have been put forward to be analysed in Task 2.2.

GEM-37: Back-up systems

The design shall have back-up systems for heat production.

GEM-53: Design cost requirement

The cost of steam production in the plant shall be competitive with the cost of steam in plants powered by natural gas or coal. The plant should be able to compete against conventional plants powered by natural gas or coal.

GEM-35: Technology maturity

The project shall rely on mature technology as much as possible. The project shall limit its reliance on future innovation which may require too much time to develop and introduce too much risk.

GEM-54: Timeline requirement

The demonstration plant shall be operating as soon as possible and at the latest in 2030. As a result, innovations that require a too long development or involving too much risk shall be avoided.

GEM-56: Component transportation

The plant shall be built out of components transportable by road. The rationale is not to add any hidden cost to the project, such as funds to build new roads. The limits regarding the maximum size and weight of modules are currently being researched.

GEM-55: Exportable design

The design of the demonstration plant shall be available for export, subject to agreement of interested stakeholders.

3.2 Project requirements

GEM-61: Prismatic block type core

The design shall be a prismatic block type core.

GEM-15: Coolant and heat transport requirement

The reactor system shall use helium as the primary heat transport fluid and shall employ forced circulation as a means of heat transport.

GEM-18: Access to primary coolant pressure boundary

The system shall be designed to provide access to the primary coolant pressure boundary to permit in-service inspection. It must be compliant with internationally accepted requirements e.g. the Korea Electric Power Industry Code (KEPIC) and the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code.

GEM-21: Dose-rate limits

The system design shall include reactor and reactor building design features that result in calculated dose rates at the Exclusion Area Boundary that meet the public and worker exposure limits criteria for normal operation, anticipated operational occurrences, and accidents. Minimising the dose rates of nuclear workers is crucial for their physical safety and mental well-being.

GEM-19: Design safety requirement

The design safety of the reactor systems shall be guaranteed by defence-in-depth, inherent and passive safety, and tolerance to extreme natural disasters. In particular, the system shall utilise inherent and passive safety features to cool the core from full power to safe shutdown conditions, should the normal cooling system be unavailable. This is necessary as all Generation IV reactors, including the HTGR, must be at least as safe as designs currently in operation.

GEM-16: Initial testing requirement

The system shall undergo an initial period of testing in support of Design Certification and the deployment of follow-on commercial plants before entering commercial operation.

GEM-57: Interface system

An interface system shall be built between the nuclear plant and the industrial application (the secondary system) in order to maximize decoupling between them. This would allow acceptable protection against radioactive contamination of the secondary system steam both in normal and abnormal conditions. In addition, it would make it easier to satisfy the load-following requirement.

GEM-17: Capacity factor over 90%

A design objective is that the overall plant lifetime capacity factor shall be greater than or equal to 90%. The plant shall have a reliability that is acceptable to the end-user and that ensures good plant economics.

GEM-13: 60-year design life

For the same reason, the design life of the demonstration plant shall be 60 years.

GEM-58: Modular design

The plant design shall be simple and made of modules to facilitate modular construction (maximizing workshop manufacturing, simplifying site assembly). The relatively small size of the projected design means that modular construction is possible and should be done to compensate for the penalty of small scale.

GEM-14: Representative design

The power level of the HTGR shall be representative of a reactor module in a full-scale commercial plant to the level that can demonstrate the design, safety and functional requirements of end users and Generation IV reactors. This would enable the demonstration plant to be used to demonstrate the safety of a larger HTGR plant and thus ease its design assessment by the regulator.

GEM-59: Technology and design convergence

For the project, efforts shall be made for converging in our technologies and designs. This is a European project and the project is undertaken with the help of international partners and it only makes sense if efforts are made for converging our technologies and designs.

4 Construction and commissioning requirements

GEM-23: Building and equipment requirement

The design of buildings and equipment shall facilitate plant construction and the installation, repair and replacement of equipment. This would reduce unnecessary loss of time during construction and during plant outages and thus boost the competitiveness of the plant.

GEM-38: Reliability of schedule

The construction schedule shall be realistic and take into account the main risks for delays. This would ensure that the cost overrun due to delays in the construction schedule are minimised.

GEM-39: Cooperation with regulators

Efforts shall be made to cultivate a good relationship with the regulatory body based on mutual respect. This would encourage honest discussions about potential regulatory issues and thus enable their proactive resolution. Ultimately this would help to save time with the design licence, the site licence and the construction and commissioning of the plant.

GEM-40: Compliance with regulatory requirements

The design and construction of the plant shall comply with regulatory requirements. They will be defined by WP1.

GEM-41: Compliance with European utility requirements

The reactor shall comply with the European utility requirements. Research needs to be done on how these apply to reactor types different from LWRs.

5 Operation and maintenance requirements

GEM-43: Number of O&M personnel

The number of O&M personnel should be acceptably low, consistent with regulatory requirements, to ensure competitive operating costs.

GEM-42: Availability of experienced workforce

Provisions shall be made to ensure an experienced workforce is available once the plant is completed. They will operate the plant after its commissioning and train a local workforce to maximise the benefits for the local economy and for the nuclear industry of the host country.

GEM-45&46: Outage frequency and outage duration

Research shall be done on the plant's projected outage durations and frequencies and on ways to minimise them. Outage duration and frequency both impact the plant's capacity factor and thus the plant's economics. They must be minimised to achieve a large capacity factor.

GEM-60: Grace period

During a grace period (the length of which is to be defined), the plant shall accommodate:

- Reactor transients without perturbation of the applications (steam generation).
- Load transients from the applications without inducing abnormal situations for the reactor.

GEM-25: Operational safety requirements

The operational safety shall be ensured by man-machine interface design, emergency operating procedures, accident management procedures, and by a well-established safety culture.

GEM-26: Maintenance activities

All Nuclear islands planned maintenance activities shall be completed during plant operation or as part of a planned outage, the duration of which is controlled by the Reactor System or Energy Conversion and Delivery Systems.

6 Decommissioning and waste management requirements

GEM-27: Decommissioning requirements

Upon completion of its useful life, the nuclear heat source shall be capable of being stored for a certain period of time and then decommissioned and dismantled to allow continued use of the land as a power plant or industrial site.

GEM-49: Decommissioning costs

The project shall include a set decommissioning cost as well as a clear plan to allocate resources for decommissioning during the lifetime of the plant. This would ensure that the financial obligations of decommissioning can be met at the predicted end of life of the reactor.

GEM-29: Worker exposure during decommissioning

Decommissioning safety shall be considered in the design in order to minimise the potential exposure to workers and the waste during decommissioning phases. Indeed, minimising the dose rates of nuclear workers is crucial for their physical safety and mental well-being.

GEM-47: Waste disposal provisions

Provisions shall be made on how to safely deal with high-level low-level waste. This includes the identification of all the waste streams and estimation of the waste quantities. It is necessary to know the different wastes produced by the plant, the amount generated and the risk they pose to minimise the disposal burden and ensure safety at normal and abnormal conditions.

GEM-48: Optimisation of waste volume

A strategy to minimise nuclear waste volume should be discussed since minimising nuclear waste volume is necessary for the effort to maintain public support for the project.

7 Conclusion and future work

The report presents a preliminary view of the requirements for the GEMINI project. Further work is needed to develop the final requirements.

This includes the following tasks:

The first is to engage with and seek feedback from all WP2 participants. In particular, the contribution of each would enable to:

- Refine the requirements presented in the preliminary report;
- Add requirements that have been missed in the preliminary review;
- Decide the priority to associate with each requirement.

The second task is to perform further research to find further requirements, assumptions and constraints for the GEMINI project. This include looking at previous industrial project such EUROPAIRS, ARCHER, NC2I-R and NGNP as well as reviewing IAEA and NEA work on requirements, along with recent scientific publications.

The third task is to coordinate with participants working on other Work Packages of the GEMINI project. Close collaboration with WP1 is especially key to provide a detailed list of the regulatory requirements for the project. In addition, impacts from innovation features from WP3 should be considered and feedback should be sought from end-users of WP4 to complement the list of requirements obtained.