GEMINI 4.0 WP2: Conditions for decarbonization of European industry with nuclear polygeneration using High Temperature Reactors

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The GEMINI project aims to deploy a 180 MW high temperature gas-cooled reactor (HTGR) in Europe. Work package 2 is focused on analysing regulatory and technoeconomic conditions necessary for decarbonisation of European industry. Nuclear cogeneration of heat, power and hydrogen is identified as the optimal solution for a large share of the industry. The largest market for heat is under 550°C, particularly in sectors of petroleum refining, fertilizer production, desalination and district heating. In some countries, most of the heat is generated with old coal boilers, which cannot be replaced with new ones due to emission norms. Most countries are highly dependent on natural gas imports, necessary both for heat and hydrogen production. Poland is one of countries where both the government and the industry express high interest in HTGRs due to a legacy of coal boilers, high share of gas imports, heat consumption at temperatures between 250-550°C above 7 GW and hydrogen consumption above 1 MT/year. Presently, natural gas-fed Steam Methane Reforming is the most affordable source of hydrogen despite high gas prices at 2-3 EUR/kg. Electrolysis is not competitive at current electricity prices, particularly with HTGRs as the energy source. High-Temperature Steam Electrolysis is a promising technology with high Technology Readiness Level and potentially competitive costs below 4 EUR/kg when combined with HTGRs. Thermodynamic efficiency of the system benefits from very high temperatures, even beyond the capabilities of the GEMINI HTGR. The system could include more affordable electricity sources, such as water-cooled reactors or renewable energy sources, to maximize the economic competitiveness of the system. Sulphur-Iodine (S-I) cycle is a potential alternative in the future. Current reactor design provides heat at up to 750°C. One stage of the S-I cycle benefits from higher temperatures, leading to temperature boosting to 850°C at one stage. Future improvements in either thermodynamic efficiency at lower temperatures and lowered capital costs would significantly improve the commercial viability of S-I. Outlook on future high prices of fuel, electricity and emission rights creates an opportunity for nuclear technology, where costs are predictable past construction phase. The main risks to the competitiveness of nuclear cogeneration of heat, electricity and hydrogen are the uncertain capital costs of HTGRs, slow decision-making of governments and industrial partners due to high risks associated with FOAK construction, and presently insufficient regulatory framework for integration of HTGRS into the existing industry.

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