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Accelerating Fusion Energy Industrialization Through Process Standardization

In the path towards the exploitation of nuclear fusion as a virtually unlimited, reliable, and carbon-free energy source, demonstrating tritium self-sufficiency and achieving competitive net electricity production for the grid are of paramount importance.

As the Eni group fosters the industrialization of magnetic confinement fusion, we are committed to mitigating risks and accelerating the development of fusion power plants.
To this end, we apply consolidated engineering methodologies and structured risk management strategies. This approach leverages our extensive expertise in engineering and project management, built over decades of experience in complex energy infrastructure projects.

This contribution presents two case studies that exemplify Eni's approach to bridging conventional engineering practices with the unique challenges of fusion systems engineering. The focus is placed on the Tritium Fuel Cycle and the Breeding Blanket System, both of which are pivotal for the availability and operability of future fusion power plants. These systems benefit significantly from know-how and technology transfer, as well as from early-stage process standardization rooted in Eni's industrial background.

An ARC-like reactor configuration, consistent with the design parameters proposed by Commonwealth Fusion Systems (CFS), has been adopted as the reference framework for this study.

Breeding Blanket System (BBS): The BBS is responsible for tritium production, heat extraction, and neutron shielding. This study adopts a systems engineering approach to assess the BBS performances. Emphasis is placed on the integration of its main components, evaluating their coherence with tritium transport pathways and heat removal strategies.
Tritium Fuel Cycle (TFC): The TFC is analyzed, focusing on key subsystems essential for the continuous recovery, purification, and reinjection of tritium, ensuring closed-loop operation. Process simulations are conducted using Aspen HYSYS®, a chemical process simulator widely adopted in the Oil & Gas sector, to assess the technical feasibility and integration of these subsystems. A structured equipment list for each subsystems also provide precious data for key performance indexes such as tritium inventory. The estimation of the tritium inventory allows for the evaluation of safety requirements, containment measures, and tritium logistics—factors that influence both CAPEX and OPEX.

In this contribution, the main outcomes of the activity are presented, focusing on: (1) the development of a pre-conceptual design of the main systems of the BBS and TFC; (2) the assessment of their technical feasibility according to the currently available technologies.

The results underscore the importance of early-stage standardization and the adoption of cross-sectoral engineering methodologies, which can significantly streamline the design process, reduce uncertainties, and support the transition from experimental devices to commercially viable fusion power plants.

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