DEVELOPMENT AND IMPLEMENTATION OF THE COMMERCIAL EAGLES-300 PROGRAM

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INTRODUCTION: In recent years, the energy policy landscape has undergone significant transformation across numerous industrialized nations. This evolution is driven by the pursuit of a balanced approach that ensures energy security, enhances cost efficiency to bolster industrial production, and supports the transition towards technological solutions with reduced environmental impact. In particular, there has been a renewed interest in nuclear technologies due to their alignment with safety, security, and reduced carbon footprint concerns. To rejuvenate the nuclear supply chain in Europe, the EU SMR Industrial Alliance (IA) was established. This alliance aims at fostering the development of small-scale nuclear plants across European territories through ad-hoc strategic policies and simplifications. Among the initiatives supported by the IA is the EU-SMR-LFR project, which focuses on the deployment of EAGLES-300, a small-scale commercial reactor utilizing lead technology (LFR). This paper provides a detailed description of the project, including its timeline and primary objectives.

1. CONTEXT AND PROGRAM

The European Industrial Alliance on Small Modular Reactors (SMRs) [1], established under the auspices of the European Commission in 2024, aims at accelerating the development, demonstration, and deployment of SMRs in Europe by the early 2030s. Along with the innovative safety features [2] and ability to provide low-carbon electricity and heat – common to all contemporary reactor concepts – SMRs are important due to their reduced scale, to which reduced footprint and capital cost are associated, making them attractive to investors. The segment of SMRs based on technologies differing from water cooling (often referred to as advanced modular reactors, or AMRs) also features higher operating temperatures, making them (in addition to the above) suitable for decarbonizing hard-to-abate sectors like transport, chemicals, steel, and district heating [3]. Responding to this interest, the objectives of the EU Industrial Alliance on SMRs include supporting SMR projects, identifying advanced technologies, addressing investment barriers, engaging industrial users, and promoting public awareness. The alliance also establishes a Nuclear Skills Academy and cooperate with international bodies to help European SMR projects reach global markets.

As a first step towards achieving its objectives, the Alliance shortlisted nine reference projects for support. Among them is the EU-SMR-LFR, which focuses on the development and commercialization of EAGLES-300, a commercial lead-cooled SMR reactor. The project is promoted by a consortium led by Ansaldo Nucleare as leading industry, involving prominent European research institutions such as ENEA, RATEN-ICN, and SCK CEN, which have significantly contributed to the development of this technology [4][5].

There are several aspects that make attractive the use of lead as a coolant in an SMR: the boiling temperature of approximately 1740 °C offers a wide liquid temperature range; it is compatible with fuels and ultimate heat sink vectors; it offers excellent gamma shielding and neutron transparency, the latter allowing a fast core spectrum [6]. It effectively retains fission products like Caesium, Polonium, and Strontium [7] and has good heat transfer capabilities due to its low Prandtl number [8]. These properties simplify the primary system design by eliminating intermediate cooling circuits and other engineering provisions. Lead's low absorption and scattering cross sections enable wider spacing of fuel pins, reducing coolant velocity and pressure drop, thus supporting natural circulation during safety events. Its large volumetric heat capacity ensures reactor safety by maintaining liquid state without pressure build-up following any Postulated Initiating Event (PIE). However, Lead's high corrosiveness towards conventional steels at high temperatures requires innovative solutions for chemistry control and surface protection [9]. Its density opens to the possibility for significant seismic loads, and complicates refuelling operations along with fluid opacity. The high melting point of Lead necessitates systems to keep it liquid, and plant overcooling poses risks of local freezing [10].

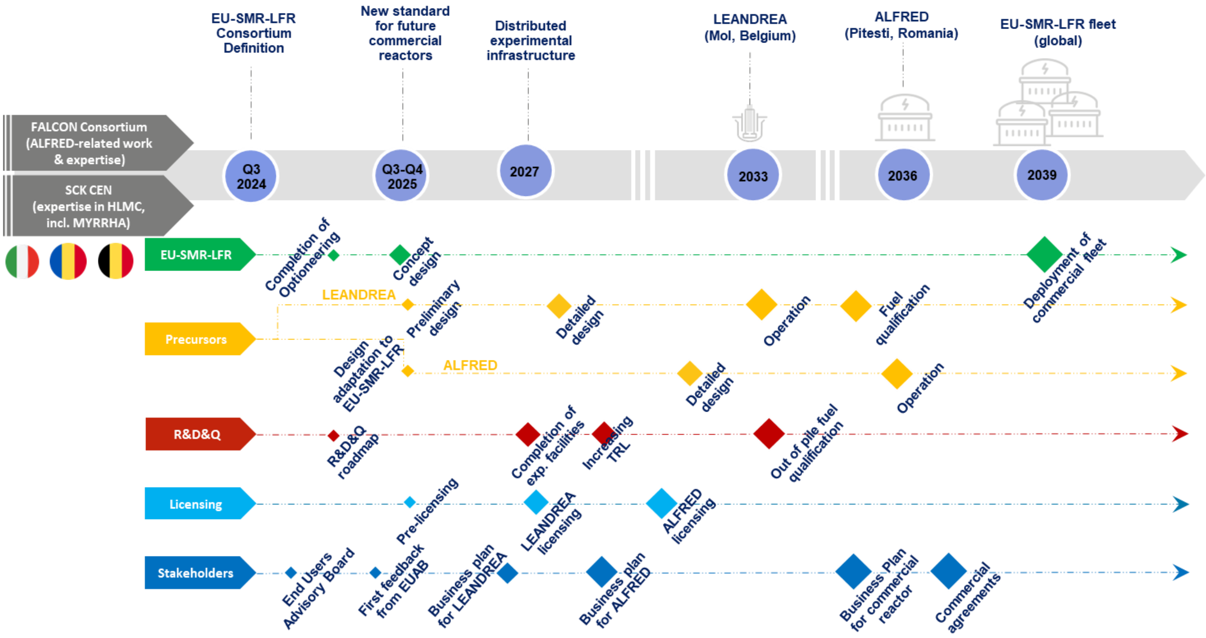

Figure 1. EU-SMR-LFR Program Planning

The development of a commercial LFR to be introduced to the market in support of the energy transition necessitates a comprehensive and methodical plan encompassing all requisite activities. The EAGLES-300 deployment strategy is structured around five principal directions:

1. Development of the commercial reactor
2. Deployment of precursors
3. Research and development (R&D) plan
4. Licensing strategy
5. Stakeholder engagement

The plan anticipates the completion of optioneering and conceptual design activities for the commercial reactor by 2025. These activities inform the development of precursors through demonstration and qualification requirements, specifically LEANDREA for irradiation activities and ALFRED for the prototyping of full-scale technological solutions. Concurrently, the qualification plan will encompass all R&D tests that do not necessitate irradiation, utilizing existing infrastructures owned by partners as well as those planned for future construction.

The European deployment of EAGLES-300 is facilitated by a unified licensing approach, supported by the IA. Currently, the consortium is engaged in pre-licensing discussions with both the Belgian Federal Agency for Nuclear Control (FANC) and the Romanian National Commission for Nuclear Activities Control (CNCAN), with the intention of expanding these discussions to include additional safety authorities from other member states. Moreover, the consortium is organizing, thanks to IAEA, an extra budgetary project to accelerate the licensing processes of the LFR fleet including precursors.

Finally, the development of technological solutions and the primary features of the product are aligned with market needs through ongoing dialogue with prospective users, leveraging operational experience from existing power plants to anticipate future market requirements.

The plan envisions the commencement of irradiation activities in LEANDREA starting in 2033, followed by ALFRED in 2036, with the first EAGLES-300 plants expected to be available on the market in the subsequent years.

2. EAGLES-300

The EAGLES-300 reactor development strategy emphasizes a time-to-market driven approach, balancing design options to optimize marketability and qualification timelines. The reactor is designed with a power output of ~350 MWe and utilizes Lead as the primary coolant. The reference fuel for EAGLES-300 is MOX, of a grade and operating in conditions compatible with previous experiences on Sodium-cooled fast reactors, in order to maximize the exploitation of previous experience and skills, as well as the qualification and codes validation background. The reactor is a loop-in-pool concept and maintains primary and secondary operating pressures of 0.1 MPa and 18 MPa respectively, with an option for advanced supercritical cycle. Lead temperature ranges from a minimum of 400°C to a maximum of about 600°C.

Economically, EAGLES-300 is designed to be competitive with future EU energy systems, making it suitable for remote applications and relevant for replacing fossil-fired power plants. The reactor's safety features include passive decay heat removal, a grace period of more than 72 hours, and significantly reduced requirements for an emergency planning zone (EPZ) beyond the site boundary, all while utilizing passive safety features.

From an environmental and sustainability perspective, EAGLES-300 supports a closed fuel cycle, ensuring that its environmental impact is the lowest possible. The design also aims at minimizing the use of raw materials. In terms of plant operation, the strategy focuses on minimizing downtime due to inspection and maintenance, with the majority of components being replaceable also to easily extend the plant's operational lifetime.

3. CONCLUSIONS

The EAGLES-300 reactor development strategy aligns with the European Union's energy transition framework, emphasizing a rigorous yet rational plan. It ensures clean energy production and significantly reduces material utilization through a closed fuel cycle. This approach positions the reactor as a key player in the future energy landscape, contributing to a sustainable and secure energy transition while meeting market demands and regulatory requirements.

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