EPG CLEAN AIR TASK FORCE

Policy Brief

SMALL MODULAR REACTORS: A TECHNICAL AND ECONOMIC ASSESSMENT

General considerations and the case of Romania

November 2023

The report offers a cautious technico-economic endorsement for the development of the most viable SMR designs. They will bring an important contribution to the intensifying efforts of reaching net-zero emissions by 2050, as well as to ensuring energy security and affordability.

SMRs represent the promise of a new nuclear technology to supply zero-emissions, safe, and dispatchable power, amid intensified efforts to reduce carbon emissions and ensure energy security. With small size (up to 300 MW per unit) and simplified design, modular and factory-made, SMRs are expected to supply new kinds of industrial consumers of electricity and/or heat – e.g., steel mills, aluminum smelters, chemical plants, off-grid mining, refining facilities, electrolyzers, and replacement of closing coal power plants. SMRs will offer zero-emissions baseload (yet partly flexible) power to an energy system with an increasing share of renewables. They will be geographically distributed, with smaller footprints, and much less dependent for cooling on water bodies.

The **LCOE** for SMR projects in some advanced economies, at cost of capital rates of 6-9%, has been put at $45-110/MWh, while a range of $50-60/MWh is envisaged for n^{th}-of-a-kind (NOAK) units. The figures should include the cost of certification and of building the SMR factories, both of which are largely uncertain. In power systems of large penetration of variable renewables, the system integration costs become increasingly significant, to the effect that more complex metrics are needed. The system integration costs for variable sources consist in the extra balancing costs, profile costs, and grid costs incurred because of variability. They depend on the characteristics of the power system. The U.S. EIA also uses a metric called **LACE** (levelized avoided cost of electricity), which captures a given power plant's value to the power grid. "A generator's avoided cost reflects the costs that would be incurred to provide the electricity displaced by a new generation project as an estimate of the revenue available to the plant." EIA calculates LACE "based on the marginal value of energy and capacity that would result from adding a unit of a given technology to the grid as it exists or as we project it to exist at a specific future date." The two metrics provide together a sound basis of comparison for the economic value of various technologies.

10 SMR designs are presented, which have various degrees of relevance for the Romanian nuclear market: NuScale VOYGR-6, GE-Hitachi BWRX-300, Holtec SMR-160, Terrapower Natrium, X-Energy's Xe-100 HGTR, UNSC MMR, CANDU SMR, Last Energy PWR-20, Rolls Royce SMR – as well as the Romanian R&D project ALFRED. The assessment criteria and scoring have been borrowed and adjusted by CATF from the NEA's SMR Dashboard, with weighted scores assigned for each design, to assess those that are nearest to deployment.

The NuScale VOYGR-6 design came out on top among the LWR-PWR reactors, due to its maturity in terms of design and licensing – indeed, the most advanced SMR design anywhere considering its certification of design with NRC, and robust governmental support. Of the Gen

IV reactors, Terrapower Natrium scored highest due to its siting, finance, and supply chain maturity, with a project under development in Wyoming (U.S.).

The **POLICY RECOMMENDATIONS** are grouped in three clusters.

(i) **Improving the licensing process for SMRs**

The Romanian nuclear program has been built around the heavy water CANDU technology, based on natural uranium. The regulator will have to create expertise and institutional capacity to deal with the new generation of LWR-PWR reactors.

International cooperation for the harmonization of licensing regimes should be pursued by the nuclear regulators – multilateral licensing coordination, bilateral collaborations, and joint safety evaluations. At EU level, a framework of **joint pre-licensing reviews** for the pro-nuclear member states would go a long way. The EU should consider the creation of guidelines of best practices for SMRs, as well as joint regulatory or pre-licensing reviews among regulators on a single advanced reactor design.

The EU should establish a **license-by-testing system** (***sandbox***) – a designated area for reactors designers to conduct full-scale testing under regulatory oversight. Also, an **International Technical Support Organization** (ITSO) for SMRs should be established to assist the national regulators in terms of know-how on license applications for construction, operation, and training.

(ii) **Improving governmental policy in the nuclear sector**

A ***FOAK demonstration plant*** will be important for operational learning on the new technology, and in paving the way for investments in further units, as well as in the supply chain.

Assessing the necessary workforce for SMR development in Romania**.** The government should identify the resources, training and skills needed to enable the development of SMRs in Romania.

Support of R&D and nuclear manufacturing capabilities**.** SMRs will require a new momentum for R&D, with needed advances in the reactor materials and fuel technologies (including reprocessing). The **EU should support nuclear R&D hubs** in the pro-nuclear member states to mobilize the existing expertise and to develop new capabilities required by modular and standardized manufacturing processes. Such hubs will have a critical role in attracting a new generation of specialists in the nuclear higher education and R&D projects.

Romania should engage with the European Commission and other member states to create **Centers of Excellence for Advanced Manufacturing on Nuclear Research**. The coordination of the nuclear supply chain would encourage investment, strengthen capabilities, and contribute to technological innovation, and fulfillment of the clean energy goals.

Creating a CfD scheme for SMRs at the national level, in order to support financial de-risking (at least for FOAK units). To support manufacturers of nuclear components and equipment, as well as service providers, the government may use **state aid**. International partnerships among technology developers and manufacturers, on the one hand, and research and educational institutions, on the other hand, must be supported, alongside coordination to harmonize codes and standards.

The Romanian authorities should be more **transparent** about the nuclear planning process. The public knows little about the economics of the plans for the construction of Units 3 and 4 at Cernavodă, as well as about the financial model behind the NuScale SMR project in Doicești.

Transparency can be improved by launching **clean transition dialogues** to promote best practices and solutions, bring new business and collaboration opportunities, and help the government identify and reflect on possible gaps to implementation, and further build the SMR business model informed by industry needs.

Public engagement requires attention and involvement from government and companies alike. Public engagement can benefit from international collaboration, with information exchanges on best practices and lessons learnt. Public engagement with local communities should not be a merely perfunctory exercise, but a patient and comprehensive involvement, based on knowledge of the communities' habits, traditions, and concerns.

(iii) **Reducing the costs of new nuclear power plants**

To mitigate cost escalation, Buongiorno et al. (2018) recommend serial manufacturing in standardized plants, incorporation of passive safety measures in the reactor design, and a focus on proven project management. These are intrinsic features of SMRs, which may well be capable of delivering diminishing costs for the NOAK plants, although this should not be taken for granted.

A more actionable recommendation aimed at cutting down SMR costs is the creation, at EU level, of a **Joint Platform for SMR Procurements**, ideally under the coordination of the Commission, to address the challenges of fragmented demand and limited economies of scale in the nuclear industry. The platform would coordinate technology acquisition by centralizing demand, consolidating requirements, and negotiating with the technology developers around a common SMR design, of which multiple units would be built across the continent. A unified orderbook among several or all pro-nuclear EU member states would support a scale of SMR demand needed to drive the industry into a mode of standardization and factory-based manufacturing. This would be a significant contribution to the cost reduction of SMR projects.

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About EPG

Energy Policy Group (EPG) is a non-profit, independent think-tank specializing in energy and climate policy. EPG does evidence-based policy analysis on the decarbonization of the energy, industry, buildings and transport sectors. Its geographical focus is mostly the European Union and Southeast Europe, yet its analyses are informed by the global market, technology, and geopolitical trends. EPG is based in Bucharest, Romania, where it was founded in 2014.

About CATF

The Clean Air Task Force (CATF) is a global environmental non-profit organization that works to accelerate the transition to a clean energy economy. CATF's experts develop and advocate for policies that reduce and regulate emissions that are harmful to people and the planet, and they work to enable the development, deployment, and commercialization of critical carbon-free technologies. CATF is headquartered in Boston, MA, USA, with offices in Europe and staff around the world.

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