



Should Brazil Invest in Small Modular Reactors?

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1. Introduction

Brazil has one of the most diverse energy matrices in the world, with the majority being renewable, representing 88% of the matrix and hydro being 64% in 2022 [1]. The importation of electricity is almost exclusively through the bi-national hydroelectric dam of Itaipu [2]. In 2021, 44,8% of energy in Brazil was renewable compared to 14,7% globally, and 84,8% of electricity was renewable compared to 28,1% globally [3]. The reliance on water for electricity can represent a risk for the grid in years of low volumes of rain [4].

Most Brazilian energy consumers are connected to the National Integrated System (SIN), which could be seen as a giant energy “highway” that connects a big part of the territory. Those that aren’t connected to the SIN, have an Isolated System (IS), mostly in the Amazon region [5]. There are 212 IS’s and they represent less than 1% of the electricity consumption of Brazil. Most of their energy comes from diesel oil (ONS, 2024) [6]. The National Operator of the Electrical System (ONS) [6] is responsible for the coordination and control of the generation and transmission in the SIN and operational planning of the isolated systems.

More than 80% of electricity demand in Brazil is for the industrial, residential, and commercial sector [7]. Despite the diverse electric matrix, both generation and demand through the National Integrated System (SIN) are uncertain due to the hydrological risk. This is due in turn to climatic risk that can negatively affect hydroelectricity production in years of low precipitation. The Generation Scaling Factor (GSF) is the measurement of this risk [8].

The Department of Economic and Social Affairs of The United Nations has gathered a global action plan called Agenda 2030 with 17 Sustainable Development Goals (SDGs) [9]. It was created to eradicate poverty

and promote human dignity without compromising the lives of this and future generations. Among the SDGs, the seventh is related to clean and affordable energy, that is, countries must ensure access to sustainable, reliable, and modern energy sources for the entire population.

The Brazilian nuclear program started after World War 2 with United States president Dwight D. Eisenhower's support, under the “Atoms for Peace” program. In the 70s [10], Brazil made a deal with West Germany to construct nuclear reactors, including the technology transfer to enrich uranium. The first nuclear power plant, Angra 1, began construction in 1972, with Westinghouse's technology and commercial operation began in 1985. The second, Angra 2, began construction in 1976 and commercial operation in 2000 [11]. Brazil has the 8th biggest uranium reserve in the world [12]. Nuclear represents a small part of Brazil's electrical matrix but has the potential to be a bigger low carbon alternative [13].

The nuclear sector is developing new technologies, including the Small Modular Reactor (SMR). SMRs have a capacity of up to 300 MWe per unit. This represents up to one third of the capacity of traditional nuclear reactors. Many advantages of SMRs are in their design, small and modular—small compared to a traditional reactor and modular as they are assembled in a factory and transported as a unit to the installation point. They offer better cost/benefit compared to a traditional reactor due to lower upfront cost and construction time. They can be used in remote regions and are primarily a base energy. SMRs also need less fuel, so they are refueled less frequently, every 3 to 7 years, compared to 1 to 2 years for a traditional nuclear plant. Some SMRs are even projected to operate up to 30 years without refueling. A big challenge of remote areas' access to electricity is the infrastructure cost to connect them to the grid [14].

The management of SMRs is simpler. The security process is more passive, with no human intervention needed to shut down the system. This means significantly less chance of radioactive emission in the environment and for the population. SMRs, like all nuclear power plants, have unique traits in efficiency, economy, and flexibility. Nuclear reactors are among the dispatchable energy sources, meaning they can adapt the production to the demand, contrary to some renewables such as wind and solar, that depend on external factors [14].

The main goal of this research is to present the reasoning as to whether Brazil should invest in the applicability of SMRs for its electric matrix. To achieve this goal, it's necessary to complete the following secondary objectives:

- Present the advantages and disadvantages.
- Correlate with other energy sources.
- Contextualize the global context of sustainability and energy security.

2. Methodology

This research is classified as exploratory in terms of its objectives, and in terms of its methods, it is substantially a bibliographic and documentary work.

For the elaboration of the bibliographic and documentary research, the systematization was done with a search string to organize the national and international reference databases of subjects that are published in books, journal articles, events, and theses, namely: IAEA, EPE, Google Scholar, Aneel, ONS, and others.

3. Results and Discussion

According to Adriano Pires, PhD in Economics at Université Paris 13, and professor and researcher at Federal University of Rio de Janeiro (UFRJ), climatic conditions can make Brazil's electric matrix very vulnerable, and the demonization of thermic generation in favor of renewables can be irresponsible. He thinks that Brazil's

electric matrix needs to be diversified to be reliable. 64% of electricity generated in Brazil is hydro [15]. One alternative to lower this dependency on rain is SMRs.

Despite not yet being a consolidated technology, and so lacking validation and economies of scale, there are already cost estimates that can be comparable or even lower than those of the large existing reactors [16].

Due to the increase of renewable sources, adjusting the supply to meet the demand is becoming more complicated for the operator. SMRs have the potential to balance the irregular energy supply from wind and solar [17]. Today this is done with polluting thermals that are also activated in periods of drought [18].

Likewise, SMRs can be used to balance intermittent power supply, or they can serve as base load power or both. This reduces vulnerability to weather conditions, water, sun, and wind, and gives more control to the National System Operator (ONS). By increasing the contribution of the nuclear source with SMRs, the CO₂ reduction target is also met. Furthermore, SMRs can be built closer to consumer centers, which reduces large investments in transmission. Moreover, SMRs have an economic characteristic similar to renewables: high initial investment but low operational cost.

Currently, according to the IAEA [19], more than 80 commercial SMR projects are under development, aiming at various results and applications, such as: electricity, hybrid energy systems, heating, water desalination, and steam for industrial applications. The Akademik Lomonosov, from Russia, was the world's first floating nuclear power plant, generating energy from two 35 MWe SMRs and started commercial operation in 2020. Other SMRs are in the licensing phase in South Korea, China, the United States, Argentina, and Canada.

Brazil, as one of the few countries with know-how in nuclear technology, should focus its efforts on opening the market for investment in the nuclear area.

In regions like the North of Brazil, where there is a lack of transmission networks or the transmission networks have restricted capacity, SMRs can be installed on an existing network or off the grid, directly on the load, due to their low energy production, providing energy with low greenhouse gas content, both for industry and for the population.

Finally, SMRs can help with achieving the goal of universal access to energy, SDG 7, because even though the country has a renewable energy matrix and an efficient interconnected system, gaps still prevail, especially in remote and difficult-to-access regions.

4. Conclusions

The reliability of a nuclear energy supply, throughout the year, regardless of the season, as well as its ability to be generated in any territory, the potential for large-scale production, in addition to being a source with low carbon emissions, places it in a fundamental role in sustainability and energy security. The energy supplied by SMRs can be classified as clean, reliable, and affordable energy. Furthermore, SMRs can serve as a backup energy source in emergency situations, replacing coal or diesel power generators. For these reasons, Brazil should invest in SMRs for reliable energy, mainly in isolated systems.

This paper suggests as a recommendation for future studies the effective applicability of SMRs in isolated systems.

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