



Risk Analysis in the Installation of Small Modular Reactors in Energy Poor Regions in Brazil

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1. Introduction

This work aims to provide a qualitative analysis of the implementation of Small Modular Reactors (SMRs), which are small, for energy-poor regions in Brazil. The author examines the challenges and risks associated with this implementation, with a special focus on risk analysis for implementing this type of reactors. For risk analysis, the 5W2H methodology is used in this work [1,2]. Conclusions include recommendations for future investigations and actions aimed at promoting the safe and efficient implementation of SMRs in energy-poor regions of the country.

2. Methodology

This work aims to carry out the following steps:

1. Analysis of temporal factors to understand the practicality and speed of implementing SMRs projects;
2. Use of the 5W2H methodology to implement risk management strategies in a project or process. The 5W2H methodology is divided into seven questions, 5 questions being What, Why, When, Where and Who and 2 questions How and How much [1];
3. From the literature, the main SMRs of the Pressurized Water Reactor (PWR) type that are being developed in the world were identified;
4. A bibliographic survey was carried out to choose the location (Where), such as: reports generated according to the EPRI Siting Guide model and the results of computer programs using Fuzzy methodology to identify ideal locations for building a nuclear power plant in an energy-poor region in Brazil with regard to risk analysis of SMRs in Brazil [3];
5. Methodologies for analyzing risks and environmental impacts were studied, such as checklists, interaction matrices, quantitative methodologies and scenario projections;
6. The analysis began by answering the questions from the 5W2H methodology.

These steps are being carried out and various aspects of the research, from understanding the factors that influence the construction schedule of SMRs to identifying ideal locations for the construction of nuclear power plants, covering risk management and environmental impacts.

3. Results and Discussion

From the literature, some PWR type SMRs were identified, which are more promising for being installed in needy regions of the country, as can be seen in Table I [4].

Table I: Some SMRs in development around the world

Project	Power (MWe)	Modules	Type	Projec	Country	Status
Water-Cooled Thermal Reactor Modules - SMRs						
CAREM	30	1	PWR	CNEA	Argentina	Under Construction
SMART	100	1	PWR	KAERI	Korea	Certified
ACP100	125	1	PWR	CNNC	China	Under Construction since 2019
UK SMR	450	1	PWR	Rolls Royce	UK	Concept
Multi-Module Water-Cooled Thermal Reactors - SMRs						
NuScale	77	12	PWR	Power United	USA	Certified. Approve Project by NRC USA in August 2020
Mobile Water-Cooled Thermal Reactors - SMRs						
ACPR50S	60	1	Floating PWR	CGN	China	Under Construction
KLT-40S	35	2	Floating PWR	OKBM Afrikantov	Russia	Comercial Operation

Some of the results of the analysis for implementing SMRs in remote regions of the country were studied, that is, one of the questions of the 5W2H methodology was answered, which was the “Where?” question: In the context of installing small modular reactors (SMRs) in energy-poor regions in Brazil, the question of “Where?” is a critical consideration. This involves identifying optimal locations for nuclear power plants, taking into account factors such as the Human Development Index (HDI) and the availability of natural resources. The selection of an appropriate site is necessary for ensuring both the safety and efficiency of the plant [1, 2, 5].

Addressing this question is part of a broader effort guided by the Electric Power Research Institute (EPRI) Siting Guide, with insights from Barros et al. (2021) and Mariz (2015). The implementation process includes a Nuclear Site Selection conducted by Eletronuclear, aligned with the Concepts and Criteria of the EPRI Siting Guide. A decision tree framework is employed, encompassing exclusion and evasion criteria, generation of candidate regions, and potential locations of interest in the initial phases. Subsequent stages involve suitability criteria, weights, and utility functions, all aimed at determining the optimal site for nuclear plant investment, and that create a list of possible sites for the construction [3].

A pivotal aspect of this process is a 2007 survey conducted by Eletronuclear, utilizing the Fuzzy Logic method to analyze and apply the EPRI Siting Guide criteria. This survey identified forty candidate areas for the upcoming implementation phase. The study advanced with an on-site analysis of the selected location, resulting in the exclusion of areas based on predefined criteria and producing a map with four potential regions. Eletronuclear's research specifically focused on validating a viable area in Pernambuco, notably pinpointing the Itacuruba region as a promising location for a nuclear power project. Field surveys were carried out, with Eletronuclear teams receiving support from COPPE/UFRJ-Garta and engineer Paul Rizzo, who recommended

the region for the new project. Years later, they carried out the same research in a region of the state of Alagoas. This new research shows four regions where a nuclear power plant can be installed in the state of Alagoas; these locations can answer the question “Where?” as seen in Figure 1 [3, 5].

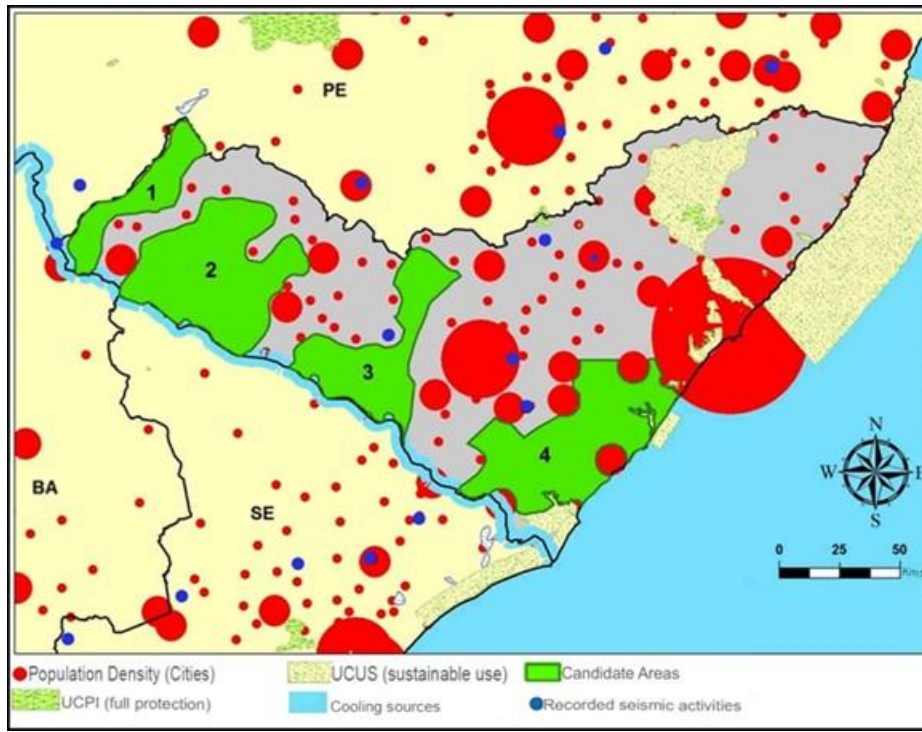


Figure 1: Areas of possible construction and exclusion zones.

Beyond the national sphere, the involvement of key entities such as Nuclebrás Equipamentos Pesados S/A (NUCLEP), affiliated with the Ministry of Mines and Energy, is instrumental. NUCLEP plays a pivotal role in the production of complex components and structures for nuclear reactors. Additionally, companies like Eletronuclear, Westinghouse, and NuScale Power Corporation are actively contributing to the development and provision of SMR technology for Brazil.

This exploration of the "Where?" question, pivotal for the success of SMR implementation in energy-poor regions in Brazil, sets the stage for further in-depth analysis. These questions, integral to the broader considerations of nuclear plant deployment, will be thoroughly examined in the final stages of the ongoing this work.

4. Conclusions

In this work, it was verified that the installation of SMRs in energy-poor regions of Brazil is viable, as it was observed that some of the convenient locations are in Alagoas, as long as appropriate measures are adopted to mitigate the risks associated with nuclear technology, thus answering the question "WHERE"? The research was also based on the importance of site selection for the construction of nuclear plants, considering factors such as the Human Development Index (HDI) and the availability of natural resources. Overall, the in this work concludes that the installation of SMRs in energy-deprived regions of Brazil can be a viable and sustainable solution for electricity generation, provided appropriate measures are taken to ensure safety and minimize environmental impacts.

The next steps of the research aim to answer the other questions of the 5W2H methodology, which are under development.

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References

- [1] G. B. de Paula, “O que é 5W2H: reduza incertezas, ganhe produtividade e aprenda como fazer um plano de ação”, “<https://www.treasy.com.br/blog/5w2h/>” (2015).
- [2] M. H. Chang, W. S. Kim, and K. W. Seul, “Safety and regulatory aspects of the smart reactor,” Korea Institute of Nuclear Safety (KINS); Korea Atomic Energy Research Institute (KAERI) (2005).
- [3] C. F. Barros et al., “A Localização de Sítios Nucleares baseado no Modelo EPRI Siting Guide e o Desenvolvimento de uma nova Central Nuclear: Uma Oportunidade”, Brasil: Garta; COPPE/UFRJ e LABRISK (2021).
- [4] International Atomic Energy Agency (IAEA). “Advances in small modular reactor technology developments 2018. Advanced Reactor Information System – ARIS”, Vienna (2018).
- [5] Empresa de Pesquisa Energética (EPE 2020), “Plano Nacional de Energia 2050”, “<https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-563/Relatorio%20Final%20do%20PNE%202050.pdf>” (2020).
- [6] R. Queiroz, “O setor elétrico brasileiro: caminhando por interesses que afetam a segurança de abastecimento”. Ilumina. “<http://www.ilumina.org.br/o-setor-eletrico-brasileiro-caminhando-por-interesses-que-afetam-a-seguranca-de-abastecimento/>” (2020).
- [7] B. M. Boldon and P. Sabharwall, “Small modular reactor: First-of-a-Kind (FOAK) and Nth-of-a-Kind (NOAK) Economic Analysis,” Idaho National Lab. (INL), Idaho Falls, ID (United States). “<https://www.osti.gov/biblio/1167545>” (2014).
- [8] M. D. Carelli et al., “Economic features of integral, modular, small-to-medium size reactors,” Progress in Nuclear Energy, vol. 52, no. 4, pp. 403–414 (2010).