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# Analysis of the SWOT matrix as a strategy for implementing the Ap-Th1000 Reactor in Brazil

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**Abstract**: This article analyzes the SWOT Matrix for the implementation of the AP-Th1000 reactor with thorium fuel, aiming at a future replacement of the current nuclear reactors that use uranium as fuel by thorium. There was a need for an in-depth study of the national and international literature linked to the Brazilian reality. After that, specific meetings were held to detect all possible situations of the 4 main points of the SWOT matrix. During the sessions, which averaged 1 hour, the authors' industrial and academic expertise was demonstrated in competencies such as creativity, collaboration, effective communication, openness and tolerance, quick thinking, synthesis ability, problem focus, and flexibility during the discussions of over 50 items found in the analysis of the 4 points of the SWOT matrix. Each meeting was divided into three parts. The first part, which would be the Creative phase; and a second part, which would be the Critical phase; and, finally, the third phase, where ideas are filtered for the permanence of those that were better founded and of better acceptance. Then, the aspects listed were classified into 4 categories: Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T). After the classification, a ranking of priorities was made, in descending order of importance, according to the authors, of the weaknesses and threats, neutralization suggestions were made. Finally, the data obtained were analyzed. We concluded through the SWOT analysis, we can observe an expressive amount of benefits of using the AP1000 reactor with MOX of Thorium and Uranium in the development of nuclear energy generation technologies in Brazil.

**Keywords:** ApTh-1000, Thorium, SWOT matrix.

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# Análise da matriz SWOT como estratégia para implantação do Reator Ap-Th1000 no Brasil

**Resumo**: Este artigo analisa a Matriz SWOT para a implementação do reator AP-Th1000 visando a substituição futura dos reatores nucleares atuais que utilizam urânio como combustível por tório. Houve a necessidade de um estudo aprofundado da literatura nacional e internacional adaptada à realidade brasileira. Posteriormente, foram realizadas reuniões específicas para detectar todas as situações possíveis dos 4 pontos principais da matriz SWOT. Durante as sessões, que tiveram uma média de 1 hora, a expertise industrial e acadêmica dos autores foi demonstrada em competências como criatividade, colaboração, comunicação efetiva, abertura e tolerância, pensamento rápido, habilidade de síntese, foco no problema e flexibilidade durante as discussões de mais de 50 itens encontrados na análise dos 4 pontos da matriz SWOT. Cada reunião foi dividida em três partes: a primeira parte, que seria a fase Criativa; a segunda parte, que seria a fase Crítica; e, finalmente, a terceira fase, onde as ideias são filtradas para a permanência daquelas mais bem fundamentadas e de melhor aceitação. Em seguida, os aspectos listados foram classificados em 4 categorias: Forças (S), Fraquezas (W), Oportunidades (O) e Ameaças (T). Após a classificação, foi feito um ranking de prioridades, em ordem decrescente de importância, segundo os autores, das fraquezas e ameaças, foram feitas sugestões de neutralização. Por fim, os dados obtidos foram analisados. Concluímos por meio da análise SWOT que podemos observar uma quantidade expressiva de benefícios do uso do reator AP1000 com MOX de Tório e Urânio no desenvolvimento de tecnologias de geração de energia nuclear no Brasil.

**Palavras-chave:** ApTh-1000, Tório, Matriz SWOT.

## 1. INTRODUCTION

In 2021, Brazil experienced a severe water crisis attributed to climate change, a consequence of global warming. This crisis manifested in a scarcity of water for human consumption in the metropolitan regions of the Southeast and South of the country.

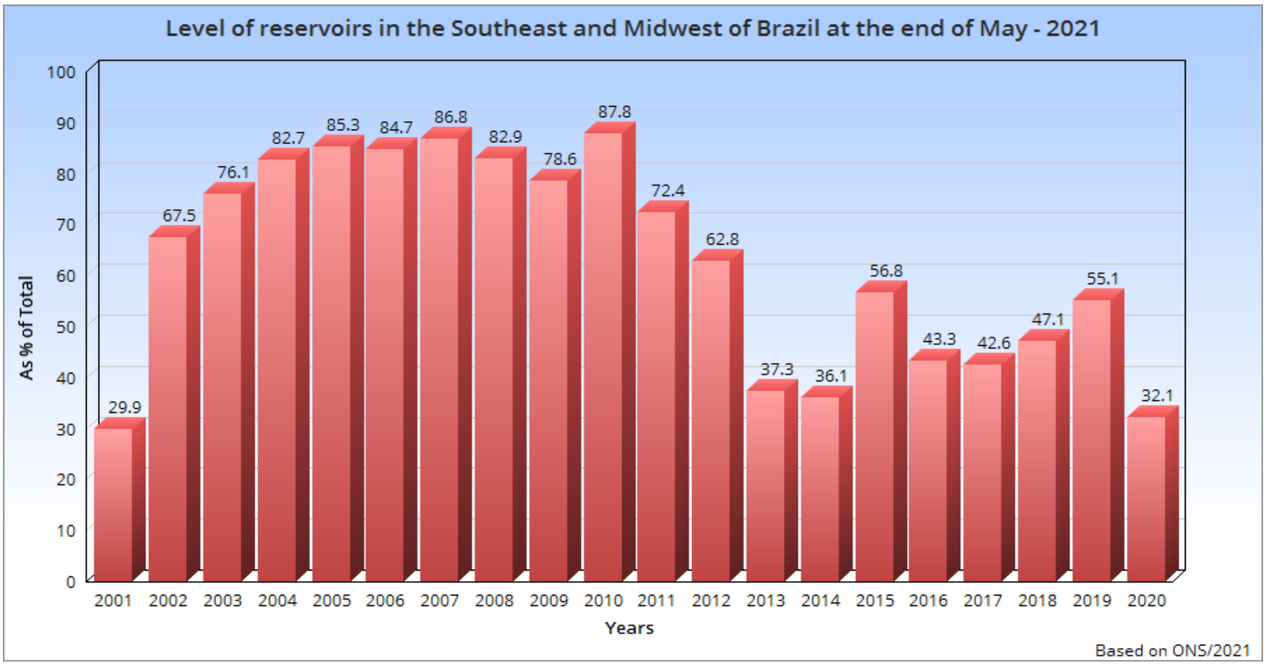
In response to the water shortage, Brazilian government authorities opted to increase energy generation in thermoelectric plants, resulting in elevated greenhouse gas emissions and contributing to global warming. To mitigate the impact, Brazil also imported electricity from neighboring countries. Consequently, this crisis prompted a tariff hike in electricity consumption, affecting the entire interconnected Brazilian Electric System.

As we can see in Figure (1) which shows the level of reservoirs between 2001 and 2021 in the Southeast and Midwest, in May 2021, it reached one of the lowest levels in 20 years. Demonstrating a weakness that directly affects the production of electricity by this energy matrix.

This vulnerability of hydropower production has intensified due to climatic variability associated with changes in rainfall patterns, making these situations more frequent.

In light of these considerations, the pursuit of a diversified and balanced energy matrix becomes essential. Combining renewable sources such as solar and wind with more stable energy sources like nuclear can provide a more resilient and sustainable approach to meet growing energy demands. It is crucial that decisions regarding the energy matrix take into account not only efficiency and stability but also the environmental impacts and risks associated with each energy source.

**Figure 1**: Level of reservoirs in the Southeast and Midwest of Brazil at the end of May 2021




Source: Based on ONS/2021

Energy is part of the production costs of everything; therefore, the competitiveness of the industry depends on energy tariffs. It is noteworthy that the survival of the industry relies on competitiveness, and people depend on jobs in the industry. The lack of jobs impoverishes people, and impoverished individuals often migrate to other countries. In this way, we visualize the interconnection of uninterrupted electricity production with competitive tariffs.

In light of these considerations, the pursuit of a diversified and balanced energy matrix becomes essential. Combining renewable sources such as solar and wind with more stable energy sources like nuclear can provide a more resilient and sustainable approach to meet growing energy demands. It is crucial that decisions regarding the energy matrix take into account not only efficiency and stability but also the environmental impacts and risks associated with each energy source. Among several actions necessary to increase energy generation in the country, nuclear power plants are an option, due to their high potential for energy conversion [1].

Nuclear reactors work independently of the weather and generate energy continuously at any time of the day or night. Different from the energy matrix based on water, wind, and solar resources, which generate electricity intermittently and are dependent on climatic variations.

Brazil has one of the largest reserves of nuclear material (uranium and thorium) in the world, in addition to mastering the technology for extracting and processing the corresponding ores; uranium enrichment; Conversion; Production of Tablets; Assembly of the Fuel Element; and generation of electric energy via nuclear power plants, as seen in Figure (2).

The uranium enrichment technology, through the ultracentrifugation process, was developed in Brazil by the São Paulo Navy Technological Center (CTMSP), in partnership with the Institute for Energy and Nuclear Research (IPEN / CNEN).

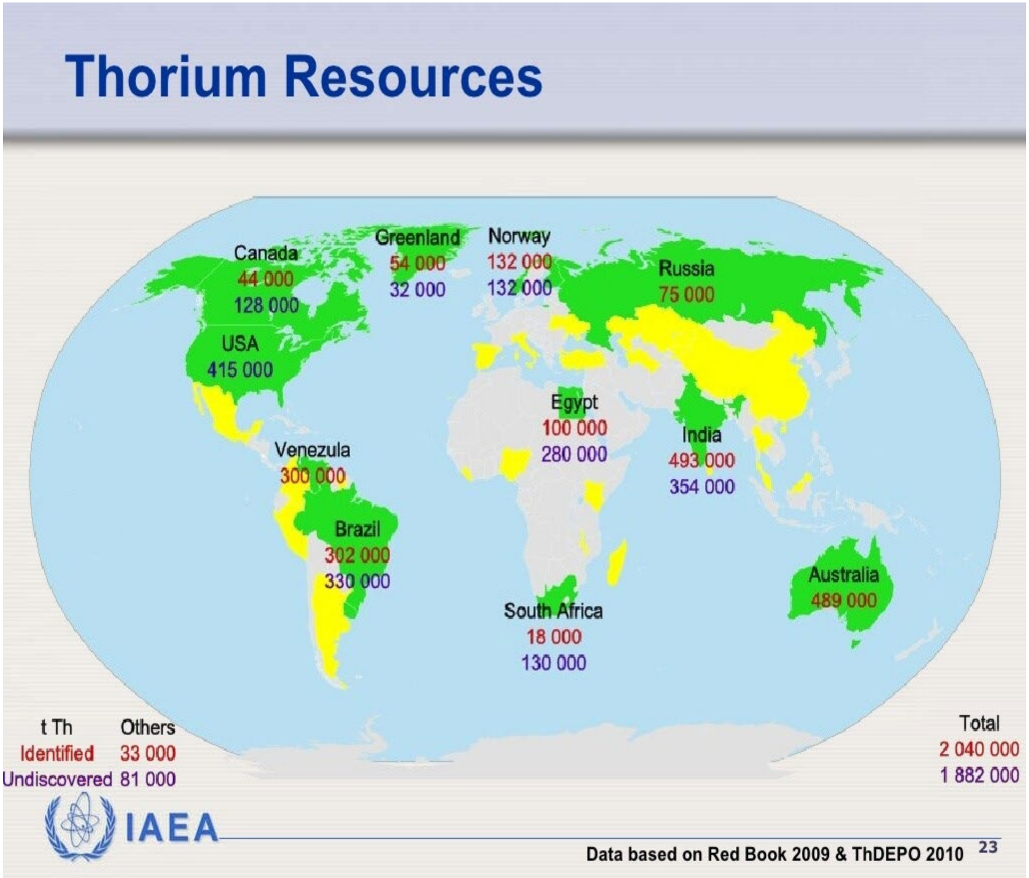
The Uranium Enrichment Plant is being implemented in stages at the Nuclear Fuel Factory (FCN), located in Resende, Rio de Janeiro. A large part of the enriched uranium is still imported to serve the Angra 1 and Angra 2 plants. In November 2021, with the inauguration of the 9th cascade, belonging to Module 4, the FCN Enrichment Plant reached the capacity to produce 65% of the average annual quantity of enriched uranium needed to supply Angra 1. To date, Brazil is not self-sufficient in the production of enriched uranium [2].

**Figure 2:** Nuclear Fuel Cycle.


Source: Thorium fuel cycle in VBER reactor for floating nuclear power plants.

In Figure (3) we observe the main deposits of Thorium around the world. Among the actions needed to increase energy generation, nuclear power plants is an option. Currently, for the generation of electric energy, most of the nuclear reactors in operation in the world use uranium as a fuel element, which is enriched in $^{235}$U. However, recent studies show that the current uranium reserves are already in insufficient quantity to meet the current demand, and the production is about 60,000 tons per year, while about 70,000 tons are consumed per year [3]. Among the alternatives to replace the $^{235}$U is the $^{233}$U, through the use of thorium. For example, according to the International Atomic Energy Agency (IAEA) report in 2020, world uranium reserves totaled around 7.6 million tons, with the majority located in Kazakhstan, Canada, and Australia. However, many of these reserves are considered difficult to extract, which may make uranium availability limited in the future [4].

**Figure 3**: World Nuclear Fuel Cycle.




Source: Based on Red Book 2009 & ThDEPO 2010

The demand for uranium is mainly driven by nuclear energy generation. According to the World Nuclear Association (WNA), global uranium demand in 2020 was around 65,000 tons, with the majority used as fuel in nuclear power plants to generate electricity. The demand for uranium is influenced by the expansion of the nuclear energy sector worldwide, especially in countries like China, India, and Russia, which are increasing their nuclear energy generation capacity [5]. Some projections indicate that demand for uranium may increase in the coming decades, especially if nuclear energy is expanded to achieve greenhouse gas emission reduction targets. However, other projections suggest that demand for uranium may decrease if renewable energy becomes more competitive and if other nuclear energy technologies, such as fourth-generation reactors, become more widely adapted [6]. The future prospects for uranium are uncertain and depend on many factors, including resource availability and demand for nuclear energy and other energy sources, like thorium.

Thorium, around the years 1940-1950, was the object of special interest in recovery from monazite. Since that time, the possibility of using thorium in the nuclear fuel cycle has been proposed [7]. Thorium is a dense silvery metal (11.7 $g/cm^3$), with a high melting point (1750°C). Practically, all thorium found in nature is in the form of its isotope 232. It is an element that has low radioactivity, not fissile, and can be transformed inside nuclear reactors into isotope U233. The incentives for the thorium cycle to be implemented arise from concerns about the large stocks of plutonium, and the consequent risks of proliferation, in addition to the possibility of reducing the amount of long-lived radioactive waste [8].

The U233 produced is usually contaminated with U232, an isotope that emits intense gamma radiation, making the handling and production of weapons more complex and dangerous. Obtaining pure U233 is challenging because the presence of other isotopes can compromise the effectiveness of a nuclear weapon. Its nuclear properties pose significant challenges in the design and manufacturing of efficient and reliable nuclear weapons.

On the other hand, reactors using U235 can produce plutonium as a byproduct, and the resulting plutonium-239 can be chemically separated from the irradiated fuel. Plutonium-239 is a common choice for nuclear weapons due to its efficient fission.

Since thorium is present in the earth's crust, in a 3:1 ratio in relation to uranium, this fertile property strengthens the possibilities of use as fuel in fourth-generation nuclear reactors, according to studies [9]. For this possibility to become a reality, it is necessary that, from the point of view of its extraction, recovery, and use in Brazil, the technology is accessible and the methods of production and use are appropriate to the country's reality.

## 1.1. The AP-Th1000 Reactor

The AP 1000 reactor was designed by Westinghouse Electric Company. It is a pressurized water reactor (PWR) with two cooling loops, designed to produce a net power of 1,117 MWe. This reactor comes from a simplification and increases in capacity compared to its predecessor the AP600, which had become an economically unfeasible project. We can see in Figure 4 the AP1000 Reactor. Due to the implementation of passive safety systems, the plant becomes easier to operate, and maintain, and with its construction being modular, we have advantages of transport and assembly. Uranium-235 is used as fuel. It is considered one of the most modern reactors of the current Generation III and is similar to the reactors already consolidated and used in Brazil for electricity generation [10]. It has an operating cycle of 18 months, and a lifespan of 60 years.

**Figure 4**: AP1000.

Source: https://en.wikipedia.org/wiki/AP1000

The AP-Th 1000 Reactor differs only from the use of mixed U-Th fuels [11]. It's a reactor design never built yet. The AP-1000 has been used as a reference PWR so that, by keeping the same geometry of the fuel elements, the same reactivity control system, the same operating cycle, and other characteristics, we could, through parametric computational modeling, operate with fuel based on a mixture of thorium and uranium oxides (Th, U)O2, instead of the traditional uranium dioxide, thus finding a better configuration of the fuel element, aiming at the reduction of long-lived actinides, especially plutonium, and to generate a stock of fissile $^{233}U$.

## 1.2. The SWOT matrix analisys

The SWOT Matrix analysis is a management tool whose main purpose is an assessment of scenarios before starting a project. The term SWOT is an abbreviation, in English, of the dimensions evaluated. Thus, there are strengths (S), weaknesses (W), opportunities (O), and threats (T). It is a tool to perform an analysis of the internal and external environments of an organization. This analysis is part of the preparation for Institutional Strategic Planning (PEI). Developed in the 1960s at Stanford University, the SWOT analysis still guides thousands of businesses around the world. Nowadays it is one of the classic and widely used methodologies in the strategic planning of companies or new projects [12].

In the matrix swot the "Strengths" and "Weaknesses" are placed, which deal with the factors that the company/project has control over, carrying out an internal analysis. The "Opportunities" and "Threats" address factors that the company/project has no control over, carrying out the external analysis. With this data, it becomes possible to identify which sets of Strengths and Weaknesses of the company or the project should receive attention and be worked on and what action can be taken to take advantage of the attractiveness of Opportunities and minimize the impact of Threats.

The methodology of SWOT matriz allows a specific evaluation for projects in different areas, serving as a basis for decision-making in general [12]. Therefore, it is a useful tool in the area of nuclear energy. In this work, a simplified form of the SWOT Matrix was used.

The SWOT matrix, as already mentioned, can be used to make decisions, direct strategic planning, observe vulnerable points and predict situations that neutralize weaknesses and threats [13-14]. Thus, from the perspective of the SWOT analysis in this work, it is intended to evaluate the strengths and weaknesses of the implementation of an AP-Th 1000 Reactor in Brazil, as well as to identify the threats to the project, anticipating the neutralization of the weaknesses and these threats.

## 2. MATERIALS AND METHODS

As a methodology for the present work, we initially highlight the qualitative character involved. Since the AP-Th 1000 Reactor does not exist in our country, there was a need for an in-depth study of the national literature, which involves (i) computational modeling, especially the international one of its main characteristics, (ii) linked to the Brazilian reality in relation to national policy, (iii) common sense of the nuclear area, (iv) territorial extension, (v) geographic location of nuclear plants, among other factors. Political influence was taken into account, mainly in decision-making common to the Brazilian reality in projects such as this one. During the sessions, which averaged 1 hour each, the authors' industrial and academic expertise, totaling more than 20 years each, demonstrated competencies such as creativity, collaboration, effective communication, openness, tolerance, quick thinking, synthesis ability, problem focus, and flexibility during discussions on over 50 items found in the analysis of the 4 points of the matrix.. Each meeting was divided into three parts from different periods. The first part would be the “Creative” phase, with the presentation of the greatest number of ideas and suggestions without worrying about analyzing or criticizing them; and the second part, which would be the “Critical” phase, where the authors, individually, justify and defend their ideas to convince the importance of each idea; and, finally, the third phase, where ideas are filtered for the permanence of those that were better founded and of better acceptance.

Then, the aspects listed were classified into four categories: Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T). In the original SWOT formulation applied to the world of business, Strengths are the advantages that can be controlled and do not depend on external factors. This can be identified, mainly, in the analysis of the differentials offered to the market, whether by the quality of service, the performance of marketing, finance, production, or the organization as a whole. Thus, we were able to identify points that reveal the organization's competitive advantage. Weaknesses are disadvantages relative to the competition that can be controlled internally. To discover the company's weaknesses, one can ask: What gaps and weaknesses can be found in the company compared to the competition? What is the qualification of people in the organization? What are the most frequent complaints? And any others that help to understand what can be improved in the internal environment. Opportunities are external forces that can positively influence and cannot be controlled by it. These are chances that the organization has to develop, grow and achieve better results. Some questions to ask when analyzing opportunities are: What trends are trending in our industry? What political, economic, or social conditions might be favorable? Are there technological innovations that we can adhere to? Threats are all external forces (which the company cannot control) that can negatively impact and reduce its performance. In the business context, it is very important that the organization recognizes the threats to which it is exposed and prepares itself to face them. Such as Economic crises, reduction of consumer credit limits, the emergence of new competitors, increase in taxes on imported inputs, reduction or suspension of tax incentives.

After the classification, a ranking of priorities was made, in descending order of importance, according to the authors, the following factors were taken into account as being of greater importance: (i) Weaknesses: high construction costs, political influence, and public perception of nuclear power as risky must also be taken into account. (ii) Threats: competition from other energy sources and regulatory changes are threats that must be considered to ensure the viability of the AP-Th 1000. (iii) Strengths: the abundance and safety of the fuel, the ability to produce large amounts of clean and reliable energy, energy security, and the ability to operate 24/7 are important strengths that should be maximized. (iv) Opportunities: diversifying the energy matrix, generating jobs, and the possibility of technology exportation are opportunities that can be exploited. Aspects referring to Opportunities can be analyzed in terms of their probability of success and their attractiveness to the direct and indirect objectives of nuclear power generation. In the case of "Threats", their probability of occurrence, severity, and impacts that could affect the daily activities of the AP-Th1000 reactor can be verified. The Weakness analysis aims to identify neutralization suggestions.

With this analysis, it is intended to take advantage of the Strengths in Opportunities that arise, using them to avoid Threats. It also aims to improve Weaknesses for the best use of Opportunities, aiming to eliminate Weaknesses and thus avoid threats.

## 3. RESULTS AND DISCUSSION

In a SWOT matrix, strengths refer to the positive points, internal advantages, or resources that an entity possesses. These are internal characteristics that provide a competitive advantage or contribute to the organization's success. Considering this, we arrived at the following results:

**Table 1:** Strength (S).

| RANKING | ASPECTS |
|---|---|
| 1. | Electricity generation is free of greenhouse gases. |
| 2. | Continuous, weather-independent electrical power generation |
| 3. | Generation of more fissile material than consumption (Breeder) |
| 4. | Reduced environmental impacts in the electricity generation sector |
| 5. | Possibility of meeting the three pillars of sustainability |
| 6. | The most secure and modern design of the current Generation III |
| 7. | Reactor with a long lifetime of at least 60 years |
| 8. | Reduced construction time due to modular construction |

Weaknesses refer to internal characteristics or limitations that may pose challenges or impediments to the effective performance of the organization. Identifying and understanding these weaknesses is crucial for developing strategies that address or mitigate these aspects. Considering this, we arrived at the following results:

**Table 2:** Weaknesses (W).

| RANKING | ASPECTS |
|---|---|
| 1. | AP-Th1000 has large complexity, increasing costs |
| 2. | Licensing Challenges |
| 3. | Geopolitical Risks |
| 4. | Lack of educated people. |
| 5. | Lack of practical research on APTh-1000 reactors in the country |
| 6. | Lack of a practical thorium fuel cycle route that is economically viable. |

Opportunities refer to positive external factors or conditions in the environment that an organization can leverage to gain a competitive advantage or achieve its objectives. Identifying and exploiting opportunities is essential for the development of strategies that can drive growth and success. Considering this, we arrived at the following results:

**Table 3:** Opportunities (O).

| RANKING | ASPECTS |
|---|---|
| 1. | Brazil has large reserves of thorium |
| 2. | Use of the thorium cycle in thermal reactors |
| 3. | Direct and indirect generation of jobs that would directly affect the country's economy |
| 4. | Recognition of the Federal Government in investing in the nuclear area |
| 5. | Recognition that the nuclear area is up to the Federal Government to legislate and not the states. |
| 6. | Existence of skilled labor due to advanced programs in the nuclear area in Brazil |
| 7. | Resumption of nuclear research and development in thorium in an institutional way. |

Threats refer to external factors or conditions in the environment that may pose challenges, risks, or obstacles to an organization. Identifying and understanding these threats is crucial for developing strategies that help minimize or effectively deal with these risks. Considering this, we arrived at the following results:

**Table 4:** Threats (T).

| RANKING | ASPECTS |
|---|---|
| 1. | Change in the current policy of encouraging the nuclear area due to the change of governments. |
| 2. | Financial cuts in the research area |
| | Increasing unpopularity of nuclear energy due to sensationalism by some media outlets |
| 3. | High source of neutrons for the production of fissile material. |
| | Relatively long time of the creation of fissile material due to the long half-life of radioactive intermediate material (Pa-233, 27 days) |
| 4. | External interference contrary to the development of the nuclear area in the country |

## 3.1. Critical analysis

As part of the characteristics of strengths, electrical energy from nuclear fission has many benefits. Unlike chemical energy, nuclear energy provides about one million times more energy per atom, produces zero greenhouse gas emissions, and enables power production independent of climate change. Nuclear fission is a type of chain reaction, as it is based on bombarding a stable nucleus with neutrons. This one, when it becomes unstable, breaks up and releases more neutrons that will destabilize other nuclei and make the process continue until there are no more free neutrons or stable nuclei, releasing a large amount of energy. For naturally occurring thorium, the fission cross section for thermal energy is zero (non-fissile material) and only fast fission is possible in thorium [15]. However, $^{232}$Th is a fertile material, which means that, while is not itself fissile (fissionable by thermal neutrons), it can be converted into fissile material by irradiation in a reactor Given the high neutron capture cross section by $^{232}$Th, it is possible to produce $^{233}$U which is fertile and which arises after two beta decays. Thus, thorium can produce $^{233}$U (fissile) when used as fuel or in fast reactor blankets [15].

In a nuclear generation, sustainability goals are focused on managing radioactive waste and making better use of nuclear fuel. Meeting sustainability goals includes providing a sustainable power generation system, replacing polluting energy sources, and promoting the effective use of nuclear fuel. This fuel must be extended to future centuries, through its recycling to recover the remaining energy. In addition, the reduction of the thermal load of the radioactive decay of the spent fuel in the repositories must be foreseen, increasing its storage capacity and shortening the time that it must be isolated from the biosphere. For this, the scientific analysis and safety demonstration of these repositories for very long times must be simplified, through a significant reduction in the lifetime and in the toxicity of residual radioactive waste sent to the repositories for final storage [16]. As already explained, these points mentioned here can be reached with the use of Radkowsky's seed-blanket together with the use of a mix of oxide thorium-uranium (MOX). With the possibility of making a PWR breeder reactor, energy efficiency can be achieved, which is an activity that aims to use energy sources more consciously, economically, and efficiently to obtain a more sustainable result. From an economic point of view, even including all costs in the tariff charged to consumers, nuclear generation is economically competitive with other forms of electricity generation, except where there is direct and low-cost access to fossil fuels. This competitiveness can be significantly altered if fees are charged for the emission of greenhouse gases from fossil fuel plants [17]. However, the use of thorium in reactors such as in the AP-Th1000 model tends to achieve these savings.

According to Kaur, G. et al [18], thorium can be used as a nuclear fuel in PWR reactors with advantages over the use of uranium and plutonium. Among the advantages, the higher fuel efficiency and lower generation of radioactive waste stand out.

The use of Thorium in nuclear reactors can reduce dependence on fossil fuels, as well as reduce the amount of nuclear waste generated [19]. In addition, the use of thorium fuel can increase fuel efficiency compared to uranium. This is because thorium is a fertile material and can be converted into $^{233}U$, which is a fissile material. $^{233}U$ can then be used to produce energy, which means that a greater amount of energy can be produced with the same amount of fuel compared to enriched uranium [20].

To complete the "sustainability tripod", it is necessary to carry out social projects throughout the assembly and operation of the nuclear plant.

The sustainability tripod, also known as the triple bottom line, is a framework that takes into account three dimensions of sustainability: economic, social, and environmental [21].

Here are 3 examples of social projects coordinated by nuclear power plants in 3 different countries: in Canada, Bruce Power, a nuclear power company in Ontario, has a community investment program that supports local charities and community organizations. In 2020, the program donated over $1 million to various organizations, including food banks, hospitals, and mental health programs [22], (ii) in South Korea, The Kori Nuclear Power Plant operates a social contribution foundation that supports local projects related to education, culture, and the environment. The foundation has funded projects such as a scholarship program for low-income students and a program to restore a local forest [23], (iii) in France, The Gravelines Nuclear Power Plant has a partnership with a local association that supports people with disabilities. The partnership includes a program that provides vocational training and employment opportunities for people with disabilities [24].

One can highlight the problems caused by the need of having a high neutron source required to produce fissile $^{233}$U from $^{232}$Th, (i) difficult and costly fuel fabrication for a potential close fuel cycle because of high gamma radiation, (ii) a relatively long time of $^{232}$Th breeding to $^{233}$U due to $^{233}$Pa half-life of 27 days [25] and (iii) need of many costly researches and licensing processes before starting industrial use and absence of them.

Regarding the opportunities, thorium is found in a ratio of 3:1 [26]. On 10/28/2010, during a lecture at the XI International Seminar on Nuclear Energy – SIEN 2020, the then Minister of Mines and Energy, Bento Albuquerque, announced investments in the order of R$ 15.5 billion in the nuclear area. According to ADI1 6895 of 10/21/2021, by unanimous vote, the Federal Supreme Court (STF) declared the unconstitutionality of a provision of the Constitution of the state of Paraíba that prohibits the deposit of atomic waste not produced in the state and the installation of nuclear power plants in the state of territory. The unanimous understanding was that the state norm invaded the federal exclusive competence to legislate on nuclear activities. The decision was taken in the virtual session that ended on 9/14/2021 [27].

In Brazil, changes in the political scenario are common due to the country's presidential system of government, where the president holds a significant amount of power and can make executive decisions that affect the entire country. The president is elected for a four-year term and can be re-elected for another four-year term, but cannot serve for more than two consecutive terms.

This system of government can lead to frequent changes in the political scenario, as each new president may have different political priorities and policies that they want to implement. Furthermore, it is common sense that nuclear energy is unpopular due to sensationalism by some media.

While a simplified concept of the SWOT Matrix was used in this work, the present exercise could be improved by using other models, such as (i) simple SWOT matrix, which is the most common model of SWOT matrix, which divides the company's strengths and weaknesses into one column and opportunities and threats into another. The goal is to identify areas where the company can leverage its strengths to capitalize on opportunities, as well as areas where it needs to improve its weaknesses to avoid threats [28], (ii) quantitative SWOT matrix, this model uses quantitative techniques to evaluate the relative importance of each factor in the SWOT matrix. This can be done through market research, financial data analysis, and other data analysis techniques. The goal is to provide a more accurate and adjective analysis of the company's situation [29], (iii) Strategic SWOT matrix, this model is used to evaluate the company's strategic position in relation to its competitors and the market in general. The strategic SWOT matrix includes additional factors, such as marketing strategies and the company’s financial resources [30].

Also, there are some disadvantages of SWOT analysis: It is just a small step in the whole planning process. More complex investigations are required when making decisions.

It is difficult to address factors that are uncertain or that may be strengths and threats at the same time. It does not provide solutions or other alternatives. Thus, concomitantly with the analysis of the Swot Matrix, it is suggested that specific studies be carried out such as the economic-financial planning of the implementation of the AP-Th1000 reactor, technical studies on the feasibility of using thorium, the adaptation of current technologies in the nuclear area.

## 4. CONCLUSIONS

The weaknesses and threats can be overcome by extensive practical research of the AP-Th 1000 Reactor, finding an economically viable route, by the extensive dissemination through the media of the various benefits of electric energy generation by nuclear energy and the consequent awareness of governments and candidates at the national, state or municipal levels. All international measures in the nuclear area must also be followed transparently, leaving no doubt as to the peaceful nature of activities of the use of nuclear energy and reiterating the commitment to non-proliferation [31-32].

In this way, we concluded through the SWOT analysis, we can observe an expressive amount of benefits of using the AP-Th1000 in the development of nuclear energy generation technologies in the country, the emission of greenhouse gases, the development of the country's scientific knowledge, the generation of jobs and the consequent reduction of poverty in the country, to avoid rationing, increases in extra energy tariffs electricity. It's worth noting that energy is very expensive in Brazil, which means that Brazil is lacking in energy. The population is aging, and young people are preferring to work abroad. Therefore, unless the country provides better living conditions, which includes affordable energy, the economically active population may decrease drastically.

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## CONFLICT OF INTEREST

The authors declare that they have no competing interests to report.

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