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# THE POTENTIAL OF NUCLEAR ENERGY TO GENERATE CLEAN ELECTRIC POWER IN BRAZIL

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## ABSTRACT

The generation of electricity in Brazil is concentrated in hydroelectric generation, renewable and clean source, but that does not satisfy all the demand and leads to necessity of a suplementary thermal sources portion. Considering the preditctions of increase in demand for electricity in the next years, it becomes necessary to insert new sources to compplement the production taking into account both the volume being produced and the needs of environmental preservation. Thus, nuclear power can be considered a potential supplementary source for electricity generation in Brazil as well as the country has large reserves of fissile material, the generation emits no greenhouse gases, the country has technological mastery of the fuel cycle and it enables the production of large volumes of clean energy. The objective of this study is to demonstrate the potential of nuclear energy in electricity production in Brazil cleanly and safely, ensuring the supplies necessary to maintain the country's economic growth and the increased demand sustainably. For this, will be made an analysis of economic and social indicators of the characteristics of our energy matrix and the availability of our sources, as well as a description of the nuclear source and arguments that justify a higher share of nuclear energy in the matrix of the country. Then, after these analysis, will notice that the generation of electricity from nuclear source has all the conditions to supplement safely and clean supply of electricity in Brazil.

## 1. INTRODUCTION

Currently, power generation in Brazil focuses on production through hydraulic sources by hydroelectric plants. It is a clean and renewable source of energy; however, it cannot supply all the demand of electricity in today's country. Moreover, the available reserves from this source are dying off, making impossible the expansion of this source for the care and support of the country's growth besides the increasing demand for electricity.

It is also important to emphasize the dependence of this source on natural regimes. The maintenance of the reservoirs is dependent on rainfall patterns and rivers cycles. The natural systems have fluctuations between regions and the seasons and changes in climate can also affect these schemes. An event that proves this vulnerability occurred in 2001, when reservoir levels dropped and the plant did not support the demand for electricity, as a result a "blackout" happens and an energy program was implemented for the population.

A factor that also needs to be considered in planning the country's power plants is the fact of not being able to rely on a major expansion of hydropower due to the characteristics of water reserves that are still available. They are predominantly located far from large centers and consumers due to geographical factors, social and environmental is an impediment to the

construction of large reservoirs required for the operation of large dams. Many of these reserves are in regions such as Amazon or on Indian or environmental reserves. And the flooding of vast areas for the construction of reservoirs brings immeasurable damage to the therein systems.

This makes necessary to supplement the electricity generation in a way to assist the country that already needs and this needed portion is nowadays obtained mainly from thermal power plants.

The country has a predominantly clean energy matrix, based on renewable sources, but the trends of increased demand for the country's growth and also the trend of electrification in Brazil, with the entry of new users to the system, indicate that changes may be necessary to maintenance of this feature and still meet the entire energy needs.

Care must be taken with the sources used in thermoelectric that complement the production of Brazilian electricity for keeping a clean energy matrix and also to be assured that the quality and security of electricity supply in the country remain.

Considering these facts, and also the growth projected in demand for electricity in the country in the coming years, it becomes necessary to increase the use of alternative energy sources to supplement the production of the country's electricity cleanly, of greenhouse gases into the atmosphere, thus with the purpose of meet the current and future needs of the country taking into account both the volume of electricity to be produced needs preserving the environment and reducing the emission ensuring the supply and maintenance of growth the country.

Alternative sources of energy need to be more explored in Brazil, as the country has a privileged situation in this area. The thermoelectric generation technologies are already economically viable and this is an option proposed in adhering to sustainable development.

In this context, nuclear power can be considered the most potential source for the generation of electricity in Brazil, since in addition the country has large reserves of fissile material to generate electricity from this source which does not emit greenhouse gases, contributing positively to the preservation of the environment. In addition, the country has the technological mastery of the nuclear fuel cycle which allows the sustainable use of nuclear energy.

The aim of this study is to demonstrate the nuclear potential as a source of electricity in Brazil, as a clean and safe option, ensuring the necessary supply to maintain the country's economic growth and the increasing demand for electricity in a sustainable manner.

## 2. METHODOLOGY

To achieve the objective of this research, it will be studied the characteristics of the Brazilian energy matrix and the availability of energy sources. It will be analyzed some economic parameters and social indicators related to supply and demand of electricity and development. In addition, there will be a brief description of a thermonuclear and discuss some of the main arguments that justify a higher share of nuclear in electricity generation in the country.

Figure 1 details the domestic supply of electric power in Brazil in 2011. This source occupies 81.7% of the offering. The total supply of electricity in Brazil reached 567.6 TWh added to the net imports. This year, the country's electricity production reached 531.8 TWh whose main source was the hydro, as said before. Adding to the domestic supply the renewable sources imports, it can be said that 89% of Brazil's electricity comes from renewable sources [1].

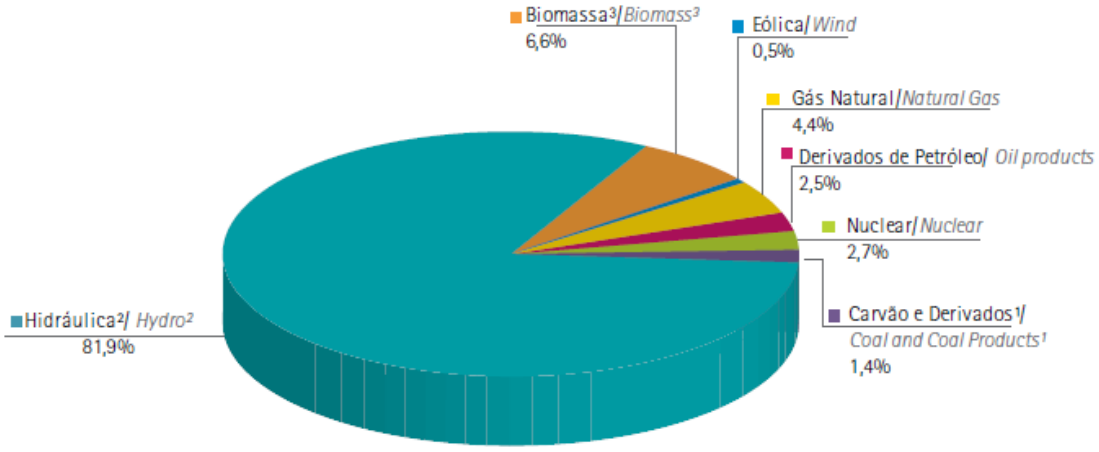


**Figure 1: Domestic supply of electricity by source [1].**

This heavy reliance on water source makes the electrical system vulnerable. This unit is based on the water potential energy in the plants and dams of the rivers, which makes the system dependent on the natural water cycle and depends for its renewal cycles between periods of dry and rainy seasons for the maintenance of reservoirs [2]. This fact brings the supply instabilities when longer periods of drought occur, making the national operator resorting to use the thermoelectric in these occasions to ensure supply.

It is also important to highlight the current barriers to the expansion of hydroelectric power generation in the country. The main available reserves are concentrated on Amazon. The topographical features of this region has no climbs between lowland Amazon and Central Plateau, which would require the flooding of an extremely wide area for storage water in dams. Moreover, the natural cycles in this region are the most severe country [2].

The share of electricity in the Brazilian economy is highlighted. The final consumption of electricity grew more than the domestic energy supply in the country. While electricity consumption increased by 3.3%, the total domestic energy supply grew by 1.3% to an increase in GDP of 2.7% [1]. These numbers reflect a trend of electrification of the country and show the need for increasing the supply of electricity, since consumption is not keeping growth supply and assure the supply of these consumers.

Projections indicate an increase in demand for electricity in the period between 2005 and 2030 of about 176% in Brazil [2]. This table highlights the need to increase the energy supply of the country, which may indicate an upward trend in the rates of development of the country.

Electrical energy can be considered as a key factor for economic development especially in the early stages of this process. The per capita consumption of energy is one of the important

factors for human development and services brought by electricity enable the provision of basic needs such as food refrigeration [2], a factor that contributes to social development.

The Human Development Index (HDI), first published in 1990, measures progress in three dimensions of human development: income, education and health and is designed to be a counterpoint to the Gross Domestic Product (GDP), which measures only the size economic development of a nation. The HDI is calculated annually and has become a worldwide reference an index of the key Millennium Development Goals of the United Nations and, in Brazil, has been used by the federal government and regional governments through the Municipal Human Development Index (HDI-M) [3].

The correlation of the HDI with the energy consumption of a population provides a good indication of the level of prosperity of a people and their country, since it is possible to verify that countries with lower economic growth has a lower energy consumption per capita, as can be seen in Figure 2. It is evident the incidence of electrification in developing countries [4].

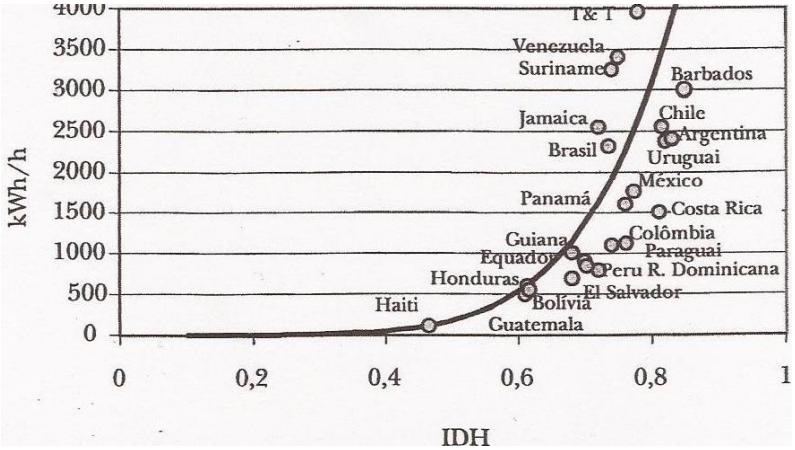


**Figure 2: Correlation between HDI and energy consumption per capita [4].**

The HDI in Brazil is 0.718[3] and its per capita consumption of electricity is about 1881 kWh/hab[4]. The minimum acceptable level of consumption by experts is around 3000 kWh / inhabitant per year for an HDI of at least 0.84. Figure 3 shows the relationship between electricity consumption per capita and HDI value, showing that countries with higher electricity consumption per capita have higher HDI values. However, it is important to note that from a certain level of consumption that relationship no longer applies. The level considered in this case is a consumption of 5000 kWh / inhabitant per year. Above that other factors are relevant, such as other policies Development [2,5].

When discussing sustainable development, it must also consider, in addition to the economic and social pillars already addressed, the environmental pillar.

So, in this context, when it is about electricity, emissions need to be considered in the generation since they are significant: 61% of total emissions of greenhouse gases (GHGs) have as their source the carbon dioxide from the generation of electric energy [2].

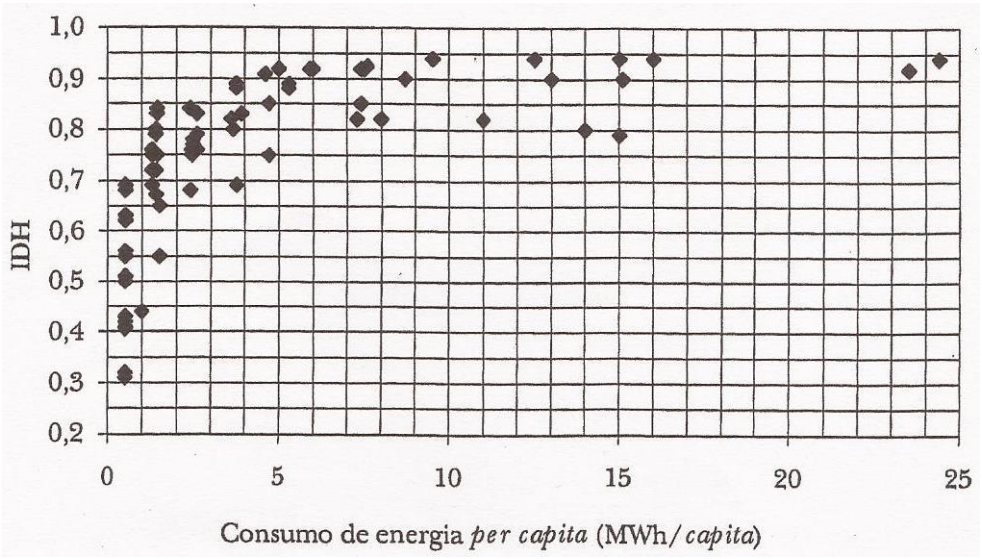


**Figure 3: Relationship HDIxEletricidade [5].**

From this data, taking into account the already mentioned projections of increased demand for electricity in the country and planning the growth of the country in a sustainable manner, it is then necessary to ensure the supply of electricity continuously, ensuring security of supply and economic growth of the country without bringing any harm to the environment. In this context nuclear energy stands out.

The thermonuclear generation differs from conventional thermal generation by way generates the heat that drives the turbines and the used fuel. The heat generation is done by the fission process where there is a release of energy from the mass loss of heavy atoms during the process, which the fuel composition containing uranium. The scheme of a nuclear power plant can be seen in Figure 4.

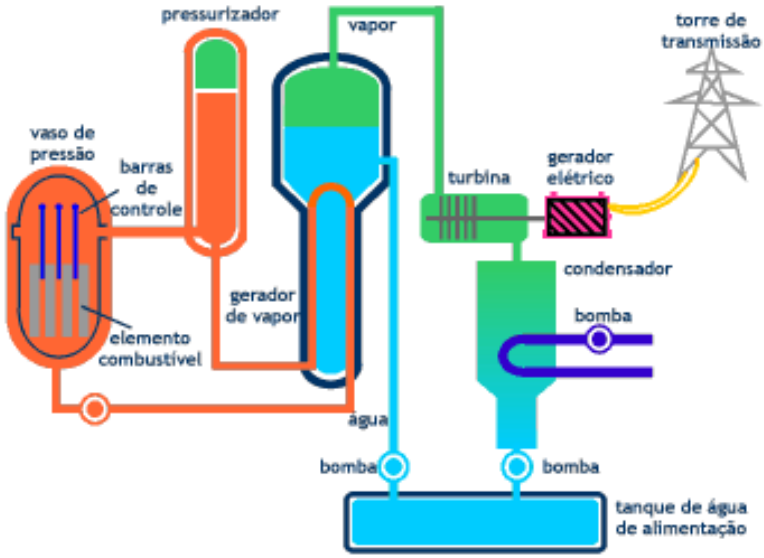


**Figure 4: Nuclear thermal power plant [5].**

One of the great advantages of nuclear power plants is the large amount of energy that can be generated from a small amount of material due to high fuel density, 10 grams of uranium 235 is equivalent to 700 kg of oil or 1200 kilograms of coal [6].

A nuclear power plant uses 35 tons of fuel such as uranium dioxide, which contains approximately one tone of fissile uranium-235, to the production year of 1000 MWe. The energy generated in a kilogram of this material can reach $8x10^{10}$ Btu, equivalent energy of 3,000 tons of coal or 14,000 barrels of oil [7].

In addition, nuclear power does not emit greenhouse gases to generate electricity, unlike the thermal emitting too much carbon dioxide, and also do not emit sulfur dioxide and nitrogen oxides, substances that cause acid rain. For his feature of free source emissions, nuclear power plants avoid the emission into the atmosphere of 2.2 billion tons of carbon dioxide per year, an amount that would be produced by generating equivalent in traditional thermal plants due to the use of fossil fuels such as oil, natural gas or coal [8,9].

Also analyzing the cycle of the use of nuclear power, in example, considering the direct and indirect emissions in electricity generation phases before generation (amount), generation after generation (deactivation or decommissioning of facilities) as well as emissions that result from leakage of GHGs in the different stages of the cycle the total emitted by this source is 27.8 $gCO_2/kWh_{el}$ factor far below sources such as coal, which emits 1346 $gCO_2/kWh_{el}$ or diesel that emits 832 $gCO_2$ / $kWh_{el}$ considering their complete cycles [10].

Another extremely important factor that leads the use of nuclear energy in Brazil is that the country is one of the few in the world that has the technology of the nuclear fuel cycle and has one of the largest uranium reserves in the world. The Nuclear Industries of Brazil (INB)[11] show that the country's reserves allow the supply of domestic needs in the long term and may be available to other markets. These reserves are estimated at 309,000 tones of $U_3O_8$ and it is the seventh largest geological reserve of uranium in the world, however were prospected only 25% of the national territory. INB also estimates additional potential uranium associated with other minerals over 300,000 tons.

The analyzes of the exposed data comes next.

## 3. RESULTS AND DISCUSSIONS

The Brazilian energy matrix is an array of clean generation, thanks to the prime characteristics of Brazil which has several sources of clean energy alternatives.

However, from the analysis of the presented data it was proved that the country's dependent on water source to produce electricity. It is a clean and renewable source, but it will not behave the needs for electricity in the country in the near future as suggested by the indicators, energy consumption is growing faster than supply in the country. One reason for this is the new user access to electricity, a factor that can increase social levels, since, as seen, access to energy is a factor of extreme importance for the economic and social well country, which shows the relationship between energy and development.

To the country achieve growth in a sustainable manner, meeting the needs of inherent power during process; thermonuclear generation is one of the alternatives that stand out in the context of sustainable development.

Nuclear energy allows the gain of large amounts of energy in a relatively small space which allows the installation of power plants close to consumer centers, which reduces the cost of energy distribution.

Moreover, the thermonuclear generation is less polluting sources for generating electricity since it does not emit GHG emissions and also cause acid rain gases to the atmosphere. It is also one of the less-polluting sources when considering the total cycle of the source, especially when compared to sources like coal, one of the sources used in thermo power plants.

Finally, Brazil has all the necessary factors for sustainable use of nuclear power to generate electricity because it has the necessary knowledge for the entire operation of the process and is the major producer of raw materials necessary for the operation of a thermonuclear plant: uranium.

## 4. CONCLUSIONS

After these analyzes, it is observed that the generation of electricity from nuclear source has all the conditions to be a clear and effective electricity supply in Brazil, ensuring conditions for sustainable development of the country.

## ACKNOWLEDGMENTS

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## REFERENCES

1. Empresa de Pesquisa Energética (EPE), *Balanço Energético Nacional 2012: ano base 2011*, EPE, Rio de Janeiro, Brazil (2012).
2. L. S Guimarães; J. R. L. Mattos, Energia nuclear e sustentabilidade, Editora Bluncher, São Paulo, Brazil (2010).
3. M. E. M. Udaeta; G. F. Burani; J. A. B. Grimoni; D. R. S. Nyimi, *Energia in* J.A. B. Grimoni; L. C. R. Galvão; M. E. M. Udaeta (Org.), Iniciação a conceitos de sistemas energéticos para o desenvolvimento limpo, cap. 3, p. 67-96, EDUSP, São Paulo, Brazil (2004).
4. J. A. B. Grimoni; L. F. Kurahassi; E. Paula; M. E. M. Udaeta, *Aspectos relevantes acerca do desenvolvimento in* J.A. B. Grimoni; L. C. R. Galvão; M. E. M. Udaeta (Org.), Iniciação a conceitos de sistemas energéticos para o desenvolvimento limpo, cap. 1, p. 27-38, EDUSP, São Paulo, Brazil (2004).
5. E. M. Cardoso, *Energia Nuclear*, Apostila Educativa, Comissão Nacional de Energia Nuclear, http://www.cnen.gov.br/ensino/apostilas/energia.pdf.

6. R. A. Hinrichs; M. Kleinbach, *Energia e meio ambiente*. Pioneira Thomson, São Paulo, Brazil (2003).
7. L. P. Rosa, *Geração hidrelétrica, termelétrica e nuclear in* Estudos Avançados 59. IEA, São Paulo, Brazil (1987).
8. M. T. Tolmasquim (Coord), *Geração de energia elétrica no Brasil*, Editora Interciência, Rio de Janeiro, Brazil (2005).
9. A. F. Alvim; O. C. Ferreira; O. M. Guidicini, F. Eidelman; A. F. Ferreira, M. A. S. Bernardes, *Comparação da emissão de gases de efeito estufa (GEE) na geração nuclear de eletricidade no Brasil com as de outras fontes*, Economia & Energia, ano XV, n. 79, oct-dec (2010).
10. Industrias Nucleares do Brasil (INB), http://www.inb.gov.br/pt-br/WebForms/interna.aspx?secao_id=48