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ALTERNATIVE THERMAL SOURCES IN THE COMPLEMENTATION OF BRAZILIAN ELECTRIC GENERATION

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ABSTRACT

An energy policy with predominantly the use of one only source for electricity generation, such as Brazil, can lead to environmental, social and economic problems, especially considering the projected increases in demand for electricity in the country. This leads to the need to incorporate sources in the electricity matrix of the country, while complementing the production for meeting the current and future electricity needs, not harming the environment and, thus, achieving a more sustainable development. In this context, nuclear energy can be used to produce electricity without emitting greenhouse gases, taking into consideration that Brazil has large uranium reserves beyond the realm of the fuel cycle technology. Biomass, a renewable source, has zero balance of emissions and Brazil possesses the largest world sugar cane plantation with harvest that coincides with periods of drought, showing their complementarity to our current array. And yet, these two sources can be used in the production of hydrogen to supply Fuel Cells, and can reach regions and consumers not served by the conventional network or that seek alternative and reliable energy generation. The hydrogen production maximizes the use of sources studied in addition to bringing the possibility of electrical energy storage. This study aims to demonstrate the potential of nuclear energy and biomass as complementary sources for the production of electricity in Brazil and, also, as potential sources for hydrogen production.

1. INTRODUCTION

Since the early 1990's, the stock of Brazilian hydroelectric reservoirs has remained almost constant, needing thermal complementation to ensure the country's electrical supply. This complementation was among 6.8 and 11.3% between 2002 and 2008 [1]. The thermal demand of the country, supplementing the hydro until then, followed constancy with a minimum of around 2200 MW, between 2006 and 2008. Over the next years Brazil will need a greater supply of energy, which will not be achieved with proportionally greater supply of electricity from hydropower, especially in the south and southeast.
Still, the energy crisis of 2001 highlighted the vulnerability of the Brazilian electric system based on hydro generation. Again, it is justified that the national interconnected system requires a thermal base complementary to the hydro source [2].

In recent years, about 90% of Brazilian electricity was produced by hydro sources and about 10% of the required thermal complementation system has been guaranteed by nuclear sources and gas-thermal power plants, with a growing contribution of biomass [1].

The present available hydro reserves are mainly in the Amazon, in areas harboring indigenous and ecological reserves that prevent the construction of large reservoirs [3]. The most developed regions of the country have practically no more probability to increase the supply of energy through hydroelectricity and this suggests the need for other sources to supplement the system, using for example, thermal sources. Brazil has a low calorific value of coal and imported coal gives rise to problems of economic and political order, since it could make us the target of external instability. Moreover, the use of this fuel has serious environmental consequences, because it is highly polluting. Hence, the possibility of expanding thermal complementation by biomass and nuclear energy is relevant.

Yet, according to Guimarães and Mattos [2],

> *"Based on the principles of sustainable development, the most recent life cycle analysis of various options for electricity generation could not design a scenario for the next 50 years without is a significant share of nuclear power to meet the demands of power generation concentrated, along with renewable sources to meet the needs dispersed."*

2. THE ELECTRICAL POWER IN THE ECONOMIC SCENARIO

The electricity has assumed a growing share in the Brazilian energy matrix. With a close relationship with the behavior of the national economy, electricity is an excellent indicator of economic performance [4].

The electricity energy is fundamental to economic development and quality of life of populations, since the electricity services enable the fulfillment of basic human needs and contribute to social development, Therefore the *per capita* consumption of energy is a very important factor for the human development [2].

The Human Development Index (HDI) was created by the United Nations Development Programme (UNDP). This index considers the per capita income, life expectancy and educational attainment of the adult population. The correlation of these factors with the consumption of energy brings a good indication of the prosperity of a country. It was verified that countries with a lower economic growth consume, relatively, less energy *per capita* [5].

The consumption *per capita* of electricity in Brazil is about 2000 kWh/year and Brazil's HDI is below 0.8. The 0.8 HDI is the minimum amount considered reasonable by the UNDP for South American countries. In developed countries, the per capita consumption is 4000 kWh / year and the HDI is equal or higher than 0.9 [1,5].

The participation of electrification in developing countries is remarkable and for the UNDP, the access to energy is a key factor in the increase of the HDI, as there is a strong relationship between energy and development [5]. To achieve these indicators, in addition to using all the available hydroelectric potential in the country, it is necessary to complement the electrical system with 15 thermal power plants with 1000 MW each [1], suggesting a warning for the issue of greenhouse gases, depending on the source.

Studies of the International Energy Agency (IEA) sought to explain the participation of energy in the production in order to estimate its contribution to the growth of Gross Domestic Product (GDP) in some countries, e 1990[1], where a rapid growth occurred, between 1980 and 1990[1]. These studies showed that the energy contributed to the growth of all countries significantly. In Brazil, it was the main engine for growth. The study suggests that in economies with intermediate growth, the energy plays a greater role because the industrial production contributes significantly to the economic growth in this intermediate phase. Taking as a comparative basis the United States, a developed, the energy contributed in that period with 11% growth of GDP of the country; in Brazil, this percentage reached 77%, in Turkey 71% and 50% in Korea. The lower participation of the energy factor in the U.S. case is justified by the fact that the country is already industrialized and the industrial productivity has greater relevance, reaching around 47% [2]. It is, therefore, clear that the supply of energy has great importance for the increase in the GDP of countries like Brazil.

The evolution of energy consumption per capita (toe /hab) and GDP *per capita* (GDP/hab)[2] was important in Brazil between the 1960´s and 1990´s. In the 1960´s, the average consumption of energy per capita was 0,54 toe/hab and in 1990 was 1,30 toe/hab to a corresponding evolution of GDP *per capita* of 875 to 2750. In the 1980´s, these values were 1,15 toe/hab and 2540, respectively. GDP per capita in the 1970´s increased by 39,43% over 1960 and in 1980 108,2% over 1970, representing 8,27% in the 1990´s, compared to 1980´s. Comparing to the other decades here commented, the 1990's was the decade with less energy consumption per habitant. Furthermore, the world average GDP *per capita* in the 1990's was 3972 and the energy consumption was 1,66 toe/hab[3] [6].

Data from the National Energy Balance Consolidated (1970-2007) show that between 1980 and 1989 there was an increase in the use of electric power in the industry by 67% versus 23% between 1990 and 1999 [7], with a growth rates of 3.0% in the manufacturing industry between 1980 and 1989 and, between 1990 and 1999, 2,5%[4] [8]. Several factors explain these data, such as greater energy efficiency of machines and equipment of the industrial park in the country and, also, the contraction of industrial activities in the country during the period.

Mercadante [9] notes that the GDP of the manufacturing industry grew by only 11.8% between 1995 and 2002, which equates to an average annual rate of 1.4% as a result of economic opening and the overvalued exchange rate, especially between 1995 and 1998, fact that increased imports significantly.

It shows that macroeconomic policies influence the GDP values and other industrial sectors and the supply of electricity is, also, strongly correlated. There´s not a linear behavior of this trend, but the correlation can be identified. An analysis of historical behavior and studies of electricity demand and consumption, by type of source, map the scenario of expanding demand and also the needs and potential for additional supply of electricity. In addition, this

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[1] International Energy Agency. *World Energy Outlook 2004*. Paris, chapter 10, p. 329-355 *apud* Guimarães and Mattos [2].
[2] GDP in U.S.$ for 1985. Values of Brazil: Ministry of Mines and Energy (MME), BEN *apud* Leite [6].
[3] Worl Energy Council. Energy for tomorrow's, 1993, pag. 276 a 278 *apud* Leite [6].
[4] IBGE, Historical Statistics of Brazil, Rio de Janeiro, 1990, IBGE, National Accounts, Central Bank of Brazil *apud* Vermulm [8].

information is important for the development of planning policies seeking sustainable development of the country.

The projections for increased demand of electricity in the world between 2006 and 2030 is 18,921 TWh to 33,265 TWh, growing around 2.6% per year, and this increase is more dramatic in developing countries, like Brazil [1]. It is important to highlight that, in this stage of development, the domestic industry still tends to grow.

In the Brazilian National Energy Plan (PNE) 2030, the projections indicate an expected increase in electricity demand of 176% between 2005 and 2030 and, in this scenario, you can not abdicate any source of energy: to meet this demand, according to the PNE-2030[5] it would be necessary to increase the hydraulic capacity by 135% and the installed thermal capacity, equally by 135%. It is necessary to rely on a diverse array of sources to provide system reliability [2]. The supply of electricity to serve economic growth and social development should be increased. And even with the prevalence of hydro source supply of electricity to the country, other sources should be considered to meet this demand. Because of concerns about global emissions of greenhouse gases, clean sources, such as nuclear and renewable alternatives tend to have their contribution increased [1].

3. ELECTRIC ENERGY, ENVIRONMENT AND DEVELOPMENT

Nowadays, it is no longer possible to think in development decoupled from environmental preservation. Today, 61% of greenhouse gases total emissions come from the CO_2 emissions, related to energy production. The electrical generation plants based on fossil fuels emitted 39% of global CO2 emissions in 2000. In Brazil, the electric energy sector is not primarily responsible for the emission of CO_2 yet (added by the authors), but, according to the World Bank[6] projections, electricity consumption will increase by 176% between 2005 and 2030 [2]. We should think what energy sources will take over this growth.

It is idealized for the future that society may operate with low emissions of greenhouse gases arising from the intensive use of electricity and, therefore, the challenge will be to generate large amounts of clean electricity. One way to achieve reduction of emissions in the electric energy sector would be the replacement of fossil fuels by nuclear power and renewable energy [2].

[5] EPE/MME, *Plano Nacional de Energia*, Rio de Janeiro, EPE, 2007, 408 p. *apud* Guimarães e Mattos [2].
[6] World Bank apud Folha de São Paulo (24 nov. 2009) in Guimarães e Mattos [2].

4. ADDITIONAL SOURCES AND STORAGE OF ELECTRICITY : MAXIMIZING THE POTENTIAL

4.1 Nuclear Energy

A thermonuclear power plant is very similar to a conventional thermo-electric power plant with fuel and the ways to produce heat to generate the steam, needed to drive the turbine, the major differences. The steam drives a turbine, turning an electric generator coupled to the axis [10].

Nuclear power is generated by a fission reaction that captures the energy stored within an atom's nucleus, which corresponds to 99% of stored energy. A chemical reaction uses less than 1% of the mass of the atom. The lower energy density of a fission reaction is 13631 times denser than coal [1]. Also for comparison, 10 grams of U^{235} are equivalent to 700 kg of oil and 1220 kg of coal and 1 kg of natural uranium produces 573 GJ of heat energy, more than 14000 times 1 kg oil [3,11].

In addition to having high energy density in the fuel, nuclear energy is able to provide safe, reliable, in scale and clean energy. The use of every 22 tons of uranium are avoided the emission of 1 million tons of CO2 into the atmosphere (in typical current plants, 22 tons of uranium are needed to generate 1 TWh of electricity) [1,11]. Tolmasquim [4] states that "the mere existence of nuclear plants in operation worldwide avoids the emission of 2.2 billion tons of CO_2 into the atmosphere annually, which would occur if an energy equivalent was produced by conventional power plants."

It is evident, then, that nuclear plants are a way of producing electricity less harmful to the environment because, besides not emitting greenhouse gases into the atmosphere, they, also, do not produce the main causes of acid rain, sulfur dioxide and nitrogen oxides [4].

Only three countries in the world have assured uranium reserves, technological mastery of the nuclear fuel cycle and use of nuclear power for electricity: Brazil, Russia and the United States [2].

Nuclear power has an important contribution to the complementation of the electrical system and the efforts of Brazilian economic growth and development of the country, including making it virtually independent from imported natural gas. Brazil has a uranium reserve of 310 x 10^3 tons proven and over 800 x 10^3 tons, to be confirmed. The national reserves of uranium added to the technological mastery of the fuel cycle may make Brazil self-sufficient in nuclear generation. The national reserves of proven uranium are equivalent to 238 years of the Bolivia-Brazil gas pipeline operation, which generates 25 million m3 per day, assuming that this gas is entirely directed to electricity generation. Compared to oil, these proven reserves correspond to 7 billion barrels of oil and: if we reckon the reserves speculated, this rises to 25 billion barrels. So, according to what was stated above, Brazil has the potential to supply the thermal amount, generated by gas imported, by domestic inputs [1,2].

This analysis puts Brazil in a political and economic strategic position distant from conflicts generated from dependence on imported energy supplies, fluctuations in prices of inputs in the international market and the risk of interruption in the supply, factors that place the country in a situation of greater energy security.

New technologies, such as the development of Generation IV reactors, fast reactors and reactors for waste incinerators [1] tend to contribute to the spread of electricity production from nuclear sources. The Generation IV reactors, besides the innovations related to the efficiency of fuels, present innovative approaches in high temperature applications and projects for remote or isolated locations. They also include advances in security and reliability to improve public acceptance; a system of very high temperature is also being researched for their potential to supply heat to a high quality process in the production of hydrogen. Programs like Project on Innovative Nuclear Reactors and Fuel Cycles (Inpro), together with Generation IV International Forum, work for the development of these advanced technologies [2].

The assessment of current and future environmental and human reality brings the premise that humanity can not achieve a global clean energy revolution without a strong expansion of nuclear power as a generator of electricity and also hydrogen to supply the fuel cells, apart from numerous other applications. Organs, such as the International Energy Agency, believe that nuclear power should play a critical role in any revolution for clean energy. Hence, nuclear energy is an essential resource for sustainable development as it has available fuel for many years of use, it provides energy security, its use causes almost no pollution or emissions of greenhouse gases, has a scalable capacity, it is cost competitive, having manageable operations and control of waste [1].

Nuclear power, because it is transmitted at the base, is strategically complementary to the Brazilian electric matrix, reinforcing the matrix with low emission of greenhouse gases [2].

With input from Angra 3 in the system, the national nuclear system will provide a liquid generating medium of 2500MW, which may even grow. This average value corresponds to 80% of the electricity consumed in the state of Rio de Janeiro [2].

4.2 Biomass

Biomass can be defined as any organic vegetable or animal matter that can be transformed into mechanical, thermal or electrical energy. It is one of the sources with the greatest potential for growth in the coming years, being considered one of the main alternatives to diversify the energy mix and reduce dependence on fossil fuels [12], besides showing zero balance of emissions, since they do not produce NO2, SO_2 and the CO_2 from the burning is absorbed in photosynthesis [13].

Among the forms of use of biomass originated from cane sugar, it is highlighted the energetic use and the use as fuel in thermal power generation cycles which, in addition to enabling self-sufficiency in energy to the power plants, enables the generation of surplus energy power that can be marketed on the national electric system [14].

In the Brazilian sugar and alcohol industries, the energy use of biomass waste from sugar cane processing, bagasse, serves almost entirely the energy demands of the productive sector.

This process has never been efficient in energetic terms, since its potential is much higher than the needs of the production process, raising the discussion to a better economic use of the sugar cane biomass. The efficiency is still relatively low in the power plants, representing a great potential to be exploited through energy conservation measures aiming the electric power generation surplus. Mechanized harvesting without burning can also increase the volume of biomass to be used significantly [4].

The bagasse from sugar cane has a great potential for power generation: the production of sugar cane in the country rose from 251,8 million tons in 1995 to 426 million in 2007, providing more raw materials for electricity generation and, moreover, its harvest coincides with periods of drought, a characteristic that makes it a good choice to complement the Brazilian energy matrix, dominated by hydroelectric power plants [13,15].

Most power plants of sugar cane in Brazil are located near the largest consumer center in the country: the Southeast. This closeness has advantages regarding the transmission costs. In addition, projects of this nature require little time to be ready, about 18 months. A major advantage of this raw material use in generating electrical energy is its characteristic of complementing the hydro system, since the harvest of sugar cane coincides with the driest periods of the year, when the reservoirs reduce their volume [15].

Tolmasquim [4] says,

> *"the technical potential to generate surplus electricity for export to a sugarcane mill in Brazil from biomass produced by the production process has as main determinants of alternative technology adopted for the cycle thermoelectric of co-generation, technical changes to reduce consumption specific mechanical energy, thermal and electrical in the production process of sugar and ethanol, the growth of the culture of sugar cane crop and the method adopted."*

According to Erlich et al.[7] and Hassuani et al.[8], only one third of the total energy contained in the sugar cane is converted into ethanol. The remainder of this energy potential is in the bagasse and in straw: the straw and the ends of sugar cane account for 34.4% and the bagasse 36.8% of this material energy potential [14,16]. Currently, 93% of the bagasse is used inefficiently in boilers for heat generation and 85% of the straw is burned during harvest, without energy generation [16].

The sustainable use of biomass for electricity generation can bring significant environmental benefits in mitigating emissions of greenhouse gases and also in carbon sequestration, in addition to presenting the great competitiveness of smaller units, allowing the decentralization of generation centers and, thus, reducing transmission costs [4,17].

According to Rosillo-Calle [18], biomass can provide reliable energy alternatives that can help fight global warming. The biomass has a potential to produce much higher energy than the exploited nowadays offering flexibility and safety in the production, distribution and consumption of energy, it can be used in small scale and be decentralized, offering benefits to rural economies and urban centers.

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[7] Erlich et al., 2006 apud Castro et al [16].
[8] Hassuani et al., 2005 apud Castro et al. [16].

Most plants of this sector in the country use the bagasse from sugar cane as fuel for heat production and electricity generation, but only 10% of them sell their surplus [15].

The new plants of this sector, with the new awareness that the generation of electricity from bagasse of sugar cane can become a source of revenue, began to adopt more boilers with a capacity to generate more steam with the same amount of bagasse and started taking actions regarding the storage of bagasse, seeking to eliminate the seasonality of this type of generation [15].

An example of success in this sector with the sale of electricity is the power plant Equipav[9], located in Promissão in northwestern São Paulo. The plant uses a high pressure boiler (the largest in power plants in Brazil, with 90 bar pressure versus 22 bar normally used by power plants) and comes to buying bagasse nearby power plant for use in generating electricity with an installed power of 134 megawatts. Equipav provides energy throughout the year for companies such as CPFL, Eletropaulo, Duratex and Unilever [19].

4.3 Hydrogen and Fuel Cells

Studies and reports warn about the rising temperatures on the planet caused by CO2 emissions originated from the burning of fossil fuels: this brought increased interest in hydrogen in the 90's for the environmental benefits in the long run and, also, for its potential to stimulate innovations [20,21].

Hydrogen is an energy vector, that is, an energy carrier and to be used needs to be extracted from a primary source of energy [22]. It can be produced without emitting any greenhouse gas to the atmosphere. Renewable energy sources, such as biomass, can provide the electricity needed for electrolysis (or generate hydrogen through gasification) and the steam of high temperature from nuclear reactors can produce hydrogen through thermo-chemical water separation [21].

Out of safety, studies have shown that hydrogen does not bring more risks than other types of fuels, and in some cases it is even more secure, since it evaporates quickly when released. International standards for production, storage, transport and use of hydrogen are produced currently by the International Standards Organization in Switzerlan [20].

Fuel cells (FC's) are electrochemical devices that transform chemical energy of a fuel directly into electrical energy and steam, with continuous operation thanks to an external power supply of constant fuel [22]. They have a wide range of applications such as stationary power generation, replacing the combustion engines of automobiles and supply electronic equipment to replace the conventional batteries [23]. The best fuel for the FC's is hydrogen, and using this fuel when pure, FC's produces, in addition to electricity, only heat and water.

The FC's distribute the electricity generation, with small units, from small electricity generation plants located near or next to the final consumer. The use of FC's for this purpose has advantages like the fact that they are clean and, being modular, they allow the user to

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[9] The authors are already in contact with those responsible for the power plant to schedule a visit.

adapt to their needs for electricity generation. This type of energy generation gained support with the growing concern about global warming and the desire for more efficient energy use, reducing CO_2 emissions [20, 22].

The electrolysis process breaks the water molecule into hydrogen (H2) and oxygen (O2) and it is an interesting way to store electrical energy in the form of hydrogen. It is a clean process, despite carbon and sulfur impurities [22,24].

One possibility to store energy as hydrogen is the use of nuclear energy or surplus in times of low demand by power plants, maintaining the flow of neutrons for the electrolysis process [22]. It is a way to maximize the potential of nuclear energy.

One of the established processes for the electrolysis of water is the electrolysis in high temperature, using heat to break the water molecule instead of electricity. This process reduces the electrical energy used greatly, because of the direct use of heat in the process and, consequently, with a much greater global efficiency: high temperature nuclear reactors can be used as a source of heat [22]. This process has advantages over conventional electrolysis due to the favorable kinetics of reactions at high temperature, high capacity of production in a small volume, allowing operation at higher current densities and with lower costs, because it uses a significant fraction of energy in the form of heat [25]. According to Saliba-Silva and Linardi [24] hot electrolysis presents an income level higher than cold electrolysis, reaching 50%.

Among some of the initiatives in the country seeking to develop FC´s technology's, it should be highlighted the first module of power generation fueled by hydrogen produced with domestic technology, developed at the Institute of Energy and Nuclear Research (IPEN), located in the University of São Paulo (USP) [26].

So, among the main reasons to invest in the technology of FC´s are its strong environmentally-safe character, high efficiency relative to fuel, reliability of the energy produced, facilitating the distribution of the generated electricity, possibility of co-generation of electricity and heat, besides the flexibility of sources for obtaining hydrogen.

5. ANALYSIS AND PRELIMINARY RESULTS

Taking into account the still small portion of the contribution of nuclear energy in electricity generation in the country, around 2.6% of total generation, and considering the projected needs, discussed above, there is still a lot of room for the growth of power generation from nuclear energy sources. It is important to highlight the importance of the entry of Angra 3 in the national electric system, since it will raise to 80% the share of nuclear energy in the supply to Rio de Janeiro. This leads to the consideration of planning the entry of new plants in the Brazilian, since, according to previously stated, the country will need is to complementation 135% of installed thermoelectric to meet the demand for electricity in the coming years.

In the refers to the biomass, the authors initiated a field study[10] which includes visits and interviews by phone and email, to the power plants of this sector in the State of Sao Paulo in order to collect data concerning the energy production of these plants, the allocation of this energy, whether there are surplus and the disposition of surplus generated. To date, two power plants were visited, located in Ourinhos and Boituva in the state of São Paulo, where it was found that the production capacity of electricity is high, and including in one power plant visited one part of the energy produced is wasted because it generates more than twice the energy needed for their activities (generation per day is 6.5 MW and use for maintenance of the plant is 3 MW) and has no kind of use of the rest. According to the responsible for the power plant, this waste is due to the lack of infrastructure of the plant to allocate this surplus energy and also the costs that the installation of such infrastructure would require, besides the lack of incentives by the government and the concessionaires. The energy is thrown away. The second power plant visited usually produces all the energy for its operation using two 1.2 MW generators, totaling 2.4 MW of electricity produced per day. It uses the network in times of low crop yields or in between crops, and when there is surplus generated, the plant supplies a small village in the vicinity. According to the responsible for the boilers, the power plant has the potential to produce a greater amount of energy, needing investment in new and more efficient equipment to do this.

Two other plants were interviewed by telephone[11]. The first, in the region of Araçatuba, has a nominal capacity of 139 MW per day, using for its energetic supply, approximately, 30 MW. The second power plant visited, in the region of Pirassununga, generates a surplus, marketed, of 30 MW. These power plants exemplify one of the issues we are seeking to prove in this work: the potential of biomass for power generation. The power plants already sell their surplus energetic production to the system and to other consumers.

The data collection, still in early stage, in São Paulo power plants, provides evidence of the large amount of energy that can be generated and sold from the bagasse from sugar cane. Moreover, it is evident that power plants are introducing more technology in the whole process, since the entry of the input in the power plants, along procedures for collection, up to the production of electric energy, optimizing procedures and increasing the energy efficiency to produce electricity.

6. CONCLUSIONS

One way to assess the performance of a given source is through its Capacity Factor which is a measure of the performance of an energy source during a period calculated as a percentage of their total energy potential. In Brazil, biomass power plants, mostly sugar cane bagasse, has averaged a Capacity Factor of 47% associated with the crop cycles. The Brazilian thermoelectric nuclear power plants, Angra 1 and Angra 2, have a Capacity Factor, respectively, of 78% and 83% [1]. In terms of Capacity Factor, nuclear power plants beat any other power source.

[10] This work aims to obtain data for the master dissertation of the author Luiza Chourkalo Stecher.

[11] Then power plants will be visited by the authors surveyed.

Nuclear power is, evidently, a complementary source of great importance for the Brazilian energy system: in addition to the fact that the country is in a favorable position as to the reserves, it has technology for processing (the fuel cycle) and for power generation. These reserves also may be an extra factor of income for the country, as Brazil could use these reserves to supply domestic power plants and also export fissile material with high added value. Nuclear power is also an energy that contributes to the country development without environmental impact, as it can be considered a clean source.

The biomass, particularly sugar cane bagasse, has a great potential to complement the country electricity supply, caused by the large amount of raw material, which could rise, and also for its strong environmental character. This potential can be increased with the adoption of more efficient technologies and measures in both, crops and power plants.

Hydrogen can harness the potential energy sources available in each region of the country and be an important tool for storing the electricity generated, helping to ensure the security of energy supply by maximizing the sources used in the generation of electricity. In the case of the Southeast, there is, currently, the possibility of using, for example, electricity generated at times of low demand for nuclear power to produce hydrogen or to use the biomass coming from sugar cane plants, in addition to the surplus electricity produced in sugar cane power plants. In the latter case, besides the possibility of selling surplus energy to the grid or to large consumers who seek an alternative cleaner energy, the power plant can store the energy generated in the form of hydrogen for consumption in times of growing season, when the harvest is low, or even supply its surroundings with this vector.

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