Energy governance in Brazil: meeting the international agreements on climate change mitigation

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CHAPTER 3
HISTORICAL OVERVIEW OF THE BRAZILIAN ENERGY SECTOR: TRADITIONAL SOURCES

The third chapter of this study describes the current energy generation in Brazil and the history of its implementation since the start of the country's industrial development in the early twentieth century. The chapter is divided into four sections to present the situation concerning Brazil's primary energy sources: hydroelectric dams, oil and gas production, ethanol industry, and thermoelectric power under which nuclear energy is tackled. Brazil has developed a considerable renewable energy industry which will be presented in the next chapter. But first, a brief introduction on how the Brazilian energy sector started is presented below.

The development of the electric power sector in Brazil had its most significant impulse with the 1930 revolution, which the main goal was to change the economic base of the country. In other words, Brazil would stop being an agricultural exporter to become a country with its industry facing the ongoing challenges since the Second Industrial Revolution started in the second half of the nineteenth century (Kerecki & Santos, 2009).

The revolution of 1930 was a coup led by the states, Minas Gerais, Paraiba, and Rio Grande do Sul, against the election of Julio Prestes, a candidate supported by the state of São Paulo who never took office. The *coup d'état* resulted in ascension of Getúlio Vargas, who stayed in power for fifteen years afterwards. In 1951, Vargas was again elected president and stayed in office until 1954, when he committed suicide. The following 18 months after Varga's death, the country had three different presidents until the election of Juscelino Kubitschek in 1956.

The second government of President Getúlio Vargas (1951-1954) emphasised initiatives for industrial development, such as the exploration of coal and ore, and created the National Road and the National Electricity Funds. In his government also founded Petrobras and proposed the creation of Eletrobras, which would only be approved in 1961 (D'Araujo, 2004) and officially installed as of June 11, 1962. Juscelino Kubitschek (JK) followed previous governments' plans for the industrial development of Brazil. One of the ways found by JK (1956-1961) to try and industrialise the country was to attract the investment of foreign capital in the country by encouraging the installation of foreign companies, especially from the automotive industry. With the end of JK's term in office, Brazil would face political uncertainty again. JK's successor, Jânio Quadros, resigned after one year in office, resulting in the ascension of his vice president João Goulart (1961-1964), mostly known as 'Jango'. The set of actions offered by João Goulart was aimed at the proletariat; it would discredit the great landowners' interests, the large business community, and the middle classes. João Goulart defended the realisation of reforms intended to promote income distribution but was unable to implement it due to a military coup that resulted in his deposition in 1964. After the coup, Brazilian politics returned to the development path driven in the first half of the century. The military stayed in power for 21 years – until 1985 – and had no interest in serving the masses, being a dictatorial government.

Marshal Humberto Castelo Branco (1964-1967), the first military president, implemented a Government Economic Action Programme (PAEG in Portuguese) to accelerate the pace of economic development and raise tax rates to reduce the public deficit. This first economic plan was considered successful since it calmed a period of uncontrolled inflation between 1964 and 1967. The economic and institutional reforms of the PAEG led the country in the following years to live a period that came to be known as an 'economic miracle.' From 1968 onwards, Brazil started to grow again due to price stability and financial reforms. Nevertheless, the economic benefits did not reach the inferior part of the population, which suffered from the flattening of wages and political and civil rights loss.

General Emílio Garrastazu Médici's government (1972-1974) implemented the *First National Development Plan* (PND1), which was elaborated by the then minister of finance, Delfim Neto. Under his strategy, "the state took advantage of the increase in revenues and access to international loans to invest in pharaonic infrastructure projects" (García, 2014). So became known the large national integration projects conducted in the transportation sector such as the Rio-Niterói bridge and the Transamazônica highway. The main objective of the PND1 was to prepare the necessary infrastructure for the development of Brazil in the following decades. Médici's priority was promoting Brazil's development and growth by taking advantage of the then favourable international environment (Moreira, 2014). In the energy sector, Petrobras and Eletrobras, created in 1653 and 1962, respectively, underwent significant transformations. Petrobras became the largest Latin American company in the oil exploration sector and still holds its place among the world's largest. Eletrobras became the official planner and coordinator of electricity generation and distribution in Brazil. In 1973, Brazil and Paraguay signed the Itaipu treaty creating Itaipu Binacional, an agreement on the construction of the Itaipu hydroelectric power plant, the second-largest dam in the world with a capacity of 14,000 MWh (Itaipu Binacional, 2019).

In 1973 the international economy suffered a radical change. Arabic countries, members of the Organization of Petroleum Exporting Countries (OPEC) boycotted the United States and European countries for their support to Israel in a military conflict that year.[17] This first shock

[17] The Yom Kippur War or the October War between Israel, Egypt and Syria fought from October 6 to 25, 1973.

in the oil market did not affect the Brazilian economy very drastically, due to Brazil's 'economic miracle' in the period between 1968 and 1973, when the GDP (gross domestic product) grew at an annual average rate of over 10% (Viana, 2004). However, the exaggerated rise in oil prices has created a global crisis. The price of the barrel tripled at a time when Brazil imported 90% of the oil it consumed. Brazilian development model was based on an energy matrix supported by the low oil price. General Ernesto Geisel took office in 1974, started his presidency with policies designed to avoid the consequences of the global oil crisis in the years to come. Its development strategy redirected investments to the economy's primary sectors, such as metallurgy and petrochemical, to reduce the import of inputs without compromising the country's industrialisation process. Geisel efforts focused on tackling the latent crisis that already manifested in the world economy by importing goods other than oil. At the end of 1974, the government launched the II National Plan for Economic Development (PND2), which prioritised the reduction of Brazil's dependence on external energy sources. To accomplish that, large projects were initiated in the energy sector, such as the construction of hydroelectric plants (Itaipu, Sobradinho and Tucuruí), the Brazil-West Germany Nuclear Agreement, the National Alcohol Programme (Proálcool) and the exploration of oil. These projects were financed by the Arabic countries and their 'petrodollars.' With the market overvalued, oil-producing countries had the resources and interest to fund projects proposed by the Brazilian government. The foreign investments made in this period influenced the current Brazilian power system.

Because of the Iranian revolution in 1979, a new oil crisis happened. In that year, Shah Reza Pahlavi's pro-Western government was overthrown by a movement under the leadership of Ayatollah Khomeini, who did not have an interest in Western countries dependent on oil. The changes in Iran caused an unbalance in the oil market, and for the second time in the same decade, the price of the barrel increased enormously, causing an event that became known as the second oil shock of 1979. In the following year, the Iran-Iraq war prolonged the international crisis. The conflict impacted the regular flow of oil when ships and oil facilities were bombed. Despite the PND2's goal of achieving a solid economic-industrial infrastructure and foster development in an attempt to make Brazil an 'emerging power', the second oil shock in 1979 generated severe economic consequences for the country, namely: the acceleration of the inflationary process; the reduction of GDP growth rates; unemployment and the public finance imbalance. If the first oil crisis did not make the military's plans for Brazil's development fail, the second crisis, in turn, caused the economic ruin of the dictatorship. The rise in the price of an oil barrel came back and triggered the US government's decision to raise interest rates. As the military's international loans were based on the American rate, the result in the Brazilian economy was a public deficit, inflation, and consumption retraction. The global crises of the 1970s caused an "impact on the world's perception of oil dependency and led the entire world, for the first time, to address energy planning from a multisector perspective, i.e., integrating the oil and electric sector" (Viana, 2004: para. 6). In Brazil, the crisis led the military government to prioritise the energy sector, leaving behind a legacy of physical, technological, and institutional structure that has solidified and is still active today: hydroelectric power plants, petroleum production, the Proálcool programme, and nuclear energy. These sources of the Brazilian energy matrix are detailed in the following sections.

3.1 Hydroelectric dams: source of energy and reputation

Dam construction in Brazil first started in the Northeast region at the end of the 19th century and progressed as part of a policy that sought to provide the north-eastern semi-arid areas with reservoirs to encourage the inlanders to stay in the region and thereby reducing migration to the Southeast of Brazil (Mello, 2011). The development of the Brazilian electric sector began in the 1950s when several research centres were created to support the construction of large dams. The introduction of hydroelectric plants in the Brazilian electric matrix accelerated from the 1970s onwards, during the military dictatorship. Between 1960 and 1980, the following hydropower plants, among others, were built: Itaipu, Tucuruí, Ilha Solteira, Itumbiara, São Simão, Jupiá, Marimbondo, Água Vermelha, and Sobradinho. Nevertheless, at the beginning of the 2000s, a drop-in energy supply forced the Brazilian government to impose a power rationing from June 2001 to March 2002. Since then, the search for alternative energy sources has been intensified, as well as the interest in new hydroelectricity projects.

To implement these new projects a growth acceleration programme (PAC, Programa de Aceleração do Crescimento) was created. The first phase of the PAC1 was launched by former President Lula da Silva in 2007 and lasted until December 2010. The second phase, named PAC2, started in March 2010, still under Lula's government but was executed during the Dilma mandate (2011-2016). The PAC programme is still in force under Bolsonaro's administration. These developmentalist policies are intended to propel the Brazilian economy through investments in the fields of energy, transport, housing, and sanitation (PAC 2013). The PAC programme is based on the exploitation of natural resources (Kuijpers, 2013) and has facilitated several large hydropower projects.

Under the PAC programme, Brazil has been planning and executing many large new dam projects with high socio-environmental impact. In 2013, the Simplício dam, between the states of Minas Gerais and Rio de Janeiro, was completed. The dam construction is considered remarkable due to its high generation power. In 2016, another two plants were completed. Both part of the Madeira River complex in the state of Rondônia. The first one, the Jirau plant, had the first of its fifty turbines activated in 2013, at the end of the same year, the second dam, called Santo Antônio, already had twenty-two turbines operating. The Belo Monte hydroelectric plant, which began in 2011 and is expected to be completed by the end of 2019, has a seasonal peak capacity of 11.2 GW, the second largest in Brazil being surpassed only by the 14 GW generated by the Itaipu on the Paraná

River, on the border between Brazil and Paraguay. Another important project completed in 2015 was the Teles Pires plant, on the border between the states of Pará and Mato Grosso, with an installed capacity of 1,820 MW. With these constructions already implemented, some in progress and a few others planned, Brazil will probably solve its energy shortage problem. However, it is essential to remember the effects of these projects on the environment. Despite the adjustments made in the dam projects to reduce social and environmental impacts, the large investments made in the construction of hydropower plants in Brazil in the last few years have attracted the attention of scholars and environmentalists who argue that these initiatives undermine the country's image regarding clean energy generation. In parallel with the expansion of hydropower in emerging countries with high exploration potential, environmental pressure against this energy source grew worldwide, especially in opposition to large dam projects (Tolmasquim & Guerreiro, 2015). Although hydroelectric dams are known as a reliable source of clean energy, they are responsible for significant carbon dioxide (CO_2) and methane (CH_4) emissions (Fearnside, 2012; Mohajan, 2012; Ferreira & Fernandes, 2019), the latter been considered even more harmful to the atmosphere.

So far, Brazil has put into operation 217 hydropower dams and 426 Small Hydropower Plants (PCH in Portuguese). According to the National Electric Power Agency (ANEEL in Portuguese), in 2018, 74.2% of the country's electricity generation was by hydropower. This firm reliance on hydroelectricity has given Brazil a great reputation as a "green energy power" (Knodt & Piefer, 2015). This international recognition reinforces the decision-making processes in the same direction, considering that Brazil's hydroelectricity generation is increasing since there are in the country 38 power stations under construction and 148 dams in the project phase (ANEEL, 2018). Nevertheless, in the summer of 2014, when there was little rainfall to keep the water levels of the dams' reservoirs, thermoelectric plants – high GHG emitters – were intensively used to generate power for national demand (Casagrande, 2015) and meet the needs of the residential, commercial, and industrial sectors.

The Belo Monte dam is currently the biggest power plant under construction in Brazil. Located in the Amazon region near Altamira city on the Xingu River in the state of Pará, the dam is one of PAC1's priority projects. It will become the third-largest hydroelectricity dam in the world with a generation capacity of 11,233 MW and investments of over US$18 billion. Brazil's ambitious hydropower expansion plan does not stop there. According to Amazon Watch (2011), the Brazilian government intends to build other dams upriver with larger reservoirs to make sure Belo Monte will generate power during the full year.[18] It took more than three decades for the Belo Monte project to be approved. The first attempt was made in 1975, but the construction started only in 2011 after many changes were made in the project because of several protests (Ferraço, 2018). Kuijpers (2013) states that the Belo Monte dam is a disputed project because of its size, the number of affected people and licensing process, which has been considered irregular, whereas it disregards Brazil's constitution and environmental law. Eight years have passed since Belo Monte's implementation started, and the social and environmental damage has been accumulated. The dam's construction has caused great biodiversity loss and affected the livelihood of riverine communities, indigenous people, and small farmers. It has submerged an area of 668 km^2, including four hundred km^2 of forest (see Appendix 3). By the end of the construction, a total area of 1,522 km^2 will be impacted (Amazon Watch, 2011). Understandably, Brazil avails itself of its great hydrological resources. However, Brazil has plenty of energy sources, such as solar and wind, which could be used to supply the country's

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[18] Due to relevant seasonal variation, the Xingu river's flow oscillates, and therefore, the dam will operate at total installed capacity only a few months a year and generate merely an average of 4,500 MW, which makes the project inefficient as it is extremely expensive. "Since the Belo Monte Dam itself will be essential 'run-of-the-river, without storing water in its relatively small reservoir, economic analysis suggests that the dam by itself won't be economically viable" (Fearnside, 2012: 2).

growing power demand without causing such environmental and social impacts.

3.2 Oil and gas production: the central role of Petrobras

The Brazilian oil and gas industry started with Petrobras' foundation in the earlier 1950s. Nevertheless, the country was still dependent on oil and gas import when the first international oil shock occurred in 1973. Even though the crisis did not immediately affect Brazil, it was possible to predict that the country would face difficulties in importing oil in the following years. To avoid these imminent difficulties, President Ernesto Geisel (1974-1979) created a plan to reduce the import of oil, which led Petrobras to focus on offshore research and qualify for this new technology. As a result, the company began to invest in know-how, staff training, and equipment acquisition. The outcome of this plan was the discovery of the Campos basin at the end of 1974. With approximately 100,000 square kilometres, this basin is currently responsible for 45% of the national oil production (ANP, 2019). This discovery caused relief in the Brazilian economy since the expenses with oil import in Brazil jumped from seven hundred million dollars in 1973 to 2.8 billion dollars in 1974.

In 1975 the government opened the oil exploration in Brazilian territory to private initiative. The provision of exploratory services was agreed through "risk contracts," which contained a risk clause whereby Petrobras would recognise the services rendered but would only pay for the job in the case of discoveries of useful oil for commercial purposes (Costa, 2012). These contracts were signed between Petrobras and international private companies holding technology and responsible for conducting oil and gas exploration activities. Although the government argued that these agreements would not break the state monopoly, much of the public opinion advocated the slogan "the oil is ours" and that this statement would only become a reality with the maintenance of state monopoly (Kucinski, 1977). The policy of opening oil exploration was maintained for 12 years. It was only interrupted with the 1988 constitution when the constituent assembly voted to prohibit the signing of new risk contracts due to its apparent inconsistency. It turned out that companies "were not interested in producing more oil, but in maintaining reserves" (Rocha, 1991: para. 4) and therefore, the veto over this type of contract was "undoubtedly a victory of Brazil" (Rocha, 1991: para. 4).

Under the new constitution, promulgated as of October 5, 1988, the government prioritised social reforms and kept its role in the economy. Regarding the oil sector, by the end of the 1980s, Petrobras achieved outstanding results for the offshore industry's technological development. In 1990, Petrobras had already discovered reserves of over forty-five billion barrels of crude oil and natural gas in both basins, Campos and Santos (Morais, 2013). At that point, the company was producing half of the national oil consumption and became less dependent on foreign capital while buying almost 100% of its equipment and materials from the Brazilian market (Guan, 2010). Petrobras' achievements were much appreciated at the Offshore Technology Conference as the company was recognised with the OTC Award in 1992 (Petrobras, 2006). Nevertheless, the Brazilian economy at the beginning of the 1990s was not very promising since the country struggled with debts and inflation. The election of President Fernando Collor de Mello (1990-1992) turned out to be a failure as he was impeached and charged with passive corruption and criminal association (Pousadela, 2009). Eventually, Collor de Mello resigned, and the vice-president Itamar Franco (1992-1995), took over the presidency. In order to stabilise the economy, President Franco's minister of finance Fernando Henrique Cardoso (hereafter, FHC) implemented in 1994 the *Real Plan* which was a three-stage strategy that started with a spending budget controlled by the National Congress; followed by an overall indexation process which would lead to the introduction of a new currency called *Real* (Hudson, 1997). Eventually, the *Real Plan* stabilised the economy and resulted in the election of FHC as president for the two subsequent mandates, from 1995 to 2003.

During his administration, FHC implemented neoliberal reforms that had important developments in the country's oil sector and Petrobras. The company was, since 1988, exclusively responsible for administering the Federal Government's monopoly on oil exploration, production, and refining. In 1997, FHC promulgated the 'Petroleum Law' (Nr. 9.478/97), which allowed the oil and natural gas sector to become more flexible. After the approval of this Law, were created both the National Energy Policy Council (CNPE) and the National Petroleum Agency (ANP) responsible for the public policies and the regulation of the energy sector, respectively (Ribeiro & Novaes, 2014). With the 'Petroleum Law' approval, FHC broke the company's monopoly, allowing new companies to explore oil in the national territory. Petrobras began participating in auctions held by the ANP in competition with other oil companies for the right to explore oil fields, including those discovered by the company itself. In FHC's administration, private companies were allowed to enter the oil sector independently or through partnerships with Petrobras. In this way, multinational companies began to have access to large oil reserves located in the Campos basin. Furthermore, FHC's government reduced Petrobras' size by authorising the selling of the companies' refineries, distribution points, oil and gas pipelines, et cetera (Ribeiro & Novaes, 2014). Shell Royal Dutch became the first privately owned company to explore and find oil with good commercial production potential in Brazil.

Luiz Inácio Lula da Silva (Lula), leader of the Workers' Party (PT) and opposite to the government, was elected FHC's successor. Initially, Lula's government (2003-2011) maintained the softening of Petrobras monopolistic operation initiated by FHC, as well as the partnerships between Petrobras and other companies. However, after the initial phase of the government, Lula started to contest the policy regarding Petrobras and launched the PROMINP (Programme for the Mobilisation of the

National Industry of Oil and Natural Gas), showing interest in stimulating the development of the national oil and gas while increasing internal labour market. In 2003, the federal government introduced substantial changes in bidding requirements for oil and natural gas exploration and production projects. One of the changes regards the minimal local content requirement[19] for investments in the developments and production stages which was 37.8% on average during the FHC's government against an average of 80.1% at the beginning of Lula's second term (Ribeiro & Novaes, 2014).

With the discovery of pre-salt[20] basin oil reserves in 2006, Petrobras became the exclusive operator in all pre-salt oil fields. From that point on, a regulatory framework was created based on sharing agreements (instead of concession) for oil exploration, demonstrating that the Lula government had "a concern to retake the Brazilian state's role in the development of the country" (Ribeiro & Novaes, 2014: 52). One of the new regulation's goals was to align the sector more closely to the nation's interest, resulting in greater participation of the State. Another important event related to the pre-salt regulatory framework was the creation of Pre-Sal Petróleo SA (PPSA), a public company responsible for managing contracts related to the production and selling of oil, natural gas, and other fluid hydrocarbons from the pre-salt area. The PPSA purpose of increasing state's monitoring of companies' contracts and veto power faced critics from the opposition because of the fear that government control instead of the market would retard the pre-salt area development (Guan, 2010).

[19] A contractual clause on local content requiring that part of Brazil's goods and services for exploration and production activities must be national. Besides, preference should be given to contracting Brazilian suppliers whenever their offers price, term, and quality conditions equivalent to those of other suppliers also invited to submit proposals (ANP, n.d.).

[20] Reserves of oil and natural gas, located up to 5,000m below the seafloor, under a thick salt crust (pre-salt layer, hence the name "pre-salt"), which extends for 800 km between the states of Espírito Santo and Santa Catarina (see Appendix 5), considered the most prominent oil province found in the world in the last thirty years (Piquet, 2012).

Between 2003 and 2010, during the two terms of former president Luiz Inácio Lula da Silva, Brazil experienced significant economic and social changes. With a strong commodities market, new oil reserves discovery, and the implementation of *Bolsa Família,* a social-welfare programme that became an international model for the eradication of poverty, Brazil achieved a remarkable growth, which stemmed from Lula's high approval rates and resulted in the election of Lula's successor, President Dilma Rousseff (2011-2016), also from the Worker's Party (Partido dos Trabalhadores, PT). For the next five years, the government would continue its effort for economic stability and poverty eradication.

Concerning the oil sector, Dilma's government was criticised. Initially, because of her participation in the decisions for the purchase of Pasadena's oil refinery in the United States by Petrobras. In 2006 Dilma was chief of staff in Lula's government and the chair of Petrobras' board of directors. As a counsellor, Dilma voted in favour of the purchase of 50% of the refinery shares. The purchase generated suspicions of overbilling and alleged foreign exchange evasion, which led to an investigation by the Federal Court of Audit. In 2014 the Federal Justice initiated investigations of corruption and money laundering involving Petrobras. The federal police's operation, called Car Wash[21] (Operação Lava Jato in Portuguese) uncovered large-scale bribery, kickbacks and money laundering involving the state-run oil company. It was then estimated that the volume of resources diverted from the company's coffers would be billions of *reais*. Suspects of involvement in the scheme were people of expression within the country's economic and political scenario, including politicians of the PT itself. According to Pinguelli Rosa (2014), Dilma's second term inherited several problems from her first term, both in the electric power and in the oil sector, although the latter has a more political character due to the irregularities in Petrobras.

[21] The Car Wash operation includes investigation on illegal transaction concerning the Belo Monte dam's constructions, the nuclear power plant Angra 3, and the Petrochemical Complex of Rio de Janeiro (Comperj). For details go to http://www.mpf.mp.br/grandes-casos/lava-jato/entenda-o-caso

These and other events in Dilma's administration unfolded in several manifestations and opinions contrary to her government from both opposition parties and society in general. This dissatisfaction led to her impeachment and her replacement by Vice-president Michel Temer. This turmoil in the political sphere contributed to the disruption of the country's energy sector and the national economy in general.

Even though Dilma had already started to implement less protectionist policies for the oil sector, it was with Temer's ascension that the entrance of foreign and private investments in the development of Brazil's offshore oil blocks was again facilitated (Chetwind, 2016). In 2016, the government passed a bill nº 13.365/2016 that removed the clause requiring Petrobras to participate at least 30% in the production sharing regime. With this bill, the mandatory operator role imposed on Petrobras was replaced by a right to preference. This change allows Petrobras to participate only in the biddings for oil blocks in the pre-salt areas of its interests, leaving the other ones to private companies (Leão, 2017; Olim, Mensah & Yamachita, 2018; EIA-2019) Despite the discovery of the pre-salt oil reserves, Petrobras has lost a great deal of its market value. According to Olim, Mensah & Yamachita (2018), this depreciation occurred not only due to management decisions, such as the purchase of the Pasadena refinery, fuel price policies alongside economic crises, but also because of the protectionist policies imposed on the company related to its role in the development of the pre-salt area.

In the last five decades, the oil exploration and production in Brazil have gone from open to closed alternately, and in the current decade, a new opening prevails that began in the Temer government and continues with the Bolsonaro government. Favouring Bolsonaro's privatisation policies, the Federal Supreme Court (STF) authorised the sale of the Associated Gas transportation Company (TAG), without deliberation by the National Congress, on condition that a public bidding process occurred under the Brazilian procurement law (Forbes Brazil, 2019).

This decision is part of Petrobras' divestment plan[22] to be realised by selling the company's assets to reduce its debt by $10 billion in 2019 (Offshore Technology, 2019). Six months have passed since Bolsonaro took office. Up to now, analysts define his government mainly as neoliberal (Schaefer, 2018; Amazon Watch, 2019; Prinsloo, 2019; Bresser-Pereira, 2019), which means that the government power tends to shrink during Bolsonaro presidency, whereas the market power grows. It is essential to observe how this openness in the Brazilian energy sector will unfold when dealing with climate change mitigation.

3.3 Ethanol production: past and future solution

The use of sugarcane ethanol as fuel in Brazil dates from the late 1920s and early 1930s (Soccol et al., 2005) with the automobile industry's increase. Ethanol was then combined with gasoline, a mix inspired by the ethanol blends largely used in France three decades before (Kovarik, 2006). The increasing demand for ethanol led to establishing the Sugar and Alcohol institute by the Vargas government in 1933 to propel alcohol fuel production and provide technical assistance. Ethanol demand rose again in 1943, during II Word War, when German attacks threatened oil supply. After the war, ethanol use diminished as oil import normalised. From the 1950s onwards, the ethanol-gasoline blend was used sporadically only to drain sugar surplus (Kovarik, 2006). Ethanol production emerged again in 1975 with the creation of the National Alcohol Programme or Proálcool. After the oil shock in 1973, the Brazilian government intended to reduce the country's dependence on imported oil. The Proálcool was a response to both the sugar and oil price crisis in the international market (Lorenzi, 2018).

[22] Disinvestment is the alienation to the private sector by the federal government of holdings within state companies or assets of these companies (National general controller (CGU) federal secretariat of internal control, 2017).

> “The programme is born based on public subsidies and financing, and the government, through Petróleo Brasileiro S/A - PETROBRAS, is responsible for buying, transporting, storing, distributing and mixing alcohol with gasoline, as well as determining the selling price of the product” (Michellon, Santos & Rodrigues, 2008: 2).

Proálcool had two distinct phases: the first one with anhydrous alcohol production, used as an additive to gasoline. Anhydrous alcohol (without water) can be mixed with gasoline in any proportion without impacting car efficiency. This flexibility was an advantage for sugarcane farming because “if the sugar price falls, alcohol could be produced instead, and vice-versa” (Soccol et al., 2005: 898). The second phase, from 1980 onwards, was marked by the production of hydrous ethanol or hydrated alcohol, to be used as pure fuel in ethanol-only powered cars, whose technology was developed in Brazilian universities and research centres (Puppim de Oliveira, 2002). In both phases, government subsidies and investments were crucial to the expansion of alcohol production and consumption to such an extent that in 1984, 94% of automobiles were powered by ethanol (Soccol et al., 2005). This high car production rate contrasting with low ethanol production led to a supply crisis in 1989, bringing discredit upon the ethanol-only fuelled car (Barbosa Cortez, 2016). The stagnation of ethanol output occurred as the result of fewer investments made in alcohol production due to economic crises and price control to fight inflation; and also because of low oil price in the international market; political hesitation concerning Proálcool; negative reaction from Petrobras;[23] and increase of national oil production.

Contrary to expectation, the oil price fell considerably in the 1990s, which resulted in Proálcool’s steady dependence on government subsidies (Puppim de Oliveira, 2002). Additionally, at de beginning of Collor de Mello’s tenure (1990-1992), an administrative reform started, putting into action the new president’s national plan of economic

[23] The rapid growth in hydrated ethanol production resulted in a large surplus of gasoline that had to be exported, forcing Petrobras to make costly oil refining structure changes (Soccol et al., 2005).

liberalisation. These new policies included the deregulation of the sugarcane industry, in other words, the curtailment of state intervention in it. As a result, price control on the fuel sector was removed. This decision raised concern among producers since ethanol could not compete with gasoline (Moraes, Azanha & Zilberman, 2014). The ethanol production stagnation – which had already started in the mid-1980s – lasted until 2003. Back then, "in the absence of a demanding ethanol market, the technology stabilised as well, being fomented only incremental innovations" (Barbosa Cortez, 2016: 46).

As of 2003, a new phase started for the ethanol sector with the introduction of the Flex-fuel technology,[24] which enabled the internal ethanol market to grow significantly. This return to growth from 2003 onwards "created the market that enabled the capital goods industry to invest in developing new technologies and equipment" (Barbosa Cortez, 2016: 46). As a result, in 2005, 55% of passenger vehicles commercialised in Brazil were Flex- fuel powered. This rate rose to 87% in 2018 (Veiga Filho & Ramos, 2006; MME, 2018). The Flex cars had a strong appeal to customers since they could profit from ethanol's low price without the risk of supply crises from the past. "Currently, 90% of all car sales in Brazil are Flex-fuel vehicles" (Stattman, 2019: 28). However, Flex-fuel technology's success does not mean a continuous favourable outcome for the ethanol industry. At the end of 2007, Petrobras announced that oil had been found in the pre-salt area. This news caused great optimism among the company's technicians and led the federal government to define a strategy that prioritised large investments in pre-salt oil exploration (Bistafa, Gurgel & Paltsev, 2016). Following this, new investments in the ethanol sector stopped due to the economic crises that started in 2008; poor harvests related to severe weather and soil management; as well as financial obligation (EPE,

[24] FFV (Flex-fuel vehicle) models already existed in the USA and run on gasoline and anhydrous ethanol blends. However, the first FFV model on the Brazilian market was Volkswagen Gol, launched in 2003 and operating with a mix of gasoline and hydrated ethanol (Barbosa Cortez, 2016: 46).

2016). Additionally, in an attempt to control inflation, the Brazilian federal government frizzed petrol price, making ethanol less competitive. According to Angelo (2012), ethanol's price for the consumers was so high in most Brazilian states in 2012 that it became cheaper to fill up Flex-fuel vehicles with gasoline that contain about 20% ethanol. Furthermore, the author states that a return to fossil fuels and the rapid growth of the vehicle fleet have increased urban air pollution and CO_2 emissions. Some producers had no choice to mitigate the financial problems but to sell their assets, and others went bankrupt or ceased operation. Data from de Brazilian Energy Research Agency (EPE) (2016) show that between 2011 and 2015, as many as ninety-two sugarcane mills closed, while only ten new ones were installed and thirteen were reopened.

From 2013 onwards, different governmental policies, directly or indirectly, have improved the sugar and alcohol sector's scenario, leading the industry to return to growth. The anhydrous alcohol percentage blended with gasoline went from 20% to 25% in 2013 and up to 27% in 2015; the gasoline price increased; BNDES (National Development Bank) created funding programmes to promote renovation and expansion of sugarcane plantations and ethanol storage (EPE, 2016). Another governmental initiative was the Biofuture Platform proposed by the Brazilian government to diverse prominent countries[25] around the globe, launched in 2016. The Platform is "a mechanism for policy dialogue and collaboration among leading countries, organisations, academia and the private sector conscious of the need to accelerate development and scale up the deployment of modern sustainable low carbon alternatives" (Biofuture Platform, 2018). One of its goals is to encourage the production and commercialisation of advanced low-carbon fuels, including second-generation ethanol, also known as

[25] Biofuture Platform's current Member States are Argentina, Brazil, Canada, China, Denmark, Egypt, Finland, France, India, Indonesia, Italy, Morocco, Mozambique, the Netherlands, Paraguay, the Philippines, Sweden, United Kingdom, United States, and Uruguay.

bioethanol. In that same direction, the Brazilian Congress approved in 2017 the Brazilian National Biofuels Policy known as RenovaBio. "The bill aims to reduce the carbon footprint of the national fuel mix as well as ensuring a long-term demand for low carbon fuels in the country" (Biofuture Platform, 2018: para. 1).

Despite several governmental initiatives in the last six years, Brazil's ethanol sector has plenty of room to grow. According to the National Agency of Petroleum, Natural Gas and Biofuels[26] (2019), the contribution rate of ethanol to the country's transport fuel market in 2018 was 18.9% against 76.7% of fossil-based fuel and a small share of 4.4% of biodiesel. These features undermine Brazil's 'ambitious' iNDC, which entered into force in 2016 and promises a significant reduction in the country's GHG emission until 2030.

3.4 Thermoelectric power: predominantly fossil fuel-based

Thermoelectric power plants are driven by a variety of heat sources such as mineral coal, fuel oil, natural gas, biomass, and uranium which is the fuel of nuclear power plants. The following section presents the Brazilian thermoelectric power.

Currently, the Brazilian installed thermoelectric capacity reaches over 46 GW generated by fossil fuels, biomass, and nuclear thermal plants (SIGA, 2020). From this total capacity, 29.3 GW (63%) is fossil fuel-based, with a total of 2.291 plants operating with petroleum products, mostly small diesel generators; 167 plants powered by natural gas; twenty-three coal-fired units and four plants powered by process heat from other fossil fuels. As for biomass, the installed capacity is 15.3 GW (32.6%) generated predominantly by sugarcane bagasse-powered

[26] ANP in Portuguese.

plants (11.6 GW), complemented by units operating with a wide variety of biomass such as agro-industrial waste, liquid biofuels, forestry waste, animal waste and solid urban waste. The nuclear-installed capacity is close to 2 GW, generated by two plants (Angra 1 and Angra 2) (SIGA, 2020).

The Decennial Energy Expansion Plan 2027 (PDE 2027 in Portuguese) published in 2018 by the Ministry of Mines and Energy and the Brazilian Energy Research Agency emphasises that the expansion of coal-fired thermoelectric plants encounters obstacles in the environmental legislation, but it considers the possibility that new plants may become part of the expansion of the electrical system, in case of the existing plants be replaced with more modern energy-efficient plants which are adapted with greater control of GHG emission as well as other pollutants. After the deactivation of the Charqueadas (72 MW), São Jerônimo (20 MW) and president Médici A and B (446 MW) plants, the installed capacity of the national coal-fired thermoelectric park is 1.227 MW added to 1,445 MW from the participation of three plants powered by imported coal –Porto Pecém I (720 MW), Porto Pecém II (365 MW) and Porto Itaqui (360 MW)– making a total of 2,672 MW. In 2019 with the entry of the Pampa Sul TPP (345 MW), which will also use national coal, the installed capacity for coal in the National Interconnected System (SIN) rose to 3,017 MW.

Today's Brazilian electricity grid relies on 2189 diesel-powered plants and another seventy-five units driven by different kinds of fuel oil (SIGA, 2020). The thermoelectric plants powered by diesel and fuel oil, which have their contracts terminated between 2019 and 2027, will be disconnected from the system on the respective contracts' expiration dates, decreasing approximately 3,000 MW of generation from these sources in the national grid until 2027. The supply of these thermoelectric plants will be replaced by plants powered by natural gas to keep up with the country's energy growing demand and, besides, it is expected that Brazil's third nuclear plant (Angra 3) will start its operation in 2026 (MME/EPE, 2018).

Natural gas is presented in the PDE 2027 as a reasonable path for the expansion of thermoelectric power. The demand for natural gas has increased due to its use as a substitute for other more polluting fossil fuels –such as coal and fuel oil– to mitigate GHG emissions as public concern about global warming has grown (Instituto Acende Brasil, 2016). Thermoelectric generation using natural gas stands out for its essential role in complementing hydroelectric generation, especially in the dry season, offering operational flexibility to the National Interconnected System (SIN in Portuguese), formed mainly by hydroelectric power plants. Furthermore, due to the expansion of intermittent renewable sources, such as wind and solar, natural gas-driven thermoelectric plants are considered an appropriate technology to be used in periods when wind and solar power generation is not available (Tolmasquim, 2016). In the short and medium-term, imported LNG (Liquid Natural Gas) represents the standard fuel for developing new plants. However, the development of pre-salt reserves, still with an uncertain horizon, could significantly expand the supply of national natural gas and, as a result, its contribution to the Brazilian energy grid. Taking into consideration the latent need for a steadier energy supply, nuclear expansion appears in the same document as an option to be considered (MME/EPE, 2018).

The primary biomass used for electricity generation in Brazil is sugarcane bagasse, and it has been growing, mostly because of the strong ethanol and sugar industry in the country that started with the National Alcohol Programme (Proálcool) in 1975. Biomass-based energy generated by thermoelectric plants is also called bioelectricity as it is considered to be a type of renewable energy. Bioelectricity in Brazil is mainly obtained through cogeneration[27] units within the sugar-energy

[27] Cogeneration is the process that allows the combined generation of electrical and thermal energy, both of which are used by sugar and alcohol production plants.

industry and, to a lesser extent, in paper and cellulose factories, with black liquor as an energy source. Depending on the energy efficiency of these units, there may be a surplus generation of bioelectricity that can be sold to power supply companies. However, a considerable number of units – especially in the sugar-energy sector – only meets its own energy demands (heat and electricity) with little or no surplus. This scenario has been slowly improving in the last two decades as both sugar and alcohol and paper and cellulose industries have expanded and implemented more modern units which are more efficient in cogeneration and energy use. This modernisation led to more significant bioelectricity surpluses and increased revenues. As a result, bioelectricity started to play a key role in complementing and diversifying Brazil's power supply (Tolmasquim, 2016).

From the total electricity supply in Brazil, 27.01% is generated by thermoelectric plants, being 1.67% by nuclear units. The larger share of 25.36% is generated by fossil fuel-powered units (65.91%) and biomass (34.09%). The fraction corresponding to biomass is divided into sugarcane bagasse (76.44%) and black liquor (16.76%). The other biomass types used in electricity generation in Brazil are forest residues, solid urban residues (incineration and gasification), firewood, rice husks, elephant grass, charcoal, vegetable oils and ethanol. These sources together represent 6.78% of the total biomass generation (SIGA, 2020).

Despite the efforts to maintain the Brazilian electricity grid predominantly renewable-based, the implementation pace of new hydroelectric plants, as well as the slow expansion and intermittency of renewable sources such as wind and solar, do not allow sectoral planning to abandon the thermoelectric options. Thermoelectric plants have beneficial characteristics, such as operational flexibility and less climatic vulnerability, which brings reliability to the system and gives the country greater energy security (Tolmasquim, 2016). Moreover, it is possible to implement thermoelectric plants in areas close to the consumption's centres, reducing losses and socio-environmental impacts inherent to extensive transmission lines. Furthermore, thermoelectric plants need relatively small areas when compared to other sources of energy. This fact associated with flexibility in the choice of site prevents conflicts over land use.

3.4.1 Nuclear energy: risky alternative

The Brazilian government first showed interest in using nuclear energy in the early 1950s with the creation of the National Research Council (CNPq in Portuguese), which happened under President Vargas' initial plan of having autonomy in research development. At first, CNPq was divided into two parts, one part being devoted exclusively to nuclear research (Carpes, 2006). The nuclear research sector was disbanded from CNPq in 1956, with the creation of the National Nuclear Energy Commission (CNEN). This commission was attached to the Ministry of Mines and Energy after its creation in 1960. CNEN took control of the Brazilian nuclear policy, which was conducted with close collaboration from the United States. Under the USA's *Atoms for Peace* programme,[28] an American nuclear reactor was installed in Brazil to develop atomic energy research.

In the 1950s and 1960s, Brazil signed cooperation agreements for the peaceful use[29] of nuclear energy with the following countries: Italy, Paraguay, Portugal, Switzerland, Peru, Bolivia, India, Spain, France,[30] USA,[31] and Germany. With the last three countries, Brazil has also

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[28] The programme originated from the "Atoms for Peace" speech of American President Dwight Eisenhower at the United Nations, pointing out the need to develop a peaceful application of nuclear power.

[29] In 1970, the Treaty on the Non-Proliferation of nuclear weapons was signed, also known as the Non-Proliferation Treaty or NPT, recognising the right of signatory countries to develop and use nuclear energy for peaceful purposes. Currently, 191 countries have signed the Treaty (UNODA, 2019).

[30] In 1974 an agreement was signed with France for knowledge transfer in nuclear reactors operation.

[31] Cooperation between the US and Brazil began in the 1940s when the two countries signed two agreements for the prospecting and trading of radioactive minerals. From then on,

reached an agreement for nuclear energy's civil use (technological and commercial). The cooperation agreement for the peaceful use of nuclear energy between Brazil and the United States was signed in 1965.

Although Brazil had signed a technology cooperation agreement with Germany in 1969, the county went through its previous agreement with the United States and in 1972 agreed to receive American enriched uranium in exchange for Brazilian natural uranium. Additionally, a contract was signed with the American company Westinghouse for the settlement of the first power reactor in Brazil, starting in the same year the construction of nuclear power plant Angra 1. Herewith the Brazilian government decided for the further use of enriched uranium and light water[32] in its reactors. According to Carpes (2006), this policy proved to be contradictory since the adoption of international cooperation policy and the signing of such agreements restricted the national scientific development in the field and thus contrasted with the interest in expanding the country's nuclear sector. In spite of the political divergence between those in favour of importing US technology and those who wanted to develop a national technology, the 1971 purchase of the American reactor to be installed at Angra 1 represented the victory of the group in favour of the development of a nuclear policy associated with US technology, contrary to the national-developmental character of the ongoing military regime. However, with the advent of the 1973 oil crisis, the international nuclear reactor market grew, causing the United States to suspend the uranium supply. To continue the ongoing nuclear projects, the Geisel government (1974-1979) expanded in 1975 the agreement signed with Germany six years earlier, ensuring the transfer of technology for uranium enrichment, construction of nuclear power plants and radioactive minerals prospecting equipment (CNEN, 2010). The PND 2, development plan implemented by Geisel prioritised the

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several other agreements were signed, mainly cooperation agreements for the civil use of nuclear energy (CNEN, 2010).

[32] Opposed to the use of natural uranium reactors and heavy water, a nuclear programme started in the 1950s.

reduction of Brazil's dependence on external energy sources and, therefore, stimulated large projects in the Brazilian energy sector. Through the PND2, the government allocated large investments to the construction of nuclear plants in an attempt to meet the energy demand generated by the 1973 oil crisis.

Initially, the Brazil-Germany agreement aimed to construct eight nuclear reactors, but only two were concluded because of the lack of financial resources and domestic and foreign criticism. The reasons leading to the agreement concerned Brazil's energy demand, at that time and in the future, due to the increase in population and industry production. In this regard, COPPE[33] researchers criticised the government's initiative by stating that Eletrobras had underestimated the existing water resources in the Brazilian territory for electric power generation and overestimated the country's energy needs in the early 21st century (Silva, 2006).

President José Sarney (1985-1990) introduced an agenda that aimed to restore Brazil's credibility within an international scope after two decades of a military regime. In this regard, the Brazilian Nuclear Programme was particularly useful. The Sarney government had the task of making the transition between the military dictatorship and a democratic civil government, and therefore it was necessary to value the achievements of the previous administration. It was equally important to maintain and capitalise on the scientific and technological development in nuclear research achieved so far. Additionally, it was also essential to dispel any uncertainty about the intended peaceful purpose of Brazil's nuclear sector (Carpes, 2006).

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In the Lula government (2003-2011), the Brazilian Nuclear Programme (PNB) was strengthened again as in the Geisel and Sarney[34] governments. In addition to contributing to Brazil's insertion in the international scenario, President Lula da Silva linked the nuclear energy sector to his agenda of valorisation of science and technology for the country's development. The PNB began in the 1950s but only gained relevance in the 1970s. Since then, its growth has gone through ups and downs and slowly evolved, but it has been able to include the production of nuclear fuel in its portfolio. As of 2006, the first module of uranium enrichment equipment plant was inaugurated at the Nuclear Fuel Factory (FCN), a centre within Brazilian Nuclear Industries (INB) in the city of Resende, in the state of Rio de Janeiro. The Uranium Enrichment Plant has been implemented in distinct stages, and its third module is already implemented since 2018. According to information released by INB (2019), Brazil is predicted to be self-sufficient in nuclear fuel production by 2037.

Today Brazil has two nuclear plants in operation, Angra 1, and Angra 2, and a third one, Angra 3, is still under construction (see Appendix 4). The three plants form the Almirante Álvaro Alberto Nuclear Power Station (CNAAA), located in the city of Angra dos Reis, in the state of Rio de Janeiro. Angra 1 was the first nuclear power plant built in Brazil. Its construction started in 1972, and it has 640 megawatts of power (IEA, 2019). The equipment for its construction was purchased from the American company Westinghouse in a 'turnkey' condition, that is, ready to be installed and did not provide for technology transfer by the suppliers (Eletrobras Eletronuclear, 2019). Angra 1 entered commercial operation in 1985. The construction of the nuclear plant Angra 2 began in 1981, but the pace of the activities slowed down from 1983 onwards due to the economic crisis that burdened the country at that time,

[34] Geisel and Sarney's administrations are considered the milestones in raising the nuclear issue to state policy (Carpes, 2006). Although the FHC government did not highlight the PNE, it was in his administration that Eletrobras Eletronuclear was created in 1997 as a subsidiary of Eletrobras (created 35 years earlier) to operate and build thermonuclear plants in Brazil.

stopping permanently in 1986. The unit was resumed in late 1994 and completed in 2000. The plant has a German technology reactor, resulting from the 1975 agreement. Angra 2 has a power of 1,350 megawatts (IEA, 2019) that can meet the energy demand of a city with up to two million inhabitants.

Angra 3 nuclear power plant is planned to generate 1405 megawatts (IEA, 2019). Its construction started in 2010. Its completion was scheduled for 2021 but has been interrupted since 2015 because of allegations of corruption in its construction bidding and contracting processes. According to Simbalista (2017), Eletrobras suspended civil engineering and building contracts after the Car Wash investigation uncovered a corruption scheme within its subsidiary Eletronuclear in mid-2015, leading to the imprisonment of Eletronuclear's chairperson, the Vice-Admiral Othon Pinheiro da Silva, a senior navy officer renowned for his expertise on nuclear energy (Netto, 2019). Following the corruption scandal, the company ran out of funding, delaying construction beyond 2018, even though Angra 3's design work and major equipment are already around 70 per cent completed or manufactured and stored on-site (Simbalista, 2017). Information about the resumption of Angra 3 released by Canal Energia Group and ratified by the Brazilian nuclear energy association (ABEN) indicates that building activities would resume in the first half of 2021. The Decennial Energy Expansion Plan 2027 (MME/EPE, 2018) indicates the start of the plant's commercial operation for January 2026.

Nuclear power is considered an alternative to the growing demand for energy in Brazil. Especially because of the large reserves of uranium in the national territory and know-how in uranium enrichment technology. In 2016, Brazil began to export enriched uranium to Argentina through INB (Brazilian Nuclear Industries). Brazil is currently the only country in Latin America that has mastered the technology needed for nuclear fuel production (Andrade, Silva, Hillebrandt & Franco, 2018). The development of a national nuclear technology attenuates the debates on the increase of energy demand in the country and presents nuclear power as an alternative to mitigate the effects of fossil fuels on the environment since nuclear energy is considered clean because of its low GHG emission index (Quintella, 2019). However, there is a constant fear of possible radioactive leakages added to the doubt whether Brazil is prepared or not to handle large disasters (Quintella, 2019) such as Chernobyl in 1986 and Fukushima in 2011. These events bring back the anti-nuclear movement's concern, which has affected the public's general opposition to nuclear energy (Bradshaw, 2018). These particularities involving nuclear power generation have contributed towards the development of policies to foment the use of other clean energy sources such as wind, solar and biomass.

Brazil has a much-diversified energy matrix. Although the generation of energy in Brazil has expanded with the use of renewable sources, most of the energy injected into the Brazilian power grid comes from traditional sources of energy. The electricity sector uses thermoelectric plants powered by fossil fuels (coal and diesel), as well as sources considered renewable (hydroelectric and nuclear energy). Large hydroelectric plants produce most of the electricity consumed in Brazil as a result of the abundance of water resources and the country's tradition of building dams. However, a change in this sector is necessary because of the environmental and social damage caused by large dams. In addition, with ongoing climate change, the risk of severe droughts resulting in a decrease in the country's water resources is great. The transport sector also makes use of renewable fuels such as ethanol. However, the most used power in the sector is fossil fuel based. Around three-quarters of the Brazilian fleet is powered by gasoline and diesel. Due to the country's continental dimensions and its mostly road-based transport sector, a radical change in the transport sector is necessary to guarantee the reduction of GHG emissions in the country. The search for alternative sources of energy in the world is growing worldwide. Likewise, Brazil has also been developing its renewable energy industry.

The share of renewable sources in the Brazilian energy sector will be addressed in the following chapter.