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Energy transitions and climate security in Brazil

Fabio Farinosi

Introduction

As of 2014, Brazil was the world’s fifth largest country and the seventh largest economy.¹ The majority of its population of about 206 million inhabits the main cities – 85% of the total in urban areas, mainly in the coast.² Sao Paulo, its largest metropolitan region, hosts the biggest financial market in South America and one of the most important ones in the world. In 2014, the service sector accounted for 71% of the total GDP (~2.2 trillion US$), followed by the industrial sector (23.5%) and agriculture (5.5%). The country’s exports largely consist of the exploitation of natural resources (iron ore, manganese, bauxite, nickel and limestone) and agriculture (soybean, sugar cane, corn, and wheat). Brazil’s endowment of natural resources is extensive and sufficient to ensure the country’s energy self-sufficiency.³ Brazil is amongst the countries that draw the highest share of their energy supply from renewable resources. While the world average is a mere 13% of total energy supply, Brazil stands out as a clear outlier with over 43% of the total energy mix.⁴ The contribution of renewable energy is made possible by the extensive exploitation of the complex and extremely abundant hydrological system for electricity generation. Brazil has, in fact, the world’s second largest hydropower installed capacity after China. In 2014, hydropower represented about 70% of the total installed capacity and 80% of the total electricity produced.⁵ Biomass, ethanol, and biodiesel are also extremely important for the Brazilian energy sector. Moreover, the recent discoveries of offshore oil and natural gas reserves are expected to change the role of fossil fuels in the future energy balance.

Given the large share of renewables in the country’s energy balance, the Brazilian energy sector’s environmental impact in terms of CO₂ emissions is fairly limited, at least when compared to other developing countries. The main sources of emissions are non-energy sectors, such as land use change for the conversion to agriculture and livestock production of forested areas, and agriculture. This situation could change in the future if the Brazilian system fails in boosting the large economic development while at the same time keeping its energy sector eco-friendly.

Driven by robust economic growth, Brazil has more than doubled energy consumption in the past two decades (Figure 16.1) and future projections expect this trend to continue over the next years.⁶ In the last decade, economic growth has been combined with initiatives aimed at including the weakest parts of the population in the development process. Social programs were
The Bolsa família (family allowance) program started in 2003 and brought more than 25 million people out of poverty in a decade. This was combined with other programs like Luz para todos (light for all), a strategy that provided access to electricity to almost 15 million people, thereby bringing the electrification rate in the country to 99% of households, and substantially boosting the internal energy demand. Large investments in the whole energy sector, considered strategic to support future development, are currently planned by the Brazilian Government. For instance, only for the electricity sector, national studies on electricity demand trends, in line with the elaborations carried out by the International Energy Agency (IEA), evaluated that Brazil needs an additional 6 GW per year in generation capacity in the next two decades. Moreover, investments in fossil fueled and nuclear power generation are planned to increase, so as to diversify the system. This is crucial to minimize the vulnerabilities of the electricity sector caused by the impacts of climate variability and change on hydropower. However, the recent economic crisis, exacerbated by the corruption scandal involving Petrobras (the main Brazilian oil company), are expected to cause a delay in the ambitious investment plans illustrated in the two main documents elaborated by the Ministry of Energy (MME) and its technical office (EPE): the 30 year and 10 years energy plans.

The Brazilian energy sector is extremely dynamic; nevertheless, hard challenges are expected in the near future. In this context, the chapter seeks to answer the following questions: how has Brazil historically dealt with satisfying the main objectives of energy security and economic competitiveness? Historically, the sustainability of Brazil’s energy sector has mainly originated from economic opportunity more than environmental consciousness. In a rapidly expanding economy, will climate security still be a defining trait of the Brazilian energy sector? Is Brazil going to succeed in managing the interplay between energy security, competitiveness, and climate-related dynamics?

The Brazilian energy mix

The Brazilian energy mix consists of a large chunk of renewables, which is a very peculiar characteristic both comparing to the developed and other developing countries (Figure 16.2). Bioenergy sources – sugar cane derived products, solid biomass, biodiesel, and hydropower – represent...
almost half of the primary energy supply. Fossil fuel demand is mainly covered by oil, which is still the main component of the energy balance (~40%); natural gas demand is constantly increasing, but, as of 2014, its role still remains relatively small in comparison to the other, more traditional, sources in Brazil. Compared to other BRICS countries, coal has a very modest share but it remains an important source for heavy industry.

The industrial and transport sectors are mainly responsible for growing energy demand. Industrial demand has significantly increased in the period 1990–2011, by about 3.5% a year. The iron and steel industries represent an important share of industrial demand. The transport sector’s demand increased at an even higher pace (about 4%) following the general economic development and in particular the growth of agriculture in the central area of the country. The main means of transportation in Brazil are via road and air. The country’s railways system is still underdeveloped and transporting goods on water is significant only on the coastal areas, and much less on the inland waterways.

Residential demand grew at a significantly lower pace (about 2%), partially due to the increasing use of modern and efficient electrical appliances instead of the use of traditional biomass, and due to high energy prices.10

The extensive use of biofuels in the transport sector, mainly sugar cane derived ethanol and bio-diesel, finds its roots in the early 1970s when the world suffered the first oil crisis. The initial approach was based on vehicles fully powered with ethanol. In the 1990s, due to a general shortfall in ethanol supply, the demand for more flexible technology rose, until the introduction in the early 2000s of flex-fuel vehicles. This technology allows the use of both

Figure 16.2 Brazil energy balance in 2014 – data in Mtoe
Source: MME, and EPE, Balanco Energetico Nacional.
fossil and bio-fuels, making the consumer more resilient to the relative price volatility of different energy sources. Ethanol is blended with gasoline with a mandated level ranging between 18% and 25%, while bio-diesel, mainly derived from soybean oil is blended with fossil diesel with a mandated level of about 5%. Liquid biofuels are not the only example of bioenergy in the Brazilian balance. Firewood is still widely used in Brazilian households, while the extensive agricultural production in the country is a source of cheap biomass for electricity and heat.

The country’s electricity mix (Figure 16.3) is historically dominated by hydropower. The economic growth-boosted increasing demand for electricity and the hydropower sector’s high vulnerability to climate variability raised the debate about the need for a larger diversification of sources. The energy planning operations in Brazil significantly changed after the electricity crisis of the summer 2001–2002, when an unusually prolonged drought, combined with a demand growing faster than the installed capacity, led to the rationing of electricity for a significant period of time. The investments in fossil fuel and biomass thermal installed capacity, in the last decade, made the system more resilient, but not enough to avoid the tangible risk of new power rationing in January 2015. A deeper interconnection with neighboring countries, such as Argentina and Uruguay, has been planned to reduce vulnerability. Large investments are also planned for the exploitation of other natural sources abundant in the country, like solar and wind power.

Energy security

Vulnerability of the electric system: the 2001/2002 electricity crisis and the response of the Brazilian institutions

The Brazilian electricity system is extremely interconnected. The country is divided into different regions and the demand for electricity in a specific portion of the grid is constantly coordinated with the supply capacity of the whole system. Responsible for the operation of the system is a specific technical institution called National Power System Operator (ONS – Operador Nacional do Sistema Eletrico). The real time operation of a complex system, even if not very diversified, allowed a big country such as Brazil to manage the potential shortages due to...
climate variability in a portion of the country – with the correct management of stored resources in other regions. For instance, if the north-east of the country was affected by a prolonged drought, the ONS could satisfy the demand from this region using some of the operating reserve stored in the large reservoirs in the south. This system worked fairly well until the end of 1990s. In this period, the generation capacity consisted of more than 85% hydropower (Figure 16.4), but the size of the system was relatively big with respect to demand, and therefore resilient to spatial and temporal weather related shocks. The situation changed with the economic growth that sensibly boosted the demand for electricity (Figure 16.1). Increasing demand in the 1990s was not supported by adequate investments in new generation capacity. In the early 2000s, a prolonged drought noticeably reduced the operating reserves of the large hydropower reservoirs in the south and south-east of the country. In the summer 2001–2002, high temperatures boosted electricity demand. The system was operating at maximum capacity, but this was not enough to satisfy demand. Between July 2001 and February 2002, the electricity available was rationed to 80% of the historical consumption. The privatization process started in 1996 with the establishment of the National Electric Energy Agency (ANEEL), but was drastically interrupted and the government re-established its total control of the electricity sector. In 2004, in order to ensure security of energy supply, control energy prices and promote access to electricity for the entire population, the Federal Government reformed the electricity sector. Three new organizations were created: the Energy Research Bureau (EPE) in charge of long term planning; Electric Sector Monitoring Committee (CMSE) aimed at monitoring the security of the electricity supply; and the Chamber of Commerce of Electric Energy (CCEE), aimed at managing the internal electricity market. A new pattern of development for the electricity sector was created. New generation capacity was installed and strategic diversification of the sources promoted. The contribution of fossil fuels, especially natural gas, and solid biomass became more significant (Figure 16.3). New investments in nuclear generation were also planned. As of 2014, only 4% of Brazil’s electricity generation came from nuclear. Two reactors are active in the state of Rio de Janeiro, a third one is currently under construction and

![Figure 16.4 Trends in electricity consumption, total installed capacity, and share of capacity represented by hydropower. Period 1980–2012](http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm#)

expected to be operative in 2018; seven more plants are planned for 2030. In 2008, the country also signed an international nuclear cooperation agreement with Argentina.18

The actions adopted after 2003 significantly boosted the generation capacity and made the matrix less dependent on hydropower, which saw its share decrease from 85% to 69% (Figure 16.4). These actions reduced the vulnerability of the Brazilian electricity system, but its resilience to shocks still needs to be increased: between 2011 and 2014 more than 180 blackouts were recorded;19 moreover, in the period 2014–2015, a new significant drought hit the country with the risk of renewed emergency and new electricity rationing.20

**Hydropower still protagonist in the country’s electricity generation**

Even though the recent offshore discoveries of fossil fuels may turn Brazil to a leading force in the oil sector, hydropower remains the main pillar of the country’s energy strategy.21 As of 2015, Brazil has developed only one-third of its estimated hydropower potential. The total potential estimated for the country’s rich and complex hydrological system is approximately 245 GW.22 According to the 2012–2022 Development Plan, issued by the MME in collaboration with the EPE, the hydropower installed capacity is expected to increase from 85 to 119 GW (about 40%).23 The IEA estimates that 42 GW of additional installed hydropower capacity is to be developed in the period 2021–2035.24 More recent economic projections, depressed by the economic crisis in 2015 will probably push the Brazilian authorities to postpone, at least in the short term, part of the ambitious investments in new generation capacity.

The reasons driving the large-scale exploitation of hydropower potential are various: hydropower represents a clean, extremely flexible and economically convenient source of electricity production. Moreover, the construction of dams and reservoirs presents several positive impacts both in the short run in terms of employment, and in the longer run in terms of water supply for human activities and flow regulation.25 Notwithstanding the large potential hydropower has, this option is also strongly dependent on meteorological variability and climate trends. Increasing concerns are animating the debate about the vulnerability of hydropower technologies to climate change and the possibility for this important renewable source to sustain its future development.26 Moreover, in order to minimize environmental and social impacts, prospective new reservoirs are relatively small in size (mainly run-of-the-river technology), a trend which is expected to significantly increase the vulnerability of the hydropower sector to climate change.27 Most of the hydropower potential of Brazil is in the Amazon basin, a critical area both from the environmental and social points of view. The development of these new installations is therefore subject to increasing constraints aimed at minimizing the social and environmental impacts that such new infrastructures may cause. This is the case, for example, of Belo Monte. This hydropower plant, the second largest in Brazil (the third in the world), is currently under construction on the Xingu river, one of the tributaries of the Amazon. Tensions with the local population and international concerns about the impact of such project on the valuable ecosystem’s diversity significantly limited the possibility to construct a reservoir able to buffer the intra- and inter-annual variability of the streamflow. The plant’s peak capacity of 11,233 MW is expected to be fully exploited only between February and May, when the Xingu reaches its maximum flow. The resulting average capacity factor for this plant is expected to be about 40%, only a bit more than half of the performance of the Itaipu installation in the last decade (77%).28 On the other hand, climate and land use changes are expected to seriously impact the precipitation and runoff patterns in Brazil. All these factors seriously threaten the country’s energy security, with potentially serious challenges for economic and social development. A recent report issued by the Secretariat for Strategic Affairs (SAE), an institution aimed at long-term
planning of economic and social development, brought attention to the possible impacts of climate change on Brazilian hydropower generation\textsuperscript{29} quantifying the losses in the range between 7\% and 30\% against the historical generation.\textsuperscript{30} Another characteristic of the planned expansion of the hydropower installation is that the majority of the new plants are designed with run-of-the-river technology. This means that the productivity of the hydropower sector would be increasingly affected by the seasonality of the river flows: a big challenge for the system’s operation. International and local technical institutions suggest that this problem could be offset by investing in the country’s wind energy potential, estimated at about 140 GW and characterized by an inverse seasonality as compared to the hydrological resources.\textsuperscript{31}

**Electricity transmission grid**

Brazil is the world’s fifth largest country and, due to its vast landmass, the generation of electricity is not always located close to the consumption site. This is particularly true, for instance, in the case of the new hydropower installations Belo Monte and San Antonio, and for the planned large development in the Tapajos river basin. These infrastructures are located in the Amazon and Cerrado areas, but the electricity produced is destined for the big industrial and urban centers in the south-east of the country (Figure 16.5). Therefore, huge investments on the transmission grid are needed to reduce the relatively high distribution losses (Figure 16.3).

**Traditional sources: oil and natural gas**

The Brazilian energy mix also largely consists of fossil fuels. The transportation sector drives Brazilian demand for oil and oil derived products, while the diversification of the electricity generation sources, with minor contribution from the transport sector, drives the demand for natural gas.

The state-controlled Petrobras is the major actor in the fossil fuel sector, controlling the exploration, production, and refinement activities. The company had a monopoly of the market until 1997, but even after market liberalization the entrance of new competitors has been slow and made possible mainly in partnership with Petrobras.\textsuperscript{32}

In 2014, the country produced about 2.95 million barrels of oil per day, mainly from the offshore fields in the states of Rio de Janeiro, Sao Paulo, and Espirito Santo.\textsuperscript{33} In the past decades, demand for oil was constantly higher than the production, the liberalization of the market in 1997 and the permits for exploration and production (E&P) issued by the government to international oil companies boosted production to reach level of consumption for the first time in 2006 (panel (a) in Figure 16.6). The US Energy Information Agency estimated that the production could be stably higher than consumption in 2016, but this estimate could be affected by the recent corruption scandal that hit Petrobras and the whole Brazilian financial market.\textsuperscript{34}

The country’s refining capacity (2.4 million b/d of crude oil in 17 sites in 2014) is constantly increasing, but demand grew faster than the refinement capacity. Moreover, the Brazilian refineries do not have the technology to process heavy crude, so part of it is exported unprocessed and light crude is imported. Large investments had been made in the past few years to expand the refinement capacity (panel (b) in Figure 16.6). In the state of Pernambuco, at the end of 2014, the first units of a US$20 billion refinery, Abreu e Lima, started production. The expansion of this refinery was planned to start thereafter, but the owner of the industrial site, Petrobras, announced the postponement of the project’s second phase due to the financial difficulties caused by the 2015 scandal. Another big project was under development in the state of Rio the Janeiro, Complexo Petroquímico do Rio de Janeiro (Comperj). It was supposed to be
operational in 2016, but the investment was temporarily suspended in 2015.\textsuperscript{35} Two additional projects at the early stage of construction in the states of Ceará and Maranhão (Premium I and Premium II) were canceled.

Demand for natural gas in Brazil has historically been very low, almost negligible (Figure 16.7). It increased significantly due to the increasing demand for electricity and for the diversification of the electricity generation sources. Petrobras operates the national distribution grid covering mainly the south and south-eastern, and the north-eastern portions of the country. The two pipelines were connected only in 2010. Petrobras also owns the three existing regasification terminals. Natural gas is produced mainly in the coast of the Rio de Janeiro and Maranhão states. Bolivia, Argentina (connected to the land pipeline), Qatar, Spain and Trinidad (LNG) are the main suppliers of the imported natural gas.\textsuperscript{36}
New discoveries and the future of fossil fuels in Brazil

Brazil has been subject to major operations of exploration for inland and offshore hydrocarbons over the past thirty years. Large fossil reserves were recently discovered in the oilfields off the coasts of the states of Rio de Janeiro, Sao Paul, and Espirito Santo. The Brazilian Agency for Oil and Gas (ANP) reported proven reserves for about 16.2 billion barrels\(^3\) of oil and about 470 billion m\(^3\) natural gas (Figure 16.8). The geology of the area of interest is made of a 2,000

\(\text{Figure 16.6} (a) \text{ Oil demand and internal production, (b) refined oil products import and export 1980–2014} \)

\(\text{Source: Authors’ elaboration based on EIA, “International Energy Statistics,” 2015.}\)

\(\text{Figure 16.7} \text{ Natural gas demand and internal production 1980–2014.} \)

\(\text{Source: Authors’ elaboration based on US EIA, 2015, Brazil: International Energy Data and Analysis, www.eia.gov/beta/international/analysis.cfm?iso=BRA.}\)

New discoveries and the future of fossil fuels in Brazil
meter thick compressed salt and rock layer. Oil reserves are located partially above the salt layer (postsalt oil reserves) and mainly below (presalt oil reserves). The presalt oil reserves, the exact quantity of which is still unknown, could be substantial in volume and make Brazil one of the world leaders in fossil fuel production. The crude is of good quality and the gas to oil ratio is about 250–300 m$^3$ of gas per m$^3$ of oil. The extraction of presalt oil is extremely difficult due to the technical challenges involved in such a deep perforation, and it requires huge investments. The extraction of presalt oil reserves started in 2009 and represented in 2014 about 25% of the total production. Petrobras became the world leader in the production of very deep oil reserves through the use of floating production, storage, and offloading (FPSO) facilities. The corruption scandal now hitting the company could affect the future presalt reserves exploitation, at least in the short term. Moreover, the second half of 2015 was characterized by very low quotations of crude oil: not a very favorable market condition for the profitable commercialization of the presalt oil, since its cost of extraction was estimated between US$41 and US$57 per barrel.

**Economic competitiveness**

While analyzing the Brazilian energy sector, it is possible to paint the profile of a country that in a relatively short time period has managed its huge and variegated natural resources to become a major player in the global economic scene. Part of the story could be defined as successful, another less so, but it is above-all important to underline how the country and its institutions are facing the challenges of fast development with a peaceful and democratic approach, maximizing social inclusion and minimizing the socio-environmental impacts. Many issues have been identified under the energy security perspective in the previous section. The majority of these issues are carefully analyzed and approached by the competent Brazilian technical institutions with the short and medium term development plans mentioned above: Decadal Energy Development Plan (Plano Decenal de Expansao de Energia), National Energy Plan 2030 (Plano...
The main messages could be summarized as need for huge investments in all the specific components of the energy system aiming at achieving: increasing production of fossil fuels; increasing refining capacity; increasing electricity generation capacity; diversification of sources; enhancing the distribution infrastructures; deeper integration of the energy system with neighboring countries. Huge investments that could not be possible without the involvement of the private sector: the country and its institutions have been facing the challenges of balancing the internal economic interests with the attractiveness for international capital.

In 2007, the Brazilian government launched the Growth Acceleration Program (Programa de Aceleração do Crescimento). In its second phase (2011–2014), the program allocated about US$250 billion to the energy sector. The rationale of this investment program is clearly to boost the sector and attract private capital. Foreign investors in the energy sector face a complex mix of structural, bureaucratic and economic difficulties, often referred to as Brazil Cost (Custo Brasil), which make investments in the country less attractive. This problem has many consequences: the slow implementation of development plans; the vulnerability of the country’s economic development to shocks in the energy and energy-related sectors; high final costs of energy hindering investments in other economic sectors. As for the last point, an example comes from electricity consumer prices in the country. Per capita electricity consumption in Brazil remains very low relative to other similar countries, like South Africa or China. As of 2012, the price paid for electricity by the Brazilian industrial sector was about $178 per megawatt-hour (MWh), while the domestic consumption was priced about $237/MWh. Industrial energy prices were higher than average prices in Europe and almost four times the prices in the United States. This significantly constrained the development of most of the energy intensive industries (chemicals, iron and steel, glass, ceramics, aluminum, and pulp and paper). An example of the energy sector’s and, in turn, the national economy’s vulnerability to shocks, comes from the close connections that the national economy has with the two main actors of Brazilian energy management: the state-controlled Eletrobras and Petrobras. In particular, the latter has been involved in a corruption scandal in 2015 that destabilized the entire country’s financial sector.

**Petróleo Brasileiro S.A. (Petrobras) and the 2014–2015 corruption scandal**

Petrobras is the largest company in the southern hemisphere; it was founded in 1953 and held the monopoly of the fossil fuels sector in Brazil till the 1997 privatization reform. The company is the major investor in the presalt exploration and production activities. The majority of the foreign companies that entered the market after the 1997 liberalization still operate in partnership with this state-controlled company: this, on the one hand, is justified by technical reasons given that Petrobras is the leader in presalt exploration and production, but also because the partnership with the state-controlled company to a large extent facilitates the interaction with Brazilian institutions. In 2014, Petrobras was investigated in Brazil and in the United States for bribery and money laundering. The investigation hit the management of the company and top members of the Brazilian institutions. The scandal had direct and indirect impacts on the company’s operations: first, it cost more than US$8 billion; second, the inability of the company to get its financial statements certified kept Petrobras from accessing the international capital market. All this happened in a moment when the economic exposure of the company was particularly high: with about US$110 billion debt, it was rated as the most indebted company in the world in 2013; while its valuation passed from US$200 billion in 2011 to US$27 billion in December 2015. The main consequence of this crisis was the immediate reduction of the
company’s short term investment plans: investments decreased by about 17% between 2013 and 2014, by an additional 25% in the period 2015/16. In 2015, the 5-year investment plan set the oil and gas production targets (national and international) to 3.7 million barrels of oil equivalent per day in 2020, markedly lower than the targets of 5.0 and 4.0 million b/d set respectively in 2013 and 2014. This situation had a great impact on Brazil’s economy and its credibility in the international financial market. The country’s sovereign debt reached 62% of GDP and its rating was labeled as “junk” by international rating agencies. The Brazilian Real touched its 10 year low value compared to the US dollar, the inflation rate skyrocketed, and the unemployment rate rose significantly.

**Fossil fuel exploration and production licensing and the “local content” requirement**

Before the presalt discoveries and after the 1997 market liberalization, all the companies were allowed by Brazilian law to win concessions for exploration and production. In 2010, with the intent to maximize the national gains deriving from large presalt discoveries, the regulation was changed. While for the postsalt reserves the concession system did not change, a new state controlled company, Pré-Sal Petróleo SA, de facto a subsidiary of Petrobras, was created to manage presalt oil and natural gas exploration and production. The second step of the reform was to provide capitalization to Petrobras through 5 billion barrels of unlicensed presalt reserves in exchange for a larger share of the company. In practice, for the postsalt reserves the concession-holder owns the oil produced after the payment of royalties and taxes, without any partnership (at least officially) with the state-controlled company. For the presalt reserves Petrobras is formally involved in each concession with a minimum share of 30%.

Another limitation to the economic profitability and development of presalt reserves concerns the “local content” requirement that the Brazilian government imposes in every concession issued. Practically, the concession winner is requested to purchase a share (up to 65%) of the components used for the exploration and production from national industries. This could seriously limit the development of ultra-deep-water exploration and production, where the technological component is crucial.

Similar considerations hold for the natural gas market. From the legal point of view, after 1997, private companies could participate in the operations of each stage of natural gas production and distribution. However, Petrobras remains the main operator of the sector, controls the pipeline operator importing Bolivian gas and owns the existing regasification facilities. In 2013, of the 27 companies distributing natural gas to the final consumer, 21 were partially owned by Petrobras.

**Licensing for electricity generation capacity**

Many studies underline the need for simplification of the licensing process for the installation of new generation in the Brazilian electricity sector, especially regarding new hydropower installation. In order to achieve more effective, faster and cheaper licensing, five aspects were highlighted: the need for clear distinction between federal and state government competencies; the introduction of a dedicated dispute resolution mechanism in the environmental licensing process; the possibility to activate the process of licensing for different projects in the same river basin; clearer specifications of the Environmental Impact Assessment contents; a more careful consideration of the uncertainties linked to each of the projects, in its financial, environmental, and socio-economic aspects.
Climate security

As highlighted in the previous sections, the Brazilian energy matrix is extremely friendly to the environment. The main source of Brazil’s GHG emissions is represented by the change in land use. The deforestation rate was a serious concern between the 1990s and the early 2000s. After the reforms in the early 2000s, namely, the Action Plan to Prevent and Control Deforestation in the Amazon, the Action Plan to Prevent and Control Deforestation and Fire in the Cerrado, and the Low-Carbon Agriculture Plan, emissions linked to land use change dropped significantly. The sector responsible for the largest share of emissions in the recent past is that of agriculture.\(^{54}\)

Regarding climate security, it is important to distinguish between the potential impacts of climate change on the Brazilian energy sector, and the impact of the energy sector on climate.

Climate change impacts on the Brazilian energy sector

The main impacts that climate change could have on the Brazilian energy sector are:\(^{55}\)

- alterations of the hydrological cycles with consequent possible reduction of the hydropower output;\(^{56}\)
- increasing intra- and inter-annual variability of the run-of-the-river hydropower output;\(^{57}\)
- uncertain impact on the potential windpower capacity, decline\(^{58}\) or increase;\(^{59}\)
- reduction of the output of thermal power plants estimated at about 2%; and\(^{60}\)
- uncertain impact on bioenergy: no change/slight increase of sugar cane production in the south, possible decrease of soybean in the Cerrado.\(^{61}\)

Energy related carbon dioxide emissions

It is important to underline that Brazil’s economy is one of the most efficient in the world, especially if compared to the other rising economies of the BRICS. As of 2011, the International Energy Agency estimated that Brazil emitted about 0.18 tonnes CO\(_2\) per thousand dollars of GDP produced. The value is considerably lower than other developing countries like China (~1.0 ton/$1000 GDP), India (~0.98 ton/$1000 GDP), Russia (~0.82 ton/$1000 GDP); but also compared to developed countries like the United States (~0.35 ton/$1000 GDP), those in the EU (~0.21 ton/$1000 GDP), and Japan (~0.2 ton/$1000 GDP).\(^{62}\) However, it has to be highlighted that with the increasing demand for fossil fuels in the Brazilian energy matrix, the energy related emissions have been rapidly increasing in the past 20 years reaching the threshold of 500 million metric tons (Figure 16.9).

In the recent 2015 Paris Conference of Parties (COP), the Brazilians pledged a 37% reduction of carbon dioxide emissions by 2025 relative to the levels of 2005, with a further indicative target of 43% by 2030 (Intended Nationally Determined Contribution – INDC\(^{63}\)). This ambitious goal could, indeed, be achieved if the future energy matrix respects the planned share of renewable sources.\(^{64}\) The MME and the EPE in the last 10-year development plan made a calculation of the possible emissions of the future Brazilian energy balance as calculated using their generation and consumption projections (Table 16.1). Attending to these projections, the energy sector should be able to maintain its level of emissions under the critical threshold fixed for respecting the Brazilian government pledges.\(^{65}\) However, a critical point that needs to be raised concerns the fact that the technically rigorous and well documented energy planning
developed by the Brazilian technical institutions is based on the stationarity assumption regarding future climate change. In case of high climate change impact on hydropower and thermal electricity production, for instance, the installation of new fossil fueled thermal generation capacity might be required to compensate for the losses. This aspect could partially modify the energy mix and, consequently, the emission scenarios projected in the 10-year energy plan.

Table 16.1 Carbon dioxide projection for Brazilian consumer sectors

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<th>Sector</th>
<th>(\text{MtCO}_2\text{eq})</th>
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<th>2020</th>
<th>2024</th>
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<td>46</td>
<td>62</td>
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<td>Energy</td>
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<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
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<td>21</td>
<td>22</td>
</tr>
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<td></td>
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<td>2</td>
<td>3</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Agricultural</td>
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<td>19</td>
<td>20</td>
<td>21</td>
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<td>237</td>
<td>269</td>
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<tr>
<td>Industry</td>
<td></td>
<td>96</td>
<td>113</td>
<td>127</td>
</tr>
<tr>
<td>Fugitive emissions</td>
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<td>22</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td><strong>489</strong></td>
<td><strong>502</strong></td>
<td><strong>577</strong></td>
</tr>
</tbody>
</table>

Source: MME, and EPE, _Plano Decenal de Expansao da Energia_ (2024).
Conclusions

This chapter describes the complex dynamics characterizing the Brazilian energy sector. Many critical points have been underlined under the perspectives of energy security, economic competitiveness and climate security. Brazilian institutions are managing the challenges presented by fast economic growth making huge changes in the country without compromising its social and environmental capital. The process of development has been socially inclusive and the participation of individuals in public decisions has been higher than in many other developing and developed countries in the world. Not all the strategies and actions implemented in the past two or three decades have been a full success, but definitely the whole story could be depicted as a successful one. In a few decades, Brazil became one of the top economies in the world. In less than 10 years, over 26 million people were lifted out of poverty. The income of the poorest part grew at a rate double that of the rest of the population. Indicators about education, health, infant mortality and nutrition show clear improvements even in the poorest part of the country. Access to electricity, clean water and sanitation is ensured for almost the whole population, even in some of the remotest parts of the vast territory.

The challenges for Brazil are not over. In order to persist on this positive trend and maximize the socio-economic benefits deriving from it, Brazil is called on to rapidly adapt its technological, institutional, and infrastructural systems to the dynamic requirements of the globalized world. The energy sector, object of this study, is crucial in this process. The country’s strengths in this regard are multiple: first, Brazil is blessed in terms of natural resources endowment; second, the country developed high competence on technical and strategic know-how – the very detailed and technically exemplary planning of the energy sector is a good example of this; third, the mindset of Brazilian people is positively predisposed to the changes and to meet the challenges posed by rapid development.

In order to support the economic development and the energy security of the country, international and Brazilian technical institutions highlighted several needs, such as: increasing production of fossil fuels; increasing refining capacity; increasing electricity generation capacity; diversification of sources; enhancing the distribution infrastructures; and deeper integration of the energy system with neighboring countries. Brazilian institutions proved to have the technical and practical competence to strategically offer a solution to each of these needs. The main problems seem to be represented by the economic and financial aspects concerning the implementation of the energy strategies. The attractiveness of private capital is crucial for the timely and correct implementation of the actions shaped in the strategy. In this regard, the financial, economic, industrial and institutional sectors of the country have shown a certain level of reluctance in fully opening the national market to international competition. A certain level of protectionism is still present in the Brazilian economic structure, in particular regarding the strategic and economically crucial energy sector. A more competitive market could increase the efficiency of the energy sector in the country. Increasing competition could maximize the benefits for other economic sectors as, for instance, more affordable energy prices for the growing industrial sector of the country. Moreover, it could maximize the capital flows needed for the adaptation of the energy sector to the needs of the country. In this way, implementing the planned actions, energy security could be rapidly achieved.

Regarding the climate security of the future Brazilian energy system, the main uncertainties are linked to the impacts of climate change on the future energy production. The system heavily relies on natural and renewable sources. A larger than expected climate change impact could potentially impose changes in the planned future energy matrix and, therefore, increase the demand for traditional energy. A more accurate planning of the transport sector, the most energy intensive and largest source of GHG emissions, would be desirable for achieving climate security.
Notes


15. MME, and EPE, *Plano Decenal de Expansao da Energia (2024)*.


23. EPE, and MME, *Plano Decenal de Expansao da Energia (2022)*.


28. Ibid.


30. Ibid., 47.


33 Agency for Oil and Gas (ANP), “Dados Estatísticos” (Agency for Oil and Gas, 2015), www.anp.gov.br/?pg=64555%26m=%26t1=%26t2=%26t3=%26t4=%E5%3C8%26cachebust=1408326992231.
34 EIA, Brazil: International Energy Data and Analysis.
35 Ibid.
36 EIA, Brazil: International Energy Data and Analysis; ANP, “Dados Estatísticos.”
37 Agency for Oil and Gas, www.anp.gov.br/?pg=64555%26m=%26t1=%26t2=%26t3=%26t4=%E5%3C8%26cachebust=1408326992231.
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41 MME, and EPE, Plano Decenal de Expansão da Energia (2024); MME, and EPE, Plano Nacional de Energia 2030.
43 Ibid.
44 Ibid.
45 https://ycharts.com/companies/PBR/market_cap.
46 EIA, Brazil: International Energy Data and Analysis.
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50 IEA, World Energy Outlook 2013; EIA, Brazil: International Energy Data and Analysis.
51 IEA, World Energy Outlook 2013; Gomes, Brazil: Country of the Future.
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60 de Lucena et al., “The Vulnerability of Wind Power.”
63 United Nations Framework Convention on Climate Change, http://www4.unfccc.int/submissions/INDC/Published%20Documents/Brazil/1/BRAZIL%20INDC%20ENGLISH%20FINAL.pdf.
64 MME, and EPE, Plano Decenal de Expansão da Energia (2024).
65 Ibid.
66 World Bank, “WDI – World Development Indicators Databank.”