# Electrical and energy expansion: improvements, risks and limitations of the proposed trajectories

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## Inesc

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# Executive Summary

This article is part of the effort to monitor socioenvironmental and climate policies in Brazil, carried out by the Institute of Socioeconomic Studies (Inesc). It presents an analysis between the energy adaptation plans and the fulfillment of climate targets voluntarily adopted by the country under the Paris Agreement (2015). Improvements, risks and limitations of the trajectories proposed for electrical and energy expansion are addressed, based on the 10-year Energy Expansion Plan, PDE 2030, and the National Energy Plan, PNE 2050.

From the PDE 2030 and PNE 2050, it becomes possible to identify a scenario that is close to stability, with respect to the supply of non-renewable and renewable energy in the Brazilian national electricity system. Both documents project a diversification of the electrical matrix, with a decrease in hydroelectric and thermal capacity. In addition, there is an increase in electricity generation through wind sources and self-production with distributed generation of renewable energy (80% solar).

Distributed generation is done in different points through generator systems that are close to the consumer unit (houses, companies, and industries) and connected to the public electricity grid. This system is seen as an alternative to large structures, such as hydroelectric power plants, which trigger significant socio-environmental impacts. However, it contrasts with the centralized model in the production and distribution of electricity, that has historically been the way to go in Brazil. Thus, the expansion of distributed generation requires adjustments to the current norms and regulations, and tests for new and different scenarios in order to assess the opportunities for even greater growth.

In both documents, the decrease of oil and its derivatives in the composition of the electrical matrix is now offset by the expansion of natural gas. In addition, the drop in supply of sugarcane products is offset by a greater presence of other renewable sources, such as wind and solar energy, soy biodiesel and black liquor. The introduction of soy as a raw material for the manufacture of biofuels triggers a warning from a socio-environmental and climatic point of view, which involves issues such as ecological risks due to the expansion of cultivation areas, the transformation of food crops into energy production crops, and the approaches that have been proposed on environmental licensing as a way to enable new businesses in the energy sector.

Environmental licensing stands out as an urgent matter. However, the aforementioned documents interpret it in a simplistic way, as a factor for the loss of competitiveness for hydroelectric generation. Along these lines, it is well known that none of the energy plans can produce an integrated analysis between the sector and the socio-environmental consequences caused by it, considering macro-regions and biomes in the country. As a result, potential impacts of the choices related to the energy matrix are minimized, particularly in the northern region of Brazil. The National Bill 3729/2004, which aims at deregulating the current environmental licensing standard, is proceeding in the National Congress, in line with the vision expressed by both the PDE 2030 and the PNE 2050.

➡ With regard to greenhouse gas emissions, the projections proposed by both documents are consistent with the climate targets established for the national energy policy in relation to both the National Policy on Climate Change (PNMC, Law N. 12.187 / 2009) and the Paris Agreement. In the ten-year horizon, the carbon portion of the energy supply remains stagnated, decreasing in relation to the gross domestic product (GDP). In the medium- and long-term projections, there is a trade-off between the reduction of accumulated emissions from 2015 to 2050 and higher costs for updating the power matrix. Even so, the option for a clear trajectory of electrical expansion proves to be technically and economically viable, leaving the Brazilian government with the task of proposing better coordination between the appropriate decision-making entities.

# Introdução

This study aims to explore the trajectories of electrical and energy expansion (electricity and fuels) in Brazil and the intentions expressed by the Brazilian government to establish additional measures related to the energy sector within the scope of the commitments defined by the country (NDC-Brazil)[1]. The year of 2005 is the reference line for this study, and the following goals (extracted from the National Policy on Climate Change, PNMC, Law N. 12.187) form its specific objectives:

> *"Brazil intends to adopt additional measures that are consistent with the objective of 2 C of temperature, in particular:*
>
> *i) Increase the share of sustainable biofuels in the Brazilian energy matrix to approximately 18% by 2030, through (i) the expansion of biofuel consumption, (ii) increase in ethanol supply, (iii) increase in the share of advanced biofuels (second generation) and (iv) increase in the share of biodiesel in the diesel blend;*
>
> *ii) Achieve 45% of renewables in the energy matrix by 2030, including:*
>
> *• Expansion in the use of renewable energy sources, not including hydroelectric, in the total energy matrix, aiming 28% to 33% by 2030;*
>
> *• Domestic expansion in the use of energy sources from non-fossil fuels, increasing the share of renewables (other than hydroelectric) in the energy supply to at least 23% by 2030, including an increase in the share of wind power, biomass, and solar energy;*
>
> *• Achieve 10% efficiency gains in the electricity sector by 2030".*

In terms of scope, the study is not limited to monitoring the national intentions mentioned above. There is also an effort to bring forward the improvements, risks and limitations of the trajectories proposed for the electrical and energy expansion based on two lines of analysis: (i) the 2030 reference scenario of the Ten-Year Energy Expansion Plan (PDE 2030) and (ii) the different scenarios of electrical expansion elaborated within the scope of the National Energy Plan (PNE 2050).

1 For more details, check : https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/%20i%20eBRAZILNDCnglish%20FINAL.pdf

# Ten-Year Energy Expansion Plan (PDE 2030)

## Sectoral demand for energy

The Ten-Year Energy Expansion Plan (PDE)[2] is an information document aimed at the entire society. Its aims to indicate prospects for the expansion of the energy sector in a ten-year horizon, within an integrated approach with the various types of electricity sources. Through this document, it is possible to extract important elements for the planning of the energy sector, also allowing a process of consultations about the sector's future.

According to the PDE 2030 reference scenario, final energy consumption should show an average growth of 2.8% per year, a trajectory close to that of gross domestic product (GDP), which would grow 2.9% per year. In this measure, the industry and transport sectors remain the most relevant, representing 65% of final energy consumption in 2030.

In industry, the average sector growth should be 2.2% per year, with emphasis on the sectors of primary goods and intermediate products for fertilizers and pesticides, along with paper and pulp, mining and pelletizing, in addition to the highest demanders of electricity, such as the chlor-alkali sector and aluminum manufacturers. Such an evolution would be much more due to the reduction of idle capacity than to a vigorous expansion of productive capacity. The few changes in the participation of energy sources refer to a greater relevance of those with low emissions of greenhouse gases, including electricity and sugarcane derivatives.

In the cargo transport sector, road transport remains a major player, despite the advancement of rail transport, whose energy efficiency per ton transported is much higher. Cargo transport activity, the segment least affected by the Covid-19 pandemic, is expected to increase by 3.6%. In this way, diesel maintains its prominent role as a fuel by representing 35% of all energy demand in the transport sector in 2030. The demand for Ethanol fuel (anhydrous and hydrated) is expected to grow 3.7% per year, reaching 42.7 billion liters in 2030.

The highlight is on account hydrated ethanol, whose share in the transport sector should rise from 14% to 16%, to the detriment of gasoline C, whose share is expected to drop from 32% to 25%. The increase in competitiveness for hydrated ethanol compared to gasoline would be due to the improvement of production factors, driven by mandatory decarbonization goals to be assumed by fuel distributors, based on the national biofuel policy - RenovaBio[3].

Biodiesel also stands out, since the demand for this type of fuel is expected to grow 5.8% a year due to the new mandatory concentration in the die-

2 Document available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-538/PDE%202030_EnvioMME_rv2.pdf

3 Law 13576, December 26, 2017.

sel blend, which will be 15% biodiesel from 2023.

Electricity's share of energy demand is expected to rise by 2% over the PDE 2030 range, driven mainly by the residential sector, whose demand grows by an average of 3.5% per year. Overall, total electricity consumption is expected to grow 1% more than the Brazilian economy, ratifying the national electrification trend.

## Sources of energy supply

For the first time, the PDE 2030 reference scenario incorporates alternatives for energy expansion through solid urban waste, floating photovoltaic plants and modernization of the existing hydroelectric infrastructure. Elements are also brought to discuss the integration between the sectors of electricity and natural gas, and simulations of the feasibility of energy storage in distributed generation.

The document also projects the expectation that, by 2030, oil production will reach 5.3 million barrels/day, something close to double the number registered in 2019, with production units located in ultra-deep waters expected to account for 84%. At the end of the decade, Pre-salt will probably be responsible for 79% of Brazilian national production, with a strong participation of the Santos basin. On the other hand, oil products will continue to have gains in relation to final energy consumption, motivated mainly by the use of diesel in heavy vehicles. Regarding internal energy supply, its share is expected to fall 3% by 2030.

In this way, Brazil will consolidate its status as an oil exporter and will remain a net importer of oil products throughout the PDE, with an emphasis on imports of naphtha, aviation kerosene and diesel.

Within the scope of the "Novo Mercado de Gás" Program[4] (freely, New Gas Market), recent studies on the possibilities of increasing the share of pre-salt natural gas (NG) have identified the current flow infrastructure and the need for a steady demand as the main obstacles to its use.

The production of NG will reach a peak of around 183 million m3/ day around 2028 and its participation in the internal energy supply will grow 3% until 2030. The most relevant basins to reach this peak are Santos, Campos, Solimões and Parnaíba, with the first two being responsible for 85% of the supply forecast for 2030 and significant production in the pre-salt. The price of NG from liquefied natural gas (LNG) will be affected by the international market, with its logic changed from a gas-oil to gas-gas competition (regasification of imported LNG against pre-salt NG).

A steady demand becomes even more relevant in the case of NG, since its consumption is associated with the production of oil through its reinjection in the wells. The increase in demand also depends on the involvement of local gas distribution companies, many of them under the control of the state governments or Petrobras itself.

In light of the increase in the share of renewables in the energy matrix, and considering the context, the highlight is on account of biodiesel, as previous-

4 Bill 4476, 2020 (Regulatory Framework for Gas, Federal Senate).

ly mentioned. It is estimated that the biodiesel offer may double in the period determined in the PDE. Soybean oil keeps its leadership as the main raw material used to obtain biodiesel in Brazil, with emphasis on the increase in installed capacity in the central-west region of the country. The total supply of ethanol is expected to reach 46 billion liters, 75% of which is related to hydrated ethanol. The production of corn ethanol may show remarkable growth in the considered period, reaching 5.7 billion liters in the projected scenario.

## Improvements in the electrical matrix and regulatory challenges for the electrical sector

The electricity generation matrix has undergone a profound transformation in the country. While at the beginning of the century the share of hydroelectric generation accounted for 90% of total electricity generation, at the end of the decade this percentage should drop to 60%. At the same time, reservoir capacity - how much energy can be stored in the form of water to supply the demand - was just over six months in 2001, and today is close to half that time, thanks to the expansion through large run-of-the-river plants located on the Amazon floodplain.

The reduction in hydroelectric participation has been accompanied by an expressive development of variable renewable sources, which have proved to be increasingly competitive, especially wind power and photovoltaic plants. In this context, the PDE 2030 states that hydroelectric plants and the National Interconnected System (SIN) - which should be expanded to support more frequent exchanges between regions in the country - would uphold the expansion of new renewable sources, with natural gas thermoelectric plants acting as a complementary source in times of greatest need.

In order to promote greater security and systemic flexibility, according to the growth of renewable sources, and in a context of centralized generation, the PDE 2030 brings some important advances for the current hydroelectric plants, as follows:

> a) the need to discuss a new responsibility (and related regulations) to operate and remunerate the existing hydroelectric generation, characterized by strategic reservoirs, in order to provide a flexible and modular power reserve to the interconnected system and
>
> b) make adjustments in regulation to stimulate investments in the modernization of existing hydroelectric plants and dams, an initiative known as repowering, which consolidates a thesis raised by civil society more than a decade ago.[5]

The role of the thermoelectric plants mentioned above, in particular, the way they will be incorporated into the Brazilian electricity system, has a direct impact on the greenhouse gas emissions of the country's electricity sector and on the performance of Pre-salt natural gas in the New Gas Market[6].

5 See: http://www.investidorinstitucional.com.br/sessoes/gente/ponto-de-vista/5392-66-revistainvestidorinstitucional-4724.html

6 See item 9. The "if-then" scenarios for GHG emissions from the electricity sector

The discussions on the valuation of the attributes of the different sources, in the context of integration or "hybridization" between them, and on the subsidies to the so-called encouraged sources (wind power, solar power, small hydroelectric plants and biomass) and the micro and mini-distributed generation (MMDG) are taking place within the scope of modernizing the electric sector and adjusting norms and regulations[7].

**What is micro-generation and mini-generation?**

According to the Brazilian National Electric Energy Agency (ANEEL), micro and mini-generation of electricity is the process that allows users to install small generators from renewable sources in their home, company or other type of consumer unit. Electricity can be generated using solar power, wind power, hydroelectric, biomass and qualified cogeneration. The energy generated in a month is deducted from the amount of energy consumed, providing a reduction in the customer's energy bill.

- Distributed micro-generation: installed power of up to 75 kW.

- Distributed mini-generation: installed power greater than 75 kW and less than or equal to 5 MW.

Source: EPE website

There is a debate about the suspension of subsidies to encouraged sources. According to an analysis by the Energy Research Company (EPE), the loss of these subsidies would not affect the competitiveness of these sources among each other or with other sources. On the other hand, these subsidies have put pressure on the Energy Development Account (CDE), funded exclusively by the regulated market, at a level around 7% of its average tariff.

At the same time, the migration of consumers to the free market has been stimulated by increasingly lower entry barriers in terms of charge[8], which further burdens the ones left in the regulated market, characterized by being smaller consumers.

7 Highlighting MPV 998, December 18, 2020, and PLS 232/2016.

8 For more details, see: https://www.in.gov.br/en/web/dou/-/portaria-n-465-de-12-de-dezembro-de-2019.-233554889

### Free and regulated electricity markets in Brazil

Energy trading in Brazil is carried out in two market spheres: the Regulated Contracting Environment (ACR) and the Free Contracting Environment (ACL). All contracts, whether ACR or ACL, must be registered with the CCEE and serve as a basis for accounting and settling differences in the short-term market. Understand the difference between the two environments in the comparative table below:

| | Free Environment | Regulated Environment |
|---|---|---|
| **Participants** | Generators, traders, free and special consumers | Generators, distributors and traders. Trader companies can only negotiate energy at existing energy auctions - (Ajuste and A-1) |
| **Contracting** | Free negotiation between buyers and sellers | Conducted through energy auctions promoted by CCEE, under the delegation of Aneel |
| **Type of contract** | Agreement freely established between the parties | Regulated by Aneel, called the Electric Energy Trading Contract in the Regulated Environment (CCEAR) |
| **Price** | Agreed between buyer and seller | Established at auction |

Source: CCEE - Chamber of Electric Energy Commercialization website

## Energy Efficiency and Distributed Energy Resources (DER)

According to PDE 2030, it is estimated that the contribution of Distributed Energy Resources (DER) may account for 19% of electricity consumption by 2030. From this amount, self-production would be responsible for 9.7%, MMDG would represent 4.6% and efficiency gains would be 4.1%. In addition, the consumption of a small portion of solar thermal energy is expected.

**Distributed Energy Resources (DER)**

Distributed Energy Resources are electric energy generation or storage technologies located in an area close to consumer units.

In the industry, the main form of self-production is cogeneration, taking into account that the yield is significantly higher from the combination of thermal and electrical energy. In the ten-year horizon, it is estimated that the self-production modality can reduce total electricity consumption by about 10% in sectors such as steel, pulp and paper, petrochemicals, refining, sugar and ethanol, among others.

Regarding electrical efficiency, the most relevant results come from the building sector, with emphasis on the residential and services sector, whose increase can reach 10%.

Although there is a remark about the importance of energy efficiency in the transport sector, the PDE's analysis of potential increases is quite limited.

On the one hand, there is talk of individual gains through technological advances in engines or new technologies, and cultural changes in individual transport. On the other, potential gains in systemic efficiency are mentioned, such as the migration to collective urban transport, or from road transport to more efficient means, such as railways and waterways.

All these changes were part of the PDE 2030 reference scenario, but there is no clarification as to what future scenarios would serve as starting points for implementation.

Actually, the analysis on efficiency improvements for transportation is based on the premise that the individual and systemic gains observed in 2019 will be repeated over the PDE's horizon, without any mention of qualitative changes along the way. With this simplistic approach, the increase in energy consumption efficiency in the transport sector would be 5.7% with or without individual gains and 17.3% with or without systemic gains.

Alternatives such as cabotage - for which economic incentives are discussed under the BR do Mar Program - or significant investments in new railways - which are part of the National Transport Logistics Plan (PNLT), prepared by the Logistics Planning Company (EPL) - were not even mentioned, revealing lack of integration among the various sector planning initiatives within the government.

This also hinders the qualitative analysis of electric efficiency gains, which involves several other economic sectors and classes of consumers for whom the electricity sector provides energy.

## Micro and mini-distributed generation (MMDG)

In 2019, the installed capacity of distributed photovoltaic technology was increased by 1.5 GW, a power similar to that of the Angra II nuclear plant, falling short only of the hydroelectricity added capacity. Although the Sars-Cov-2 pandemic slowed down new installations in 2020, the market continued to develop until it surpassed an accumulated installed capacity of 3 GW.

The high electricity rates for the end-consumer, the good performance of solar power as an alternative in the country - responsible for more than 80% of the distributed generation installations - and a credit compensation model, which reduces costs of the distribution and transmission fees, made self-generation a very profitable investment in Brazil. This fact ended up attracting not only residential consumers, but also large retail chains, banks and industries, making them bet on MMDG systems for consumption and local or remote compensation.

The high growth of MMDG systems ended up putting in doubt the sustainability of its regulation, which is part of ANEEL REN Normative Resolution No. 482/2012. This is because the amounts not paid by MMDG end up being passed on to other consumers through tariff reviews for distributors, harming the vast majority of customers in the regulated market.

Thus, PDE 2030 prepared two reference scenarios for its evolution considering the uncertainty related to the future of the compensation mechanism and the low voltage fee model, which will affect the incentives for MMDG, as follows:

- **Summer Scenario:** maintenance of significant incentives for MMDG. As of 2022, the distribution portion of the compensation mechanism (Wire B) would be withdrawn, while the use of transmission (Wire A), charges, losses and the energy portion would be kept. From 2026, MMDG systems would be subject to a binomial tariff, which includes the distribution and transmission portions.

- **Spring Scenario:** withdrawal of fiscal incentives, securing moderate growth for the MMDG system. In 2022, new rules would come into force, making only the energy portion of the tariff eligible for compensation, since, in that same year, the application of the binomial tariff would also occur.

**Scenarios for MMDG in 2030:**

| In 2030 | Summer Scenario | Spring Scenario |
|---|---|---|
| Installed power capacity | 24,5 GW | 16,8 GW |
| Energy generated | average 4,3 GW | average 2,9 GW |
| % of total charge | 4,6% | 3,2% |

Fonte: Minuta para consulta pública do PDE 2030

## Autonomy and flexibility in MMDG

To promote autonomy and flexibility in MMDG and given the regulatory framework, the use of batteries is allowed, with three different possibilities within the PDE horizon:

i. Greater autonomy of distributed micro-generation, with increased self-consumption;

ii. Consumption displacement, considering residential hourly rates[9] and

iii. Consumption Displacement at high voltage.

In the three scenarios mentioned above, the advantages of investing in batteries depend on the consumption profile and the balance of credits and debits between the distributor and the independent consumer, known as “net metering”. In this sense, the simulation

9 Also known as white rate, an optional modality for low-voltage consumers.

developed by EPE, within the scope of PDE 2030, used real data from 15 consumers of distributed generation.

For a consumption profile that requires greater autonomy (for example, high consumption during peak hours or at night), the subsidies that regulate the compensation of credits related to energy received from the grid (REN 482/2012) discourage a greater degree of MMDG's autonomy, that is, they do not serve as an incentive for investments in batteries in order to increase self-consumption.

However, there is an expectation that this regulation will be revised, in order to bring the network consumption tariff (distributor credit) closer to the credit compensation tariff by the autonomous consumer, making self-consumption more attractive.

Anyway, given this new regulatory scenario, investment in batteries would be inviting only at prices around BRL 500/USD per 92 kWh. Currently, the value is in the range of BRL 4,500/USD 826 per kWh. With the expected reduction of 8.3% per year, it would drop to around BRL 2,000/USD 368 per kWh in 2030[10]. The expected reduction in the global cost of batteries is due to changes in the technological scenario, as well as in the market (scale of production), and can be stimulated by a policy of local battery production or the reduction of its import fees, an addressed further in this document[11].

In the case of displacement of consumption with white tariff, the picture would be similar, with the battery price ranging between BRL 500/USD 92 per kWh and BRL 1,000/USD 183 per kWh.

In high voltage, which has had a horo-seasonal tariff for a long time, several commercial and industrial consumers resort to diesel power generators to avoid high peak hour rates. According to an analysis by the Energy Research Company (EPE, 2015), there are about 9 GW of generators of this nature operating daily in Brazil during peak hours (for three hours on working days). This means three times more than the installed capacity of diesel generators in isolated systems in the Amazon.

Thus, the use of batteries could occur through storage of electricity purchased in the most favorable period (off-peak) to supply the internal demand during peak hours, replacing the existing diesel generators. With a drop in battery costs, it is expected that they will become viable so that consumers subject to the horo-seasonal tariff (Group A[12]) can perform hourly charge management.

On the other hand, results from a simulation indicate that diesel generation would remain more attractive than the storage solution, unless the battery costs between BRL 500/USD 92 per kWh and BRL 1,000/USD 183 per kWh.

Apparently, such a simulation disregards the cost of greenhouse gas (GHG) emissions from diesel generation. This reflects one of the greatest difficulties in controlling emissions in

10 For more details, see: https://www.researchgate.net/publication/330269949_Projecting_the_Future_Levelized_Cost_of_Electricity_Storage_Technologies/link/5c4059d5299bf12be3ce119d/download

11 All currency rates in this document consider current values for March 2021, with USD 1 corresponding to BRL 5,45.

12 Consumer units receiving power at a voltage equal to or greater than 2300V.

the energy sector, the lack of signaling the cost of GHG emissions to society.

Anyway, some results of the analysis on the attractiveness of batteries presented so far must be analyzed.

The calculations were made for a few consumers, based on current electricity rates adjusted for inflation. A specific consumer profile or a different trajectory for tariffs can change the perspective of the analysis. On the supply side, the lithium-ion battery market is still quite narrow. Any change in this scenario, such as local production, can change the cost and, therefore, the appeal of batteries.

Battery production in Brazil is limited to a plant recently opened at the Free Economic Zone of Manaus. However, this facility meets the manufacturer's demand, whose business also involves assembling electric buses. For all other cases, the solution is to import batteries that are subject to a tax corresponding to around 80% of their final cost, according to market data. In other words, in an import tax exemption scenario, the price of batteries would be around BRL 2,500/USD 456 per kWh or between BRL 1,000/USD 183 per kWh and BRL 1,500/USD 276 per kWh over the decade.

This point brings back the question of integration between different government sectors. In addition to planning for energy expansion, there should be economic policies for the empowerment of consumer producers (known as "prosumers") through autonomous and flexible MMDG systems, with energy storage. This, however, requires integration of the energy policies and industrial policies in Brazil.

Such systems would enable a more efficient management of MMDG, which would mitigate the demand of centralized generation for public use, for example, during peak hours. This gain in efficiency by MMDG would also represent a reduction in emissions from the Brazilian electrical system, since the thermoelectric plants, which use fossil fuel, would be less used during peak hours.

## Consolidation of results

Considering the evolution of the energy supply in the period of ten years until 2030 (table below), renewable sources will grow less than non-renewable sources, although other renewable sources (wind, solar, biodiesel and black liquor) are expected to grow on average 6.9% per year. On the non-renewable side, it is worth mentioning the growth of uranium and its derivatives, with the forecast for the start of the Angra 3 operation and the rise of natural gas.

**The evolution of internal energy supply over the 10-year horizon**
(in millions of tons of oil equivalent)

| SOURCES | 2021 | % | 2025 | % | 2030 | % | Variation 2021-2030 (% p.a.) |
|---|---|---|---|---|---|---|---|
| **Non-renewable energy** | **148.108** | **51** | **162.648** | **50** | **190.134** | **52** | **3,1** |
| Oil and petroleum products | 96.792 | 34 | 102.920 | 32 | 116.050 | 31 | 2,4 |
| Natural gas | 33.101 | 11 | 40.196 | 12 | 49.903 | 14 | 4,7 |
| Coal and derivatives | 13.476 | 5 | 14.420 | 4 | 15.799 | 4 | 2,5 |
| Uranium and derivatives | 3.688 | 1 | 3.900 | 1 | 6.910 | 2 | 6,4 |
| Other non-renewable sources | 1.053 | 0 | 1.211 | 0 | 1.474 | 0 | 3,6 |
| **Renewable energy** | **140.302** | **49** | **160.391** | **50** | **178.716** | **48** | **2,8** |
| Hydraulic and electricity | 38.398 | 13 | 43.682 | 14 | 46.275 | 13 | 2,2 |
| Firewood and charcoal | 24.260 | 8 | 26.425 | 8 | 26.465 | 7 | 1,0 |
| Sugar cane derivatives | 53.880 | 19 | 59.039 | 18 | 64.193 | 17 | 2,0 |
| Other renewable sources | 23.764 | 8 | 31.245 | 10 | 41.782 | 11 | 6,9 |
| **TOTAL** | **288.410** | **100** | **323.039** | **100** | **368.850** | **100** | **3,0** |

Source: PDE 2030 public consultation draft

A The composition of the energy supply by source would therefore be illustrated as below. In summary, on the non-renewable side, the loss in the percentage of oil and petroleum products is offset by the gain in natural gas. On the renewables side, the highlight is the increase in the percentage of other renewables and the relative loss of sugarcane products.


Source: PDE 2030 public consultation draft

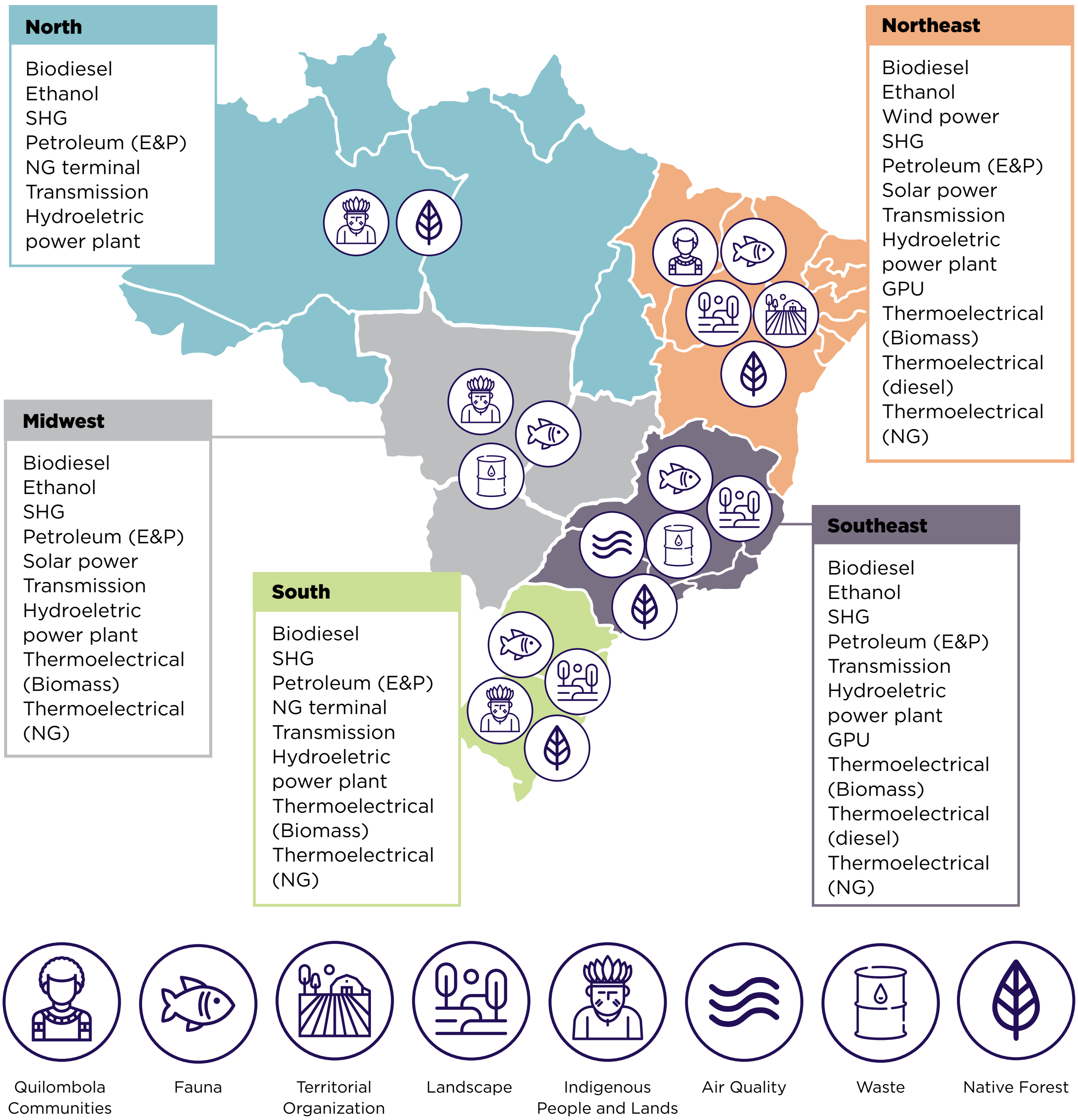
Hydraulic power and electricity, in turn, maintain their participation in the matrix by sources. Basically, this is due to the proposal to repower existing plants, since, despite the reference scenario envisioning expansion of existing hydroelectric plants, the new power plants indicated for the decade were not viable and economically attractive for expansion of the electrical system.

The PDE understands that the processes and deadlines involved in obtaining environmental licenses for hydroelectric plants "directly impact the viability of these projects and affect the competitiveness and risks associated with hydroelectric plants compared to other technological solutions".

The PDE 2030 does not recognize the complexity and socio-environmental risks involved in the implementation of hydroelectric plants. Those factors have been generally underestimated in the process of preparing these projects, especially regarding the Amazon.

In this sense, in its integrated analysis, which involves socio-environmental subjects and Brazilian geographic regions, the points of interest of the PDE 2030 are restricted to indigenous peoples and lands and native vegetation, omitting relevant socio-environmental aspects such as fauna, landscape, territorial organization, quilombola communities, small and medium farmers.

## PDE 2030 Integrated Analysis




Source: PDE 2030 public consultation draft

Finally, in terms of installed capacity, there is a process of electric matrix diversification, with the reduction of hydroelectric and thermal participation being offset by the growth in installed capacity of wind and solar sources, in addition to self-production with renewable distributed generation (Self-production + Renewable DG, mostly solar).


Source: PDE 2030 public consultation draft

## Greenhouse gas emissions from the energy sector

According to the Greenhouse Gas Emissions and Removal Estimation System (SEEG, 2020), the participation of the energy sector in the profile of Brazilian emissions was 19% in 2019.

The main responsible for these emissions in the production and consumption of energy are the sectors of transport and industries, which should maintain their percentage of representation in 2030 similar to that of 2019, which is around 65%, in the proportion of 70% for transport and 30% for industry.

The table below details the emissions of the energy sector from 2005 to 2030 in millions of tons of CO2 equivalent. The reductions between 2019 and 2021 reflect the economic impact of the Covid-19 pandemic.

**Emissions from the energy sector**

| Sectors | Emissions from the energy sector ($MtCO_2eq$) | | | | |
|---|---|---|---|---|---|
| | 2005 | 2019 | 2021 | 2025 | 2030 |
| Electric Power sector | 27 | 56 | 31 | 35 | 41 |
| National Interconnected System | 21 | 39 | 17 | 19 | 22 |
| Self-production | 6 | 17 | 14 | 16 | 19 |
| Energy sector | 23 | 30 | 34 | 41 | 47 |
| Residential | 26 | 19 | 20 | 21 | 22 |

| Sectors | Emissions from the energy sector ($MtCO_2eq$) | | | | |
|---|---|---|---|---|---|
| | 2005 | 2019 | 2021 | 2025 | 2030 |
| Commercial | 2 | 1,5 | 1,4 | 2 | 2 |
| Public | 2 | 0,8 | 0,7 | 1 | 1 |
| Agriculture and livestock | 16 | 19 | 20 | 21 | 22 |
| Transportation | 140 | 191 | 178 | 191 | 224 |
| Industry | 62 | 76 | 76 | 83 | 93 |
| Fugitive emissions | 20 | 20 | 22 | 26 | 31 |
| TOTAL | 317 | 412 | 383 | 421 | 484 |

(1) The sectoral breakdown was made according to the National Energy Balance (BEN).

(2) Fugitive emissions include transportation and processing of NG and losses in E&P activities, in addition to coal mining.

(3) The 2005 emissions were updated according to the 5th edition of the annual estimates of GHG emissions in Brazil (MCTIC, 2020). CO2 equivalence is given by the global warming potential (GWP) metric for 100 years, according to the IPCC's 5th evaluation report (IPCC, 2014).

(4) 2019 emissions were obtained from BEN 2020 (EPE

Source: PDE 2030 public consultation draft

Considering emissions by type of fuel, the highlights in 2030 will be diesel oil (38%), natural gas (20%) and gasoline (13%). In this scenario, the carbon intensity in energy use will remain practically stable, while the carbon intensity in the economy will decrease by 2.5%, as shown below:

**Intensidade de carbono**

| Variable | 2005 | 2021 | 2025 | 2030 |
|---|---|---|---|---|
| GHG emissions: energy production and use ($MtCO_2e$) | 317 | 383 | 421 | 484 |
| GDP (BRL billion, 2010) | 3122 | 4013 | 4495 | 5211 |
| Gross domestic energy supply (Mtoe) | 218 | 288 | 323 | 369 |
| Carbon intensity in energy use ($kgCO_2e$/toe) | 1,45 | 1,33 | 1,30 | 1,31 |
| Carbon intensity in the economy ($kgCO_2e$/BRL) | 101,3 | 95,3 | 93,6 | 92,9 |

Source: PDE 2030 public consultation draft

Maintaining the level of representativeness of the most carbon intensive sectors, in this case, transport and industry, seems to be the main reason for the stability of carbon intensity in the use of energy.

Systemic changes were expected, mainly in the efficiency of the cargo transportation sector, as well as greater autonomy for the producer-consumer of renewable electricity, be it micro, mini or large. However, they were not covered by the PDE 2030 in proportion to its transformation potential, with relevant implications on energy efficiency gain, demand management and emission reduction.

## The "if-then" scenarios for GHG emissions from the electricity sector

As previously noted, the expansion of electricity generation is predominantly based on renewable sources according to PDE 2030. Those would be complemented, in the reference scenario, by fully flexible thermoelectric plants, by the modernization through expansion of existing hydroelectric plants (repowering) and by demand responses.

Thus, despite the increase in the installed capacity of thermoelectric plants, the generation of energy from these plants tends to occur sporadically. It should be noted, however, that the success of this strategy relies on resource availability, allowing the plants to be activated whenever necessary.

In any case, PDE 2030 offers an analysis of greenhouse gas emissions for different expansion possibilities, involving aspects that may change the reference scenario (case 1), namely: hourly assessment of demand and supply (case 2), change in demand expectation (cases 3 and 4), expansion with inflexible thermoelectric plants (UTE), that is, on the basis of supply (cases 5 and 6), and with changes in the role of hydroelectric plants (case 7).

**Scenarios for electricity sector emissions**

| PDE 2030 | | Emissions (MtCO2eq) | |
|---|---|---|---|
| **Case** | **Description** | **2025** | **2030** |
| 1 | Reference expansion | 26,3 | 24,4 |
| 2 | Considering hourly evaluation | 25,8 | 24,1 |
| 3 | Low demand scenario | 24,1 | 20,0 |
| 4 | High demand scenario | 30,9 | 25,9 |
| 5 | With 1 GW/year of inflexible thermoelectric plants | 26,1 | 34,6 |
| 6 | With 2 GW/year of inflexible thermoelectric plants | 26,6 | 42,7 |
| 7 | With change in the role of hydroelectric plants | 25,7 | 31,2 |

Source: PDE 2030 public consultation draft

The greatest risk of an increase in emissions from the electric sector is due to the pressure for inflexible thermoelectric plants, which are obviously of interest to the natural gas sector, since they guarantee a reliable demand for gas supply. This “if-then” scenario methodology for electrical expansion was also adopted in PNE 2050, which is the subject of the second part of this study.

## Commitments of the energy sector in the light of NDC-Brazil

The scenario of expansion of energy supply and consumption over the ten-year horizon is in line with the trajectory presented in the Brazilian NDC, as shown below:

| Indicators | | NDC | PDE |
|---|---|---|---|
| | | Reference year 2025 | |
| Energy efficiency | Electricity | 8% | 6% |
| Electric power | Wind, solar and biomass + DG and self-production | 22% | 24% |
| | Hydroelectricity in centralized generation | 71% | 74% |
| Energy matrix | Renewable sources, except hydroelectric | 32% | 36% |
| | Bioenergy | 18% | 20% |
| | Total - renewable sources | 45% | 50% |

Source: Author, w/ data extracted from PNMC, Law N. 12.18; PDE 2030 public consultation draft

Therefore, it can be said that the PDE scenario is aligned with the PNMC and with the international commitments assumed by Brazil in the Paris Agreement - except for the energy efficiency target.

## National Energy Plan (PNE 2050)

Like the PDE, the National Energy Plan[13] is an instrument for planning public policies. Its objective is to analyze trends related to energy availability, production and consumption in a multi-year scenario.

For this study, the analysis of the PNE 2050 is restricted to the 64 long-term scenarios elaborated for the electrical matrix (see item IV Annex). This analysis follows the "if-then" approach, also used in PDE 2030, in the specific case of the GHG emissions scenarios in the electricity sector.

In this approach, the main subdivision of the set of scenarios refers to the possible interference of the expansion of hydroelectric plants in indigenous lands (TI) and/or conservation units (UC). Thus, 29 scenarios are presented without interference, 29 with interference in IT and UC and 6 with interference in IT or UC.

The first observation regarding this approach is the long-term maintenance of a centralized generation model, with a recurring focus on large hydroelectric expansion in the Amazon floodplain. This pattern disregards an entire history of technical, economic and socio-environmental problems that have characterized investments in this alternative, including the high costs for the National Interconnected System to serve the consumer market, located largely in the southeastern region of the country.

Hence, considering the constitutional and legal restriction to interfere in indigenous lands and conservation units, this study chose to limit the analysis to scenarios of hydroelectric plants that do not reach protected areas[14].

In addition, some scenarios reveal a bias to "accommodate" some more problematic sources and alternative generation sources with few historical usage records. This category includes nuclear power plants, coal and electrical integration in South America.

It is important to note that the energy supply for the period up to 2050 was based on simulations of an expansion optimization model. Briefly, the simulation indicates the set of projects aimed at expanding the supply of electricity that minimizes the present value of investment (PVI) in new plants and interconnections, plus operating costs and the electricity deficit. This results in an optimal expansion of the Brazilian electrical system.

In addition to the restriction on meeting demand (deficit), the model incorporates a restriction on meeting

13 Document available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao227/topico563/Relatorio%20Final%20do%20PNE%202050.pdf. See also: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-563/PNE%202050%20-%20Anexo.pdf

14 The PDE does not make it clear what is the total power of the hydroelectrical power plants inventoried in the Amazon and how much of that power interferes in protected areas (TI, UC and others). However, informal sources report that two out of three hydroelectric projects can be included in the group that interferes with indigenous lands or conservation units.

maximum power, translated into an availability factor for the power balance. This restriction is especially important when considering the prospect of an increasing participation of variable renewable sources and run-of-river plants in the Amazon, whose seasonality in energy supply is very relevant, especially in the second half of the year, when rivers have a drastically low water flow.

In summary, the main parameters of the expansion model are source capacity factor, availability for the power balance and data on total investment, operation and maintenance costs.

The nuclear plant is the only option that deviates from the parameters of the decision model, since it previously determines a nuclear power to be installed in a compulsory manner (scenarios 24 and 25). Nuclear plants also stand out for the number of scenarios with reduced capital cost - CAPEX - and, in a single case, also for their operational cost - OPEX (scenarios 20 to 23).

In the line of privileging centralized generation and admitting an unlimited expansion of the SIN, there are several scenarios that delimit distributed generation and other renewable sources within the horizon of the PNE 2050. This logic includes scenarios 13 (wind limited to 50 GW), 14 (wind and solar limited to 50 GW), 16 (solar limited to 50 GW), 27 (DG installed capacity limited to 75 GW) and 28 (DG capacity installed limited to 25 GW).

Excluding the previously mentioned scenarios, in addition to others with a very low probability, such as stagnation (scenario 1), electrical integration with South America without transmission cost or with a 50% cost reduction (scenarios 9 and 11), a fully electric light vehicle fleet in 2050 (scenario 12) and coal financed with a 20% reduction in CAPEX (scenario 26), reaching a total of 16 excluded scenarios. The reasons for this were previously explained.

In this selection process, 13 scenarios remain, arranged in the table below in increasing order of PIV:

| Cenário | Descrição do cenário | % renovável 2050 | % renovável 2050 (critério NDC) | Emissões acum. 2015-2050 ($MtCO_2e$) | VPI fluxo até 2050 (R$ bilhões) |
|---|---|---|---|---|---|
| 19 | Repotenciação + aumento F.C. usinas a bagaço | 94% | 55% | 818 | 664 |
| 17 | Aumento de F.C. de usinas a bagaço | 93% | 58% | 837 | 767 |
| 8 | Repotenciação de UHE | 93% | 54% | 929 | 797 |

| Cenário | Descrição do cenário | % renovável 2050 | % renovável 2050 (critério NDC) | Emissões acum. 2015-2050 ($MtCO_2e$) | VPI fluxo até 2050 (R$ bilhões) |
|---|---|---|---|---|---|
| 18 | Aumento F.C. usinas a bagaço, 50% a mais no custo | 94% | 58% | 841 | 804 |
| 15 | Eólica offshore com CAPEX reduzido em 20% | 93% | 57% | 923 | 806 |
| 4 | Expansão com fósseis | 92% | 57% | 939 | 807 |
| 29 | GN Pré-sal a US$ 6/ MMBtu | 95% | 61% | 815 | 813 |
| 7 | CAPEX PCHs com 100% de sobrecusto | 92% | 58% | 952 | 824 |
| 3 | Expansão sem fontes emissoras | 98% | 66% | 472 | 837 |
| 10 | Integração Sulamericana, custo transmissão 50% maior | 87% | 44% | 1247 | 854 |
| 2 | Matriz 100% renovável em 2050 | 98% | 71% | 460 | 859 |
| 5 | Efeito de MC's na disponibilidade hídrica | 92% | 59% | 974 | 937 |
| 6 | MCs na disponibilidade hídrica, expansão sem emissões | 98% | 70% | 475 | 1005 |

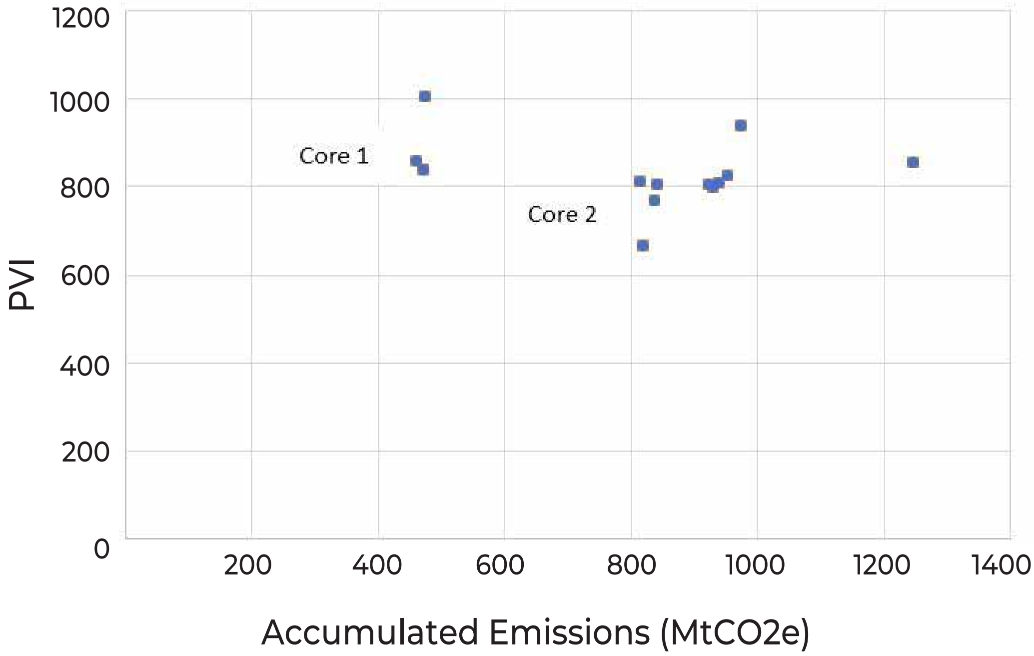
Fonte: Anexo 9, PNE 2050.

In 2050, the share of renewables would be in a range between 87% (scenario 10, South American integration, with transmission cost 50% higher) and 98% (scenarios 3 and 6, expansion without emissions, with or without the impact of climate change in water availability).

According to the NDC criterion, the variation for renewable sources, except for hydroelectric generation, would be 44% (scenario 10) to 70% (scenario 6).

Regarding accumulated emissions (average period) against PVI, two groups of scenarios demonstrate a better combination of total investment costs and accumulated emissions from 2015 to 2050:

**Accumulated Emissions versus PVI – present value of investments**




Fonte: Autoria própria, com base no Anexo 9, PNE 2050.

Core 1 consists of scenarios 2 (100% renewable matrix in 2050) and 3 (expansion without emission sources), which are characterized by lower emissions and very close investment values.

Core 2 consists of the scenarios with higher emission values, listed below in an increasing order of costs: 19 (repowering, with an increase in the load factor of bagasse power plants), 17 (with an increase in the load factor of bagasse power plants), 18 (increased load factor from bagasse power plants with 50% more cost) and 29 (pre-salt natural gas at USD 6/MMBtu)u).

# Final Considerations

During the 2020-2030 decade, carbon intensity in the energy supply remains stagnant, decreasing in relation to the gross domestic product (GDP), as a result of the influence of the agricultural sector's growth on Brazil's GDP performance.

In this scenario of stagnant carbon intensity, the percentage of participation of renewable and non-renewable energy sources remains very close. In general terms, this means that an eventual improvement in the decarbonization of the energy matrix is being neutralized by the growth in demand.

This reality is observed despite the fact that the national context is characterized by an abundant and diversified supply of renewable energy sources, present either through rivers, sunlight, wind or biofuels. On the other hand, it is true that this abundance of non-fossil sources is, at this moment, facing a dilemma that involves new opportunities for the intensive exploration of fossil resources, arising from the exploration of the Pre-salt, which is abundant in Brazil. In this regard, it is worth noting that the political context was made unfavorable by the agenda to combat climate change.

In other words, the expected Brazilian energy transition ends up not being as forceful as it could be, because there are two groups of economic-political forces vying for the opportunities offered by the growth in demand. The most emblematic case of this dispute must be due to the way rules of the Pre-salt auctions will be presented in relation to energy supply from natural gas thermoelectric plants, sporadically ("flexible plants") or continuously ("inflexible plants")

In this sense, the proposed energy plans seem more concerned with accommodating different interests, than facing decisions that could accelerate the energy transition in the country. There are several examples of this "accommodation", such as the PDE's bet on carbon capture alternatives for thermal generation using mineral coal and the maintenance of incentives for oil exploration, in terrestrial areas[15] or in the process of decay, despite its low relevance in national production.

Even some long-term scenarios, which pre-determine an offer of nuclear thermal generation, mentioned in the plans as "energy generation without emissions", present the same profile of accommodation of interests that do not consider the regulated electricity market consumer. It is worth noting that if the thermonuclear generation were subjected to the optimal expansion model, to which all other sources were submitted, its high costs would make it a problematic candidate.

Still in the long-term of the PNE and in the line of "accommodation of specific interests", the proposal to bring a new

15 In this case, through the "Revitalization of Exploration and Production Activities for Oil and Natural Gas in Terrestrial Areas (REATE) program"

breath to the large hydroelectric plants in the Amazon draws attention, by admitting a significant number of scenarios where the projects would interfere in indigenous lands and/or conservation units. This position disregards the current legal framework and ends up bringing difficulties, to the detriment of any expectation of a solution for expanding the electrical system.

Regarding fuels, the PDE is modest in the analysis of structural changes in the cargo transport matrix. It must be considered that the prominence of diesel derives, in large part, from the preference for road transport. Even for long distances, where other modes such as railways, river navigation and cabotage are much more efficient and cleaner per ton transported.

Perhaps, the most explicit aspect of the expansion plans is the attachment to perpetuating a centralized generation model. This increases pressure on the investments and technical losses of a network of transmission lines of increasing scope and complexity, especially in a global context where the technological advancement of energy storage alternatives - whether for electric generation or mobility - brings opportunities for transformation in the role of the consumer-generator of electric energy and in urban transport.

However, the analysis of selected scenarios in the long-term electrical expansion shows that a clean path proves to be technically and economically viable, leaving the Brazilian government with the task of promoting a better coordination between the appropriate decision-making entities.

# Annex

Total cost and accumulated emissions for electric expansion scenarios up to 2050

| Scenario name (without interference) | | Average generation renewable sources period 2050 (average MW) | | | | | | | REN-UHE-SHP | Average generation Non-renewable sources period 2050 | | | | | REN/TOTAL | NDC/TOTAL | Emissions | PVI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HPP | SHP | Wind | Solar | Biomass | DG | Tot REN | | NG | Coal | Nuclear | Others | Tot NREN | | | | |
| 1 | Stagnation | 50199 | 6107 | 3096 | 0 | 4097 | 3664 | 67163 | 10857 | 1065 | 0 | 2918 | 428 | 4411 | 94% | 15% | 6 | 252 |
| 2 | 100% Renewable Matrix in 2050 | 46875 | 4692 | 92687 | 22740 | 5267 | 11464 | 183725 | 132158 | 0 | 0 | 2873 | 0 | 2873 | 98% | 71% | 0 | 859 |
| 3 | Expansion without emission sources | 52570 | 6696 | 83747 | 23625 | 4750 | 11464 | 182852 | 123586 | 783 | 0 | 2963 | 0 | 3746 | 98% | 66% | 0 | 837 |
| 4 | Expansion with Fossil fuels | 58832 | 8208 | 68818 | 21111 | 4097 | 11464 | 172530 | 105490 | 10588 | 0 | 3053 | 428 | 14069 | 92% | 57% | 50 | 807 |
| 5 | Effects of climate change on water availability | 55172 | 6099 | 71454 | 23851 | 4097 | 11464 | 172137 | 110866 | 10980 | 0 | 3053 | 428 | 14461 | 92% | 59% | 88 | 937 |
| 6 | same as 5, expansion without emissions (3) | 47201 | 5025 | 86091 | 25097 | 7071 | 11464 | 181949 | 129723 | 1302 | 0 | 2918 | 428 | 4648 | 98% | 70% | 14 | 1005 |
| 7 | CAPEX SHG with 100% overhead | 58832 | 5620 | 70715 | 21531 | 4437 | 11464 | 172599 | 108147 | 10517 | 0 | 3053 | 428 | 13998 | 92% | 58% | 22 | 824 |
| 8 | HPP Repowering | 64427 | 8222 | 66546 | 18557 | 4116 | 11464 | 173332 | 100683 | 9785 | 0 | 3053 | 428 | 13266 | 93% | 54% | 22 | 797 |
| 9 | Electrical Integration South America | 69051 | 7117 | 69264 | 9605 | 8371 | 11464 | 174872 | 98704 | 8289 | 0 | 3008 | 428 | 11725 | 94% | 53% | 20 | 795 |
| 10 | EISA, 50% higher transmission cost | 72493 | 7997 | 49182 | 12439 | 8697 | 11464 | 162272 | 81782 | 20845 | 0 | 3053 | 428 | 24326 | 87% | 44% | 27 | 854 |
| 11 | EISA, 50% lower transmission cost | 73986 | 7214 | 53816 | 10959 | 8730 | 11464 | 166169 | 84969 | 16947 | 0 | 3053 | 428 | 20428 | 89% | 46% | 29 | 847 |
| 12 | Fully electric light vehicle fleet in 2050 | 57358 | 7367 | 107121 | 12101 | 3979 | 11464 | 199390 | 134665 | 11902 | 0 | 3053 | 428 | 15383 | 93% | 63% | 22 | 882 |
| 13 | Wind power limited to 50GW | 59832 | 9004 | 21048 | 53376 | 8371 | 11464 | 163095 | 94259 | 20021 | 0 | 3053 | 428 | 23502 | 87% | 51% | 27 | 828 |
| 14 | Wind and solar limited to 50GW | 60759 | 10210 | 21786 | 14131 | 8625 | 11464 | 126975 | 56006 | 56141 | 0 | 3053 | 428 | 59622 | 68% | 30% | 24 | 866 |
| 15 | Offshore wind power with CAPEX reduced by 20% | 58868 | 8208 | 68638 | 21938 | 4097 | 11464 | 173213 | 106137 | 9905 | 0 | 3053 | 428 | 13386 | 93% | 57% | 22 | 806 |
| 16 | Solar power limited to 50GW | 58874 | 8208 | 77572 | 11956 | 3979 | 11464 | 172053 | 104971 | 11064 | 0 | 3053 | 428 | 14545 | 92% | 56% | 21 | 811 |
| 17 | Increase of FC from bagasse power plants (off-harvest season) | 58685 | 8208 | 64096 | 14919 | 17077 | 11464 | 174449 | 107556 | 8713 | 0 | 3008 | 428 | 12149 | 93% | 58% | 17 | 767 |
| 18 | Same as above, with 50% increase in cost | 58726 | 8208 | 67301 | 15847 | 13097 | 11464 | 174643 | 107709 | 8491 | 0 | 3036 | 428 | 11955 | 94% | 58% | 18 | 804 |
| 19 | Repowering (8) + Increase FC bagasse power plants (17) | 63849 | 8222 | 60829 | 13413 | 17077 | 11464 | 174854 | 102783 | 8309 | 0 | 3008 | 428 | 11745 | 94% | 55% | 19 | 664 |
| 20 | 45% Decrease in Nuclear CAPEX | 58818 | 8222 | 68691 | 21203 | 4097 | 11464 | 172495 | 105455 | 10623 | 0 | 3053 | 428 | 14104 | 92% | 57% | 21 | 806 |
| 21 | 50% Decrease in Nuclear CAPEX | 58743 | 8222 | 65491 | 20891 | 4231 | 11464 | 169042 | 102077 | 10330 | 0 | 6798 | 428 | 17556 | 91% | 55% | 21 | 806 |
| 22 | 45% Decrease in Nuclear CAPEX and OPEX | 58742 | 8222 | 63865 | 20444 | 4252 | 11464 | 166989 | 100025 | 9711 | 0 | 9470 | 428 | 19609 | 89% | 54% | 20 | 805 |
| 23 | 50% Decrease in Nuclear CAPEX and OPEX | 58231 | 8222 | 57853 | 15717 | 4251 | 11464 | 155738 | 89285 | 9277 | 0 | 21154 | 428 | 30859 | 83% | 48% | 19 | 799 |

## Recommendations

Considering the cross analysis between energy adaptation plans and the fulfillment of climate targets voluntarily adopted by Brazil under the Paris Agreement (2015), we address in this policy brief the advances, risks, and limitations of the proposed trajectories for electric and energy expansion in the country, taking as a basis the Ten-Year Energy Expansion Plan (PDE 2030, in Portuguese) and the National Energy Plan (PNE 2050, in Portuguese). Based on this framework, we present the following recommendations:

- Government and private initiative should invest in a greater supply of renewable energy, with reduced costs, preserving the relevance of distributed renewable generation as an option in relation to large structures, such as hydroelectric plants, which social and environmental impacts have already been proven.

- The production of biodiesel from soy and corn is not an environmentally and socially responsible option, so its production as a substitute for diesel made from fossil inputs should not be stimulated by the national energy policy.

- The proposals for the flexibilization of Environmental Licensing underway in the National Congress through Bill N. 3729/2004, must be abandoned. Indeed, a joint effort of the entire Brazilian society and of the political forces in the country is necessary to bring new meaning to the treatment that has been given to this instrument, no longer as a bureaucratic obstacle to national development, but as a norm that seeks to guarantee its sustainability.

- Finally, the mandate elected for the period 2019-2022, has shown ineptitude for actions of political articulation and coordination between different decision-making instances within the government, which is also reflected in the case of the national energy policy. However, political articulation and coordination between different bodies involved with the supply and demand of electricity and fuels  is fundamental for an energy policy capable of facing contemporary climate challenges, as well as the goals defined in international agreements and the national legal framework.

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