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TEN-YEAR ENERGY EXPANSION PLAN

epe Empresa de Pesquisa Energética

Ministério de Minas e Energia

10. Socio-Environmental Analysis

The socio-environmental analysis of the planned energy expansion is guided by the concept of sustainability and seeks to discuss the main socio-environmental issues associated with the production, generation, and transmission of energy within the timeframe of PDE 2031. The general situation, such as policies and discussions related to energy, resource availability and climate change, is also investigated to more broadly understand the context expansion takes place in.

Regarding this cycle, it is worth mentioning important points for socio-environmental analysis: *i*) the scenario of economic downturn due to the COVID-19 pandemic, which impacted the forecasts of energy demand and supply; *ii*) Brazilian energy policy that indicated greater fossil fuels utilization; and *iii*) Brazilian government's recent declarations regarding net carbon neutrality by 2050 and emission reduction commitments signed at the 26th United Nations Conference on Climate Change (COP26), which, in the medium and long term, are significant constraints to build Brazil's energy pathway.

The water scarcity faced in 2021 is also worth mentioning. The crisis raised an alert for the risks related to electricity supply and water security in the country, leading the sector to address the water availability uncertainty in planning the expansion of National Interconnected System (SIN in Portuguese acronym). The fact is that both the global situation of climate change policy and the specific issue of water availability reinforce the need to consider adaptation measures to climate change in planning.

The energy transition is yet another important debate that permeates the socio-environmental analyzes of PDE. The idea was to see interesting possibilities that arise with energy transition process, such as decarbonization initiatives and various sustainability mechanisms.

Starting from this overview, we seek to have an integrated vision of energy expansion that allows the identification of the main socio-environmental challenges to be faced and socio-environmental opportunities that can be taken advantage of in the ten-year timeframe. Specifically, PDE 2031 socio-environmental analysis includes the following activities:

1) To contribute to the expansion definition during the decade.

2) To assess the major socio-environmental issues associated with the ten-year expansion by means of an integrated socio-environmental analysis, qualitatively related to major interferences of the expansion to the most outstanding Brazilian regions socio-environmental sensitivities, represented by socio-environmental themes (EPE, 2012).

3) To point out strategic socio-environmental challenges and opportunities for expansion, discussing important socio-environmental issues that may pose risks, as well as envisioning innovative perspectives related to the planned expansion.

4) To discuss challenges and opportunities related to energy and climate change, considering political context analysis, planned expansion greenhouse gas (GHG) emissions profile and mitigation and adaptation measures.

PDE 2031 socio-environmental analysis result will be presented in this order in this Chapter.

It is noteworthy that, as a subsidy to the integrated socio-environmental analysis, a socio-environmental analysis of each energy source has been carried out in the Technical Note "Socio-environmental analysis of PDE 2031 energy sources" (EPE, 2022).

10.1 Socio-environmental Analysis to define the expansion

In planning studies, environmental variable is considered since energy planning initial stages. The studies vary according to the nature of the subject matter; however, in general, they seek to avoid or reduce interference in sensitive areas from a socio-environmental point of view. **Table 10 - 1** presents some of these studies and the socio-environmental analyzes carried out considering socio-environmental impacts minimization.

Table 10 - 1: Energy planning studies and the environmental variable

Planning study	Socio-environmental analyzes and impact minimization
Hydropower inventory (hydropower project initial identification phase)	• Consideration of environmental criteria in choosing the best alternative for dividing falls for a watershed. • Minimization of negative socio-environmental impacts and maximization of positive ones, by comparing alternatives. • Execution of the Integrated Environmental Assessment (AAI in Portuguese acronym), which gages the cumulative and synergistic effects of the set of uses that make up the alternative selected in the inventory.
R1 and R3 reports (initial studies of transmission lines (LT in Portuguese acronym) - corridors and routes)	• Avoidance of interference in protected areas and areas with relevant socio-environmental sensitivity. • Visualization of possible complicating factors for the implementation, reflecting on implementation cost and time.
Environmental Study of Sedimentary Area (EAAS in Portuguese acronym) (oil activity planning study)	• Classification of the study region in suitable and unsuitable areas and in moratorium on oil and natural gas exploration and production activities and preparation of recommendations for environmental licensing. • Contribution to local conflicts reduction, investment risks and exemption from environmental licensing.
National Energy Plan (PNE in Portuguese acronym) (long-term energy planning study)	• Identification of high socio-environmental complexity areas to exclude oil and natural gas volumes from production curves calculation.

When defining the portfolio of projects that make up the expansion over the ten-year timeframe, the results of these initial studies are considered.

We can mention transmission to illustrate the point. Among the 269 lines mapped in PDE 2031, about 20% had their route influenced by their proximity to Indigenous lands or integral protection conservation units. Feijó - Cruzeiro do Sul C1 LT 230 kV, for example, was planned to divert from the Kaxinawá Colônia Vinte e Sete and Campinas/Katukina Indigenous lands from its inception, with sufficient distance to avoid interference in these areas and give greater predictability to the project implementation process.

In addition to considering initial planning studies, regarding PDE 2031, the environmental variable contributes to the definition of the planned expansion through the following analyses:

1) ***Procedural analysis of hydropower plants (UHE in Portuguese acronym)***, with the objective of estimating the possible year for entry into operation of UHEs. The analysis considers the deadlines for environmental and engineering studies, for environmental licensing and for construction, considering individual characteristics

and most up-to-date information of each project. Additional deadlines are also considered for projects that interfere in protected areas (Indigenous lands or conservation units) or that must resolve technical, legal, and administrative demands. Projects that are in the feasibility study phase are considered to carry out procedural analysis.

36 UHEs registered for feasibility studies at the Brazilian National Electricity Regulatory Agency (ANEEL in Portuguese acronym) were analyzed. 20 UHEs of that group are in protected areas or have had their studies stopped. For the remaining group of 16 UHEs, when assessing the studies status, the environmental licensing process and the deadlines adopted in the methodology, the result indicated that eight UHEs would have a possible operation date in the ten-year timeframe[1]. Only one UHE was selected from this group after the energy simulations.

2) ***Analysis of the socio-environmental complexity of oil and natural gas production units***, to adjust production forecasts according to the concerns posed by environmental agencies. In Federal Government areas, resource volumes in sensitive areas (Indigenous lands, conservation units and buffer zones, urban areas, and sensitive marine areas) are deducted.

As for areas with concession contracts, these are rated by complexity (based on the Environmental Guidelines for Block Bidding Rounds from the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA in Portuguese acronym), and on the concerns indicated in the environmental licensing by state environmental agencies) and the estimated time for environmental licensing.

For the 27 Federal Government Production Units (UPUs in Portuguese acronym) slated to start production over the decade, there was an 8% and 9% deduction in the volume forecast for natural gas and oil, respectively. As for areas with concession contracts, 744 Production Units (UPs in Portuguese acronym) were analyzed, 313 of which were offshore and 431 onshore. The result indicated that 76 of the 744 UPs were considered of high socio-environmental complexity. Of these, 70 are production fields or had their E&P activities recently licensed. The additional period for environmental licensing was applied to the six remaining UPs. However, it is noteworthy that it was not necessary to allocate this additional time to the production start forecasts, since the deadlines demanded by logistics and infrastructure for these UPs already exceeded the expected times for the environmental licensing (see Chapter 5 - Production and Natural Gas and Technical Note “Socio-environmental analysis of PDE 2031 energy sources”).

[1] These UHEs are part of the project portfolio offered for the last five years of the ten-year timeframe, since the first five years are composed of UHEs that have already been contracted in energy auctions.

10.2 Integrated Socio-environmental Analysis

The integrated socio-environmental analysis presents a holistic view of the socio-environmental issues associated with the expansion of energy supply[2].

The analysis consists of three steps: 1) Expansion spatial analysis, 2) socio-environmental themes and 3) strategic socio-environmental challenges and opportunities.

EXPANSION SPATIAL ANALYSIS

The energy expansion spatial analysis in the ten-year timeframe presents the set of planned projects, which allows for the preliminary identification of possible cumulative effects in the regions with the highest occurrence of projects. In this sense, the map indicates areas subject to overloads on natural resources or pressure on sensitive environments, thus requiring more strategic action in certain situations. Another aspect of spatialization is the possibility of visualizing synergies from the expansion itself, such as complementarity between sources or optimization of transmission expansion, thus contributing to more efficient energy planning.

Thermoelectric plants (UTE in Portuguese acronym) using natural gas, refinery gas, coal, diesel and nuclear should increase the electricity supply by 31.3 GW in the ten-year timeframe. In contracted expansion, a power increase of 6.3 GW in the system is foreseen from new UTEs. 7 of these are natural gas UTEs (3.3 GW), 2 diesel (0.3 GW), 1 nuclear (1.4 GW) and 1 refinery gas (40 MW), added to the amount of 1.2 GW of existing natural gas UTEs.

The contracted units are in the North, Northeast, and Southeast regions, predominantly in the coastal area, close to load centers, the fuel source or the gas pipeline network. The indicative expansion of non-renewable UTEs totals 25 GW. Of this total, 22.6 GW are from natural gas UTEs provided for in all subsystems, with 10 GW in the Southeast/Midwest, 7.8 GW in the South, 2 GW in the Northeast and 2.7 GW in the North. Coal-fired UTEs will expand by 1.4 GW in the South subsystem and the nuclear UTE will expand by 1 GW in the Southeast/Midwest.

Wind projects will have an expansion of 10.7 GW, located exclusively in the Northeast region.

There are 183 contracted farms (6.4 GW), scheduled to come into operation until 2026, and 4.3 GW indicative expansion with operation expected to start from 2027.

[2] A summary of the expansion foreseen in PDE 2031 is presented in Chapter 11 - Consolidation of results.

Box 10 - 1: Positive Socio-environmental Aspects of the Planned Expansion in PDE 2031

When analyzing the expansion planned in PDE 2031, several positive aspects are noted from the socio-environmental point of view, both in the electrical and energy matrix, contributing to lower emission of GHGs and pollutants and to minimization of impacts to the environment. Some points are presented below.

Positive socio-environmental aspects of the electrical matrix:

- Growth of distributed micro and mini-generation, contributing with 7.9% of electricity consumption in 2031.
- 83% of the installed electricity generation capacity in 2031 will be renewable, with wind and solar sources responsible for 27.7% of the centralized ten-year expansion.
- About 7.2% of the centralized electrical expansion will come from the upgrading of existing hydropower plants, that is, increasing the system capacity without building new plants, with greater efficiency in the use of water resources and in hydropower generation.
- 3.4% of the centralized expansion will come from renewable thermoelectric plants that basically use waste, including urban solid waste, thus avoiding a series of socio-environmental impacts.
- 20% expansion of the transmission system, including isolated systems interconnection to the SIN and increasing system reliability, with cost and emissions reduction.

Positive socio-environmental aspects of the oil, natural gas, and biofuel supply:

- Expansion of 75% in the production of biodiesel, used in blending with diesel oil, reducing pollutant and GHG emissions.
- Expansion of 48% in the production of ethanol, used as an additive and direct substitute for automotive gasoline, contributing to the reduction of GHG emissions.

The hydropower expansion takes place in all Brazilian regions and is responsible for an increase of approximately 7.9 GW (UHE: 5.2 GW; PCH: 3.3 GW) in ten-year timeframe. Among the contracted expansion of 0.25 GW of UHE, there are two projects in the South and one in the Midwest. In the indicative (about 5 GW), 4.3 GW are expected to be obtained from the upgrading of existing units in all regions and a UHE (650 MW) in the North. Regarding small hydropower plant and hydropower generation unit (PCH and CGH in Portuguese acronym), 47 projects (635 MW) are under contract, scheduled to come into operation by 2026, and 2.7 GW are part of the indicative expansion, located mainly in the South, Southeast and Midwest regions.

Photovoltaic expansion is responsible for the increase of 5.8 GW in the decade, 3.1 GW of which were contracted, distributed along 92 projects in the Northeast and Southeast. The remaining 2.7 GW correspond to the indicative expansion in the Southeast.

2.1 GW are estimated to be installed for renewable thermoelectric plants. Of these, 1.4 MW are already contracted (21 new and 7 expanded UTEs), as follows: 18 sugarcane bagasse UTEs (666 MW), 2 black liquor UTEs (363 MW), 4 wood chip/waste UTEs (297 MW) and 4 municipal solid waste (RSU in Portuguese acronym) biogas UTEs (33 MW). The contracted renewable UTEs are concentrated in the Southeast, mainly associated with the cultivation of sugarcane, but they are also in the Northeast, Midwest, and South. As for indicative expansion, 400 MW of sugarcane bagasse plants and 300 MW of plants that use incinerated urban solid waste are foreseen, totaling 700 MW in the Southeast/Midwest subsystem.

The next 10 years transmission expansion foresees the implementation of 33,633 km, that is a 20% increase in the system extension, with 17,361 km expected to come into operation by 2026. There is expansion of lines in all regions with large interconnection trunks that increase the electrical exchange capacity between the subsystems and interconnect isolated regions to SIN. There is also a network expansion to meet the increased electricity demand, especially in capital cities. The great expansion in the Southeast is to drain energy from UTEs and solar plants and boost the subsystem. In the North, the Manaus-Boa Vista interconnection and Acre´s main urban centers integration to SIN can be observed. In the Northeast, the lines meet the generation potential of wind, photovoltaic and thermoelectric plants. In the South, the lines for conveying energy from existing wind farms and for metropolitan regions stand out.

For oil and natural gas projects, conventional resources are planned to start being produced in 277 UPs (Production Units) in contracted areas, and in 27 indicative UPUs (Federal Government Production Units) in non-contracted areas. Onshore UPs are in the North, Northeast, Midwest, and Southeast regions; while offshore UPs are mainly concentrated in the Southeast region, with some also in the Northeast, North (along the equatorial margin) and South regions. In terms of supply, the following are planned: 2 new refineries in the Southeast and Northeast and 2 expansions of existing refineries in the Southeast and Northeast; 3 hydrotreatment units in existing refineries, in the Southeast; 2 gas pipelines (1 planned in the Southeast and 1 indicative in the Northeast); in addition to 4 liquefied natural gas (GNL in Portuguese acronym) regasification terminals (1 planned in the North and 3 indicative in the South, Southeast and Northeast). Two natural gas processing plants (UPGN in Portuguese acronym) are also indicated, one scheduled for the Southeast and another indicative for the Northeast.

13.7 billion liters expansion is planned for ethanol. To reach that volume, the operation of 18 plants under construction, the expansion of 57 plants and the implementation of 24 other projects (sugar cane, corn and flex) - still under study - are scheduled.

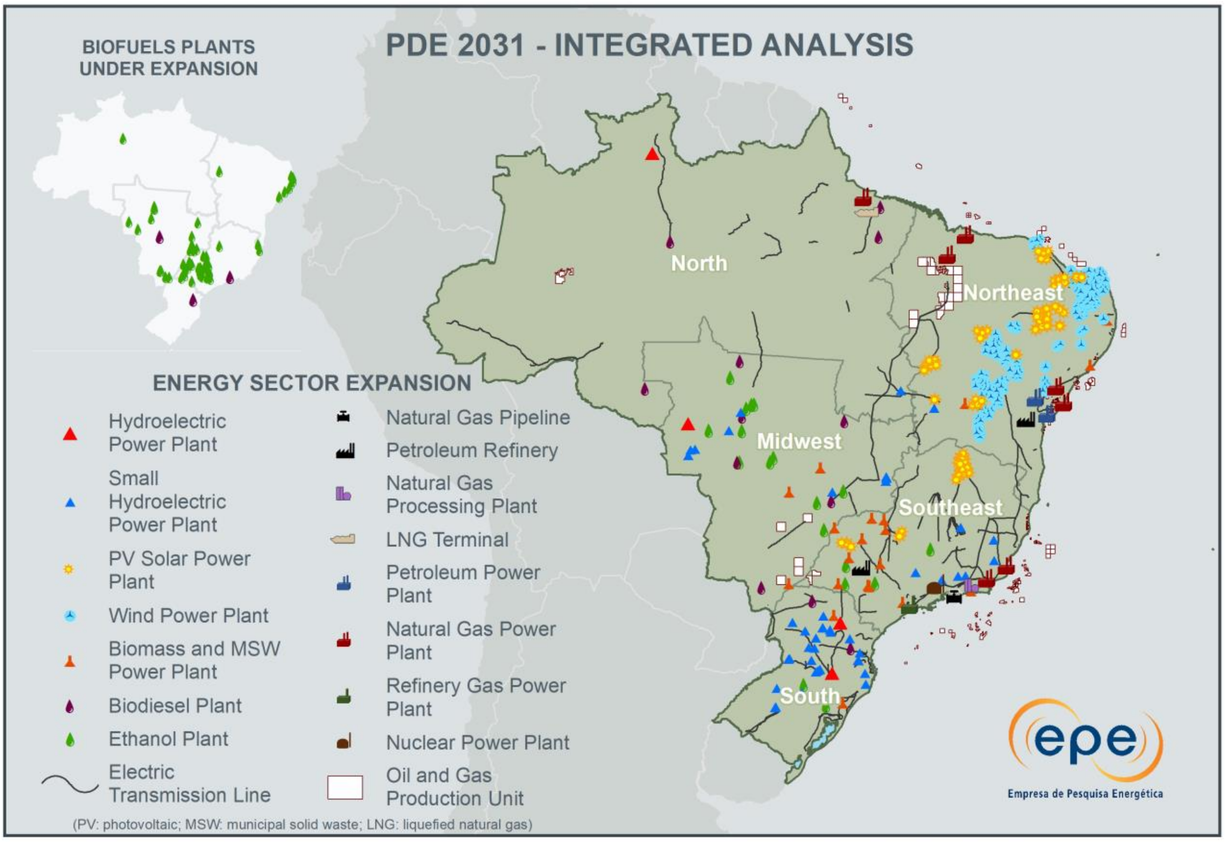
From the 18 plants under construction: 2 are flex (corn and sugar cane), 8 are full (corn), 4 are sugar cane and 4 use other raw materials (soy and grain). They are located essentially in the Midwest, mainly in areas of high and medium agricultural aptitude for sugar cane and have also proven feasible for corn ethanol production. The 57 plants under expansion are scattered along all regions, but mainly in the Southeast and Midwest.

As for biodiesel, the PDE 2031 offer scenario provides for a 5.5 billion liter expansion in installed capacity. Installation of 13 new plants concentrated in the Midwest is scheduled; these are associated to the expansion growth of soy, their major raw material. There are units also in the North, Southeast and South regions. The three scheduled expansions are in the Southeast, South and Midwest.

Figure 10 - 1 shows projects location provided for in PDE 2031[3].

[3] Figure 10-1 shows only contracted (electric system) and scheduled (oil, natural gas and biofuels) expansion. Mapping of indicative expansion per energy source can be seen in Technical Note "Socio-environmental analysis of PDE 2031 energy sources" (EPE, 2022).

Figure 10 - 1: Energy foreseen projects map - PDE 2031



SOCIO-ENVIRONMENTAL THEMES

The socio-environmental themes are intended to summarize the significant interference of the planned expansion to the environment and society, considering the sensitivities identified for each Brazilian region (EPE, 2012). The topics are reviewed with each edition of the Plan according to the expected expansion and related interferences.

The analysis aims to point out the major interferences associated with the energy supply expansion planning in the ten-year timeframe (considering both contracted or planned expansion and indicative expansion). Therefore, it is not intended to cover all possible project´s socio-environmental impacts. Project externalities are addressed in more detail during feasibility and environmental licensing studies. It is also worth noting that, from planning and licensing phase to project´s operation, measures are adopted to avoid, reduce, or compensate the negative impacts, as well as enhance the positive ones.

It is important to clarify that accidents risks associated with some sources of energy production, such as, for example, the possible risks of oil leakage at sea or radiation from nuclear plants, are not reflected in the socio-environmental issues. However, these issues are widely discussed between energy and environmental sectors, especially in licensing project proceedings. Socio-environmental issues, mitigating measures and accident risks are addressed in the Technical Note “Socio-environmental analysis of PDE 2031 energy sources” (EPE, 2022).

In light of these considerations, the integrated socio-environmental analysis of PDE

2031 includes seven socio-environmental themes[4]. **Table 10 - 2** presents a synthesis containing the socio-environmental themes; the interferences represented by each of the themes; and the justifications for the theme relevance by geographic region, considering the major interferences identified for each energy source in each of the regions.

[4] Comparing PDE 2031 with the previous PDE, one socio-environmental theme was considered (Water resources) and another was not considered (Quilombola communities). The Quilombola communities topic was no longer considered for transmission lines in the Northeast in PDE 2031, due to the significant reduction of planned LTs in the region in relation to previous PDEs and the non-occurrence of overlaps between planned LTs and Quilombola lands for the next 10 years.
Also noteworthy in this PDE the inclusion of the Biodiversity theme, which covers themes of Native Vegetation, Fauna and Conservation Units, presented in previous PDEs.

Table 10 - 2: Synthesis of socio-environmental themes in PDE 2031

Socio-environmental themes	Represented interferences	Relevance rationales
Biodiversity 	comprises loss of individuals; loss or transformation of natural aquatic or terrestrial habitats; and impacts on ecosystems and their functions. It also portrays complexities noticed in environmental licensing process.	**N: Interference with terrestrial and aquatic habitats** - Project located in a region with great environment heterogeneity (UHE) **NE: Interference with terrestrial and marine habitats** - Cumulative and synergistic effects of the combined interferences in terrestrial habitats (EOL, UFV and LT) - Bat and birds crashing into wind turbines (EOL) - Interference with high-biodiversity marine fauna and environments (E&P) **MW: Interference with aquatic ecosystems** - Cumulative and synergistic effects of rivers fragmentation and plants in headwater regions that are important for aquatic fauna (PCH and CGH) **SE: Interference with terrestrial and marine habitats** - Cumulative effects on marine ecosystems due to substantial number of projects (E&P) - Cumulative and synergistic effects of rivers fragmentation and plants in headwater regions that are important for aquatic fauna (PCH and CGH) - Interference in Atlantic Forest remnants (LT) **S: Interference with terrestrial habitats and aquatic fauna** - Combined effects in Atlantic Forest remnants (UHE, PCH, CGH and LT) - Cumulative and synergistic effects of rivers fragmentation and plants in headwater regions that are important for aquatic fauna (PCH and CGH)
Territorial organization 	portrays potential conflicts of land use and occupation. It also encompasses impacts resulting from population attraction and pressure on local infrastructure and its equipment and services.	**N: Pressure on services and infrastructure in urban areas** - Historical process of attracting population to urban centers and support centers (E&P) - In a heterogeneous way, in addition to resettlement of rural and urban populations (UHE) **NE: Interference in local communities' ways of life** - Restrictions on access and use of areas previously used for social reproduction (EOL) - Onshore activities not common in the region and cumulative due to the proximity of production units (E&P)

Socio-environmental themes	Represented interferences	Relevance rationales
Landscape	refers to natural and urban landscapes visual impact.	**NE: Interference with natural landscapes** - Projects in flatland plateau regions with relevant tourist attractions (EOL) **S and SE: Interference with natural and urban landscapes** - Projects in mountainous regions of recognized scenic beauty (LT) - Projects in urbanized landscapes, to serve urban expansion areas (LT)
Indigenous peoples and lands	are linked to ethnic diversity, the territorial issue, and the need to manage conflicts over resources. Added to this are the challenges of environmental licensing processes and prior, free, and informed inquiry.	**N: Interference with Indigenous peoples and lands** - Proximity to Indigenous peoples and lands, complexity of the topic and impact on the environmental licensing process (UHE and LT) **S: Interference with Indigenous peoples and lands** - Project in a basin declared as Indigenous territory (UHE)
Air quality	is related to atmospheric pollutants emission in electric energy generation.	**S and SE: Emission of pollutants** - Expansion in areas saturated with existing plants and expansion in large urban and industrial centers with compromised air quality (fossil UTE).
Water resources	represent possible conflicts from water resources use.	**NE and SE: Water use conflicts** - Increase in water demand (fossil UTE) - Challenges to UHE operation in water availability restriction scenarios (UHE upgrading) **MW: Water use conflicts** - Challenges to UHE operation in water availability restriction scenarios (UHE upgrading) **S: Water use conflicts** - Increase in water demand (fossil UTE)
Residual waste	concerns the importance of waste in power generation and fuel production processes.	**SE: Waste generation** - Radioactive waste that require special management due to their hazardous nature (nuclear UTE) - Concentration of plants and large volume of vinasse, effluent with a high polluting potential (ethanol) **MW: Waste generation** - Concentration of plants and large volume of vinasse, effluent with a high polluting potential (ethanol)

Caption:
Geographic regions – N: North, NE: Northeast, S: South, SE: Southeast and MW: Midwest
Energy sources – UHE: hydropower plant, EOL: wind, UFV: photovoltaic plant, LT: transmission line, E&P: oil and natural gas exploration and production, PCH: small hydropower plant, CGH: hydropower generation unit, and UTE: thermoelectric plant

Table 10 - 3 shows a matrix summarizing PDE 2031 integrated socio-environmental analysis. The matrix shows in a systematic way the socio-environmental themes related to energy source provided for in the Plan and the regions they are located. Thus, we can see the interference of different projects on the same region.

Table 10 - 3: Summary matrix of PDE 2031 integrated socio-environmental analysis

Regions → Sources ↓	North	Northeast	South	Southeast	Midwest
UHEs	biodiversity, territorial organization, Indigenous peoples and lands	water resources	biodiversity, Indigenous peoples and lands	water resources	water resources
PCHs and CGHs	low-significance interferences	low-significance interferences	biodiversity	biodiversity	biodiversity
Fossil UTEs (natural gas, refinery gas, coal, and diesel)	low-significance interferences	water resources	air quality, water resources	air quality, water resources	low-significance interferences
Nuclear UTE	-	-	-	residual waste	-
Renewable UTEs (sugarcane bagasse, black liquor, wood chips/forest residues and RSU)	-	low-significance interferences	low-significance interferences	low-significance interferences	low-significance interferences
Wind	-	territorial organization, landscape, biodiversity	-	-	-
Solar photovoltaic	-	biodiversity	-	low-significance interferences	low-significance interferences
Transmission	Indigenous peoples and lands	biodiversity	landscape, biodiversity	landscape, biodiversity	low-significance interferences
Oil E&P and Natural Gas	territorial organization	biodiversity, territorial organization	low-significance interferences	biodiversity	low-significance interferences
Refineries, UPGNs and GNL terminals	low-significance interferences	low-significance interferences	low-significance interferences	low-significance interferences	-
Gas pipelines	-	low-significance interferences	-	low-significance interferences	-
Ethanol	low-significance interferences	low-significance interferences	low-significance interferences	residual waste	residual waste
Biodiesel	low-significance interferences	low-significance interferences	low-significance interferences	low-significance interferences	low-significance interferences

Legend

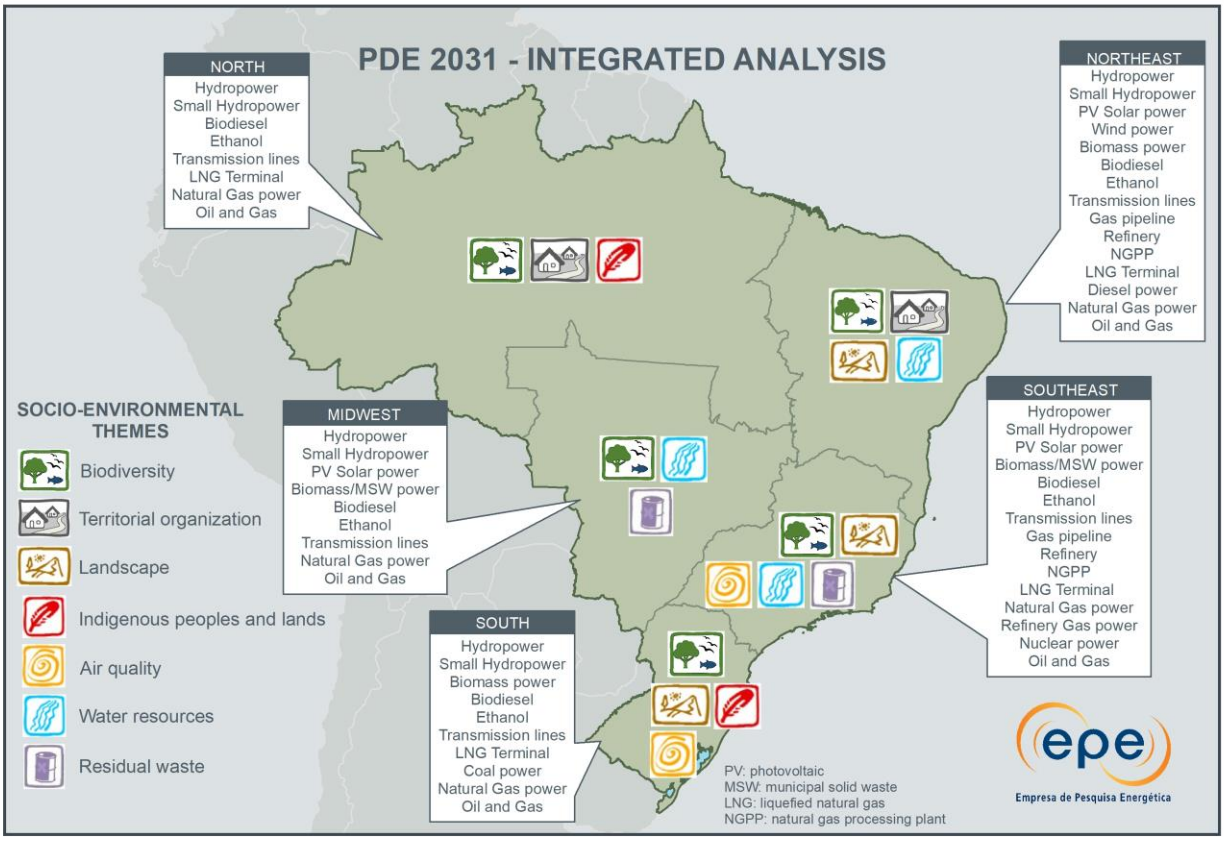
- biodiversity
- territorial organization
- landscape
- Indigenous peoples and lands
- air quality
- water resources
- residual waste
- low-significance interferences
- \- no expasion planned

Notes: (1) The expression "low-significance interferences" means that, although the impacts exist, they are not so significant in face of the expansion and the regional sensitivities, and relevant socio-environmental issues have not been identified.
(2) For the socio-environmental issues related to oil and natural gas E&P, the main interferences associated with the activities were taken into account, not considering the effects of eventual accidents.

Icon credits: EPE and designed by Flaticon

The map in the **Figure 10 - 2** illustrates the information presented in the matrix and summarizes the result of the integrated analysis, indicating the expansion sources by region and the socio-environmental themes that must be carefully observed when preparing studies and projects for each region.

Figure 10 - 2: Summary map of PDE 2031 integrated socio-environmental analysis



For the Northeast region, all types of projects are foreseen, except for a nuclear thermoelectric plant. It is the region with the greatest expansion of wind and photovoltaic plants and, consequently, transmission lines for conveying the energy. Thus, the cumulative and synergistic effects of the combination of interferences of these three types of projects are highlighted, especially in terrestrial habitats. Therefore, the theme that stands out the most for the Northeast region is Biodiversity.

For the Southeast region, all types of projects are foreseen, apart from wind farms. The region is sensitive, due to the large concentration of existing plants and conflicts, especially over the use of water. This makes us pay attention to the modernization of existing hydropower plants, which already face operational challenges in water restriction scenarios. That is why the Water Resources theme stands out in the Southeast region.

For the South region, the combined effects of hydropower plants, PCHs, CGHs and planned transmission lines that interfere in remnants of the Atlantic Forest stand out. Added to this are the cumulative and synergistic effects of river fragmentation due to the number of existing dams added to the planned PCHs and CGHs. Thus, the topic that most attracts attention in the South region is Biodiversity.

In the North region, sensitivity is due to the populations of Indigenous lands. The proximity to Indigenous peoples and lands, the complexity of the theme and the impact on the environmental licensing process of the transmission line and hydropower plant foreseen in the expansion make the Indigenous Peoples and Lands theme stand out in the region.

Finally, in the Midwest region, the expansion of PCHs and CGHs and the cumulative and synergistic effects of existing and planned hydropower plants in the same basin are observed, which can cause fragmentation of rivers in important regions for aquatic fauna. Thus, the theme that stands out the most in the region is Biodiversity.

Therefore, in view of the expansion foreseen in PDE 2031, the Biodiversity theme stood out the most in the Northeast, South and Midwest of the country. The Water Resources theme stood out in the Southeast and the Indigenous Peoples and Lands theme, in the North. Special attention should be given to these issues when the energy projects planned for each of the regions are installed.

STRATEGIC SOCIAL AND ENVIRONMENTAL CHALLENGES

Socio-environmental challenges expose the socio-environmental complexity of an issue in the face of energy expansion. In a way, they are related to relevant socio-environmental themes, as they reflect major topics to be discussed. The challenges considered as strategic involve issues that may pose risks to expansion with sustainability and demand greater efforts to solve them.

When considering PDE 2031 planned expansion; the matrix and the synthesis map; and Brazil's regionalization, it can be seen that some themes stand out from the others. This is the case of the Biodiversity theme, which appears in all regions of Brazil and for different energy sources. In the same way, the Water Resources theme was also identified in all regions, except for the North.

As much as the energy sector tries to avoid, since its initial planning stages, installation of projects in environmentally sensitive areas and has also invested in technologies to reduce their impacts, the compatibility between energy generation and transmission with biodiversity conservation is still a challenge for the sector.

Conflicts over water use increase as the demand by various sectors that use it also increases, especially in regions where there are already water use conflicts or low water availability. That is why making energy generation compatible with other water uses is one of the main challenges to the sector.

Expanding the scale of analysis from a local or regional view to a global outlook, the challenge of managing GHG emissions associated with production and use of energy is highlighted.

Thus, the following socio-environmental challenges were considered strategic for the expansion of PDE 2031: compatibility of energy generation and transmission with biodiversity conservation; compatibility of energy generation with other uses of water; and management of GHG emissions associated to energy production and use.

Compatibility of energy generation and transmission with biodiversity conservation

As well as by other human activities, natural resources use by the energy sector has negative impact processes on the biota, whether directly on individuals, on habitats or on ecological processes.

The concentrated expansion of wind and photovoltaic projects poses challenges to the management of interferences in biodiversity, mainly due to the possible cumulative and synergistic effects of the combination of these projects with the transmission lines planned to convey their energy. Initiatives have been currently carried out on a project scale to avoid or minimize native vegetation suppression and adopting measures to mitigate, monitor and compensate for interference, such as forest recovery and bird fauna monitoring programs. In the case of transmission lines, since the planning phase there are remarkable sector's efforts to divert their route from native vegetation remnants and other areas of regional importance for biodiversity conservation.

Likewise, biodiversity conservation is also a challenge for hydropower projects in sensitive regions or regions that are fragmented by many dams. To deal with this issue, the main tool used has been studies that consider effects of the entire set of projects in a watershed, such as the Integrated Environmental Assessment (AAI) and the Integrated Watershed Study (EIBH in Portuguese acronym). In addition, sustainability guides and protocols and adoption of socio-environmental performance standards by institutions such as the International Hydropower Association (IHA) and the World Bank Group helped to spread international best practices at all stages of hydropower projects. In these documents, risk management on biodiversity includes aspects of maintaining environmental resources, valuing ecosystem services, managing habitat and ecological flows, among others.

The oil sector also faces the challenge of making its activities compatible with biodiversity conservation and, therefore, has made efforts towards an integrated planning with the environmental sector. It is worth noting that Environmental Assessments of Sedimentary Areas (AAAS in Portuguese acronym) were carried out, aimed at reconciling future oil and natural gas activities with regional socio-environmental aspects. For areas that have not yet been submitted to the AAAS, joint manifestation prior to offer of blocks carried out by the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP in Portuguese acronym) and IBAMA still stand, with state environmental agencies having also been heard. Intersectoral discussions within the scope of environmental licensing processes for E&P activities can also be mentioned, to promote good practices and harmonize procedures.

The numerous initiatives, articulations and efforts mentioned above reflect the importance and strategic nature of this challenge for energy and environmental sectors. Thus, it is essential to continue searching for joint solutions that are in line with energy development and biodiversity conservation policies.

Compatibility of energy generation with other uses of water

Water is an essential natural resource for various activities, such as human supply, animal thirst-quenching, irrigation, energy generation, navigation, leisure, among others. As recommended in Federal Law no. 9,433/1997, water resources management has the role of promoting this multiple use, making different interests and demands compatible and avoiding possible conflicts.

Water resources management is complex, especially in regions where there is great demand for water or even in areas of low water availability. Conflicts tend to increase in the future, with the increase in number and diversity of users, especially in water scarcity periods, such as the year 2021. According to the National Water and Sanitation Agency – ANA in Portuguese acronym (ANA, 2019), the demand for water in Brazil is growing, with an estimated increase of approximately 80% in the total withdrawn in the last two decades. The forecast is for a 24% increase in demand by 2030.

In this context, the energy sector plays an important role as a water resources user. Water is used as a primary input for hydroelectric generation or as part of production process for cooling thermoelectric plants, for example. In addition, the sector can store and regulate water through hydropower reservoirs.

In PDE 2031, the challenge of making energy generation compatible with other uses of water is related to hydropower plants, non-renewable thermoelectric plants, solar photovoltaic plants, and the production of ethanol. In view of the planned energy expansion, it is essential to continuously improve methodologies and tools for managing water stored by hydropower complex, seeking to optimize the use of this resource, as well as the use and development of technologies that reduce water consumption.

Box 10 - 2: Water scarcity and the 2021 crisis

The scenario of water scarcity and low levels of hydropower reservoirs stood out in the year 2021. This situation was the result of a period with the worst hydrological sequences observed in the entire history of flows from 1931 to 2021 (ONS, 2021), in the main hydrographic basins of SIN. The criticality of the situation was reflected in the first Water Emergency Alert issue by the National Meteorology System (SNM in Portuguese acronym) in May 2021, associated with precipitation scarcity in Paraná hydrographic region, which covers the states of Mato Grosso, Goiás, Mato Grosso do Sul, São Paulo and Paraná, for the period from June to September 2021.

Although generation capacity and energy sources diversification in the electricity matrix have increased significantly in recent years, security in electric energy supply still largely depends on inflows and energy storage in UHEs reservoirs that, in turn, are related to climatic situation and increase in water consumptive uses. To overcome the exceptional situation, several measures were adopted to maintain the levels of reservoirs to last the dry period.

Also in 2020, the Electric Sector Monitoring Committee (CMSE in Portuguese acronym) authorized dispatch of thermoelectric generation and energy import from Argentina and Uruguay, to save water in hydropower plants reservoirs. Also noteworthy was the creation of the Chamber of Exceptional Rules for Hydropower Management (CREG in Portuguese acronym), with the aim of strengthening governance to face water crisis, thus establishing the necessary articulation between bodies and entities responsible for water-resource-dependent activities. Within the scope of CREG, flexibilities of operational restrictions of hydropower plants were discussed and implemented for the preservation of storage conditions in SIN.

In order to promote the recovery of storage levels in reservoirs, the Contingency Plan for the Recovery of SIN Reservoirs was published (ANA, 2021). It indicates operating measures of main hydropower plants with a regularization reservoir to be adopted in wet season, from December 2021 to April 2022, aimed at refilling them, with a focus on water security and ensuring water multiple uses in 2022 and beyond.

The situation experienced in recent years raises the point of reflecting on the need to improve electricity sector planning studies. This is because river flows forecast is complex, and future water availability is one of the variables that make up uncertainty in SIN planning studies. The period of intense drought observed in recent years may have been a cyclical issue and rainfall will resume in the coming years. Another possibility is that it is a structural change associated with climate change, increased water use, changes in land use, or even a combination of all these factors. Although it is difficult to anticipate and measure these changes, it is essential to carry out a risk analysis to reduce impacts on energy supply and on different water uses.

With regard to hydropower plants, the increase in other uses of water in hydrographic basins can result both in reduction of energy production, due to the increase in withdrawals for consumptive uses upstream of the hydropower plants, and in the expansion of the inflexibility of hydropower generation through the establishment of operational restrictions to UHEs.

Concerning the indication of modernization and repowering of existing hydropower plants in the ten-year timeframe, it is noteworthy that, although the increase in energy production is expected with the available resource, new operational standards of reservoirs to meet power and flexibility requirements for SIN can change the downstream hydrological regime, making resource management difficult and or creating new operational restrictions.

For thermoelectric generation, considering that the planned expansion is significant and considering water consumption for cooling processes, making the implementation of new projects compatible with other water uses can be a challenge for UTEs planned for regions with water deficit. On the other hand, the locational flexibility for UTEs implementation allows the use of other water sources, such as sea water, which is being increasingly used. In addition, low water consumption cooling technologies already exist, which can be encouraged. These cooling solutions, however, imply higher costs and are not always adopted.

Water consumption in photovoltaic solar plants deserves attention due to frequent location of projects in regions with a water deficit history, such as the Brazilian semi-arid region. In these projects, water is mainly used for cleaning the panels. It is worth noting that there are already (and are still under development) technologies that prevent the accumulation of dirt or allow cleaning with little or no water.

As for the sugar-alcohol sector, despite the sector's evolution in recent years regarding the reduction of water consumption, this aspect must be observed in view of the expected increase in ethanol production in the decade added to the number of existing plants.

In short, the energy sector has a responsibility to optimize water resources use in generation and reduce consumption when possible. For this, it should seek to encourage research, monitoring and implementation of practices and technologies aimed at greater efficiency in the use of water. At the same time, it is essential to maintain constant dialogue with water resource management bodies to seek solutions to make water multiple uses compatible and avoid use conflicts.

Management of greenhouse gas (GHG) emissions associated to energy production and use

This challenge has a global nature, as it dialogues with international climate change policies and global discussions on the transition to a low carbon economy. Although Brazil stands out for its highly renewable energy matrix, the global situation drives the country to further reduce emissions associated with the production and use of energy. Added to this, the engagement of the entities involved, and the availability of renewable natural resources and technologies make the domestic energy sector assume a crucial role in meeting Brazil’s commitments.

In the context of world politics, it is noteworthy that Brazilian government recently formalized the goal of net emissions neutrality in 2050. The path necessary to meet this goal involves all sectors and society in the search for the adoption of more cost-effective solutions. Even though responsibilities are shared, the energy sector has the challenge of maintaining the high share of renewable sources in the matrix, as well as reducing and offsetting their emissions, even in face of economic growth.

Along these lines, GHG emissions management is particularly challenging for the entire oil, natural gas, and derivatives chain, considering its industry significant expected expansion in order to meet country's energy requirements. Given this situation, the sector has invested in alternatives to mitigate or offset its emissions. Naturally, oil and gas companies have stood out in adopting measures such as reduction of GHG emissions from operations; implementation of technologies for capturing and storing or using carbon (CCS and CCUS); investment in renewable energy projects; and implementation of emission compensation mechanisms. Offsetting is seen as key to achieving net carbon neutrality after strategies for effective decarbonization have been exhausted. One option that has been discussed is carbon removal and fixation, through forest conservation and restoration projects.

As for government initiatives related to the energy sector as a whole, biofuels promotion through Renovabio Program and the renewable expansion paths indicated in PDE stand out. Specifically for the electricity sector, regulatory advances are highlighted, such as Law n. 14,120/2021, which provides for implementation of mechanisms that consider environmental benefits, and the replacement of Bill no. 2,148/2015 and its appendices, which deals with the creation of Brazilian System of Registration and Trading of Greenhouse Gas Emissions (SBRC-GEE in Portuguese acronym).

Finally, it is indisputable that the sector must continue to contribute to climate change minimization, through investments and implementation of measures that reduce and offset emissions. The trend is to direct more and more efforts to the development of new decarbonization solutions and technologies, considering the desired energy transition process.

STRATEGIC SOCIO-ENVIRONMENTAL OPPORTUNITIES

Socio-environmental opportunities represent the possibility of adding socio-environmental value to energy expansion. Those assessed as strategic have a high potential to provide socio-environmental improvements, but they are still little explored. A favorable environment is essential for opportunities to materialize.

With this in mind, benefits and opportunities associated with each of the sources were pointed out in energy sources analysis (EPE, 2022). Based on this survey, the following strategic socio-environmental opportunities were envisaged: use of waste and residues for energy, resources and infrastructure optimization, and sustainability mechanisms for energy projects.

Use of waste and residues for energy

The opportunity to make use of waste and residues for energy is addressed in energy planning context due to high availability of agricultural and urban waste and residues in all Brazilian regions. More than reaching appropriate solutions for the correct disposal, seeking alternatives for its use as an energy resource is a chance to replace non-renewable fuels, contribute to emissions reduction and increase production processes efficiency. The possibility of obtaining them from different raw materials and routes is worth mentioning; this allows for a variety of energy uses, such as vehicle fuels with biomethane and electrical generation from biogas or incineration.

When looking into activities that produce waste and residues, it is noted that there is still a considerable and diversified energy potential to be used, among which the following uses stand out: beef tallow and used oil for biodiesel production; vinasse, municipal solid waste, agricultural residues and domestic sewage effluents, for biogas production or fuel derived from waste; and forest and agricultural residues, such as straw and tip for electric generation. In addition to energy gain, the use of these substrates can contribute to a better environmental management of the producing regions.

The importance of producing biogas using biodigesters is worth mentioning, as the sending of components to landfills or dumps is reduced and is still produced digestate, a rich biofertilizer. Especially in case of municipal solid waste and domestic effluents, is remarkable the potential to promote basic sanitation, a critical socio-environmental issue in country's large metropolitan areas. With the global commitment to reduce methane signed by Brazil at COP26, grows the importance of biomethane production, which, in addition to capturing methane gas, is equivalent and interchangeable to vehicular natural gas.

The institutional framework, with National Solid Waste Policy and Renovabio Program, financing lines and decarbonization projects and, more recently, New Basic Sanitation Framework (Law no. 14,026/2020), point to the relevance in using waste for energy. Toward that, stimulating waste management in Brazil and the expansion of sewage collection and treatment can be characterized as opportunities, since the improvement of these services could incorporate waste energy generation, producing sustainable business models and improving social, environmental, and economic aspects for Brazilian society.

Resource and infrastructure optimization

Enterprises already in place for the generation and conveyance of energy can be optimized or used for other purposes, contributing to a better energy resource use and to environmental impacts minimization.

Through repowering and upgrading of existing hydropower plants, it is possible to increase Brazilian hydropower capacity, optimizing water resources use to generate electricity. The levels of reliability and efficiency of the existing hydropower complex can be improved, in addition to representing a great opportunity insofar as the socio-environmental interference associated with the construction of new projects is avoided and a more efficient water resource use is sought. Planning studies (EPE, 2019a) pointed to energy and capacity gains for SIN, as well as other positive effects, from repowering and upgrading measures for a group of existing UHEs. When considering the importance, size and age of the existing Brazilian hydropower park, a significant potential (50 GW) for UHEs repowering and upgrading is observed in the country. Recent initiatives show a drive by the electricity sector toward UHEs modernization. However, it is noteworthy that, to leverage this new market, regulatory improvements, and economic incentive instruments capable of mobilizing more entrepreneurs for this purpose are still needed.

Specifically in the case of PCHs, reservoirs built for other purposes (such as water supply) can also be used for energy generation. Initiatives of this type also reveal themselves as an opportunity to optimize the use of water resources.

Mechanisms that encourage energy sources hybridization with existing projects (generation of photovoltaic solar energy in hydropower reservoirs or in existing wind farms, for example) can encourage the sharing of electrical systems, minimizing the need for new works and reducing associated socio-environmental impacts. In SIN, the regulation has already allowed for the sharing of land and constructive and operational synergies (EPE, 2019b), and recently Aneel approved the regulation for hybrid and associated plants.

The infrastructure, technology and knowledge of the oil sector can also be used for other types of energy production, minimizing socio-environmental impacts associated with the implementation of new facilities. As an example, the existing natural gas flow and transport infrastructure can be used, with adaptations or not, for other products such as biomethane (ANP Resolution no. 685/2017 and ANP Resolution no. 8/2015) and hydrogen (blue and turquoise, produced from natural gas and which are among the routes envisioned for the National Hydrogen Program). The oil sector's expertise in the installation of structures, logistics and operations in the marine environment could also benefit offshore wind development.

Sustainability mechanisms for energy projects

There is a global context of pressure to build an increasingly sustainable business scenario that starts from a greater involvement and commitment of entrepreneurs to climate change (decarbonization and adaptation), the local community, and the maintenance of natural resources and ecosystem services. To that end, different mechanisms to foster sustainability and add socio-environmental value to energy projects were created.

The energy sector plays the role of user of ecosystem services, having an interdependent relationship with climate and natural resources. Based on this idea, it was seen as an opportunity to invest in sustainability practices that result in multiple benefits, including energy benefits, obtained from the synergy of actions related to biodiversity, local communities, ecosystem services and climate change adaptation. Currently, opportunities of this kind are more evident for hydropower projects, considering the strong dependence on water resources availability.

With this focus, hydropower projects have developed Payment for Environmental Services (PSA in Portuguese acronym) programs with arrangements that recognize rural landowners as environmental services providers such as water sources protection through reforestation. These programs were recently braced by Law no. 14,119/2021. The programs aim to improve the quality and availability of water resources and, therefore, benefits are also expected for power system management, increasing its resilience in the face of climate change.

With the progress in the creation of certification instruments aimed at decarbonization, opportunities arise for all renewable sources. Among the already-implemented mechanisms, the transaction regulated in Renovabio Brazilian program stands out, in which the producer certifies his biofuels production and can sell decarbonization credits (CBios), calculated according to energy-environmental efficiency scores. In the case of renewable electrical projects, it is possible to seek certification to trade renewable energy certificates, either those validated by the Global I-REC system, which has international standards for carbon accounting, or others, if they meet recognized standards for accounting in emissions inventories. In addition to the financial gain, the opportunities allow renewable projects to add socio-environmental value and obtain recognition through sustainability seals.

Under the same context of encouraging sustainability, financial institutions have developed guidelines and standards for environmental performance as defined by the International Finance Corporation (IFC) and the signatories of the Equator Principles. Energy companies are increasingly embracing to these financing instruments. Companies have also been adopting ESG (acronym for Environmental, Social and Governance) practices and observing the Sustainable Development Goals (SDG). These actions result in socio-environmental benefits and help society to have a positive image of these companies.

In a broader outlook, international treaties such as the Sustainable Development Agenda – Agenda 2030 and the Paris Agreement (2015), among others, consolidate this movement through voluntary commitments and proposals for goals to be achieved by companies. Given this context, it is essential that the sector continues to identify mechanisms that promote sustainability while generating energy benefits and adding socio-environmental and economic value to projects.

10.3 Energy and Climate Change

The energy sector is strongly related to climate issues, either because of its relevance to GHG emissions in energy production and use, or because of its vulnerability to climate change. Thus, climate policies and discussions are crucial for energy planning.

Along these lines, PDE was established as the Sectorial Plan for Mitigation and Adaptation to Climate Change, becoming an instrument of the National Policy on Climate Change – PNMC (in Portuguese acronym) (Law n. 12,187/2009). PDE is also directly related to Sustainable Development

Goal 13, which makes up the 2030 Agenda. This SDG refers to actions to combat climate change and their impacts, and its target 13.2 refers to the integration of climate change measures into national policies, strategies, and planning.

The emission forecasts associated with the expansion of energy production and use of the productive sectors presented in the Plan serve as a subsidy for defining national strategies related to climate change. At the same time, the PDE itself already incorporates the result of the adoption of mitigation and adaptation measures in progress and foreseen in the ten-year timeframe.

The Brazilian energy sector stands out for having an energy matrix with a large share of renewable sources, a situation of few countries in the world. This means that GHG emissions per unit of energy consumed in Brazil are small compared to other countries. According to The Greenhouse Gas Emission and Removal Estimating System (SEEG, 2021), the participation of the energy sector in Brazilian emissions profile was 18% in 2020, maintaining the trend of the general panorama of emissions in which those related to land use (46%) and agriculture stand out (27%).

However, Brazil still has a long way to go to reach socioeconomic standards comparable to those of developed countries. For this reason, energy consumption per capita is expected to increase considerably by 2031. As shown in the sequence, the sector's emissions will increase, even with a large share of renewable sources.

The next topics seek to present national commitments related to climate change, understand emissions profile projected in this PDE and ongoing mitigation and adaptation measures, and, finally, discuss the main challenges and opportunities for the energy sector.

CLIMATE AGREEMENTS AND POLICIES

Brazil, a signatory to the Paris Agreement, has committed in its Nationally Determined Contribution - NDC (Brazil, 2020), updated in December 2020, to a 37% reduction in its emissions in 2025 and 43% in 2030. This commitment relates to the entire economy, based on 2005 emissions. The document mentions that the proposed trajectory is compatible with the neutrality of emissions around the year 2060, but the Brazilian government formalized the anticipation for the year 2050 in October 2021 (MRE, 2021).

No sectoral targets were presented in the current NDC. However, at COP26[5], the Brazilian delegation announced the following actions that go beyond the NDC text (MMA, 2021a):

- 50% of clean energy matrix by 2030[6];
- Zero illegal deforestation by 2028;
- Decrease carbon emissions by 50% by 2030[7] and zero net emissions by 2050;
- Restore and reforest 18 million hectares of forests by 2030;
- Recover 30 million hectares of degraded pastures;
- Reduce 75% of polluting gas emissions from freight transport and encourage railway network expansion.

Additionally, other commitments assumed by Brazil are highlighted in **Table 10 - 4**.

It is important to note that there is no formal distribution – and commitment – of targets among the several sectors, so that the country is free to allocate its efforts to the most cost-effective measures, thus being able to achieve the targets through different alternative paths. Nevertheless, the energy sector foresees and adopts important measures and initiatives aimed at reducing emissions associated with the production and generation of energy. Even so, the commitment to

[5] 26th Conference of the Parties to the United Nations Framework Climate Change Convention, held from 1 to 12 November 2021 in Glasgow, Scotland.

[6] Announcement made by the Minister of Mines and Energy during a panel on clean energy at COP26 (MME, 2021a).

[7] In relation to the base year 2005 resulting in absolute emissions around 1.3 $GtCO_2eq$.

emission neutrality in 2050 poses challenges for the energy sector, particularly regarding emissions that are difficult to mitigate.

The creation of the Interministerial Committee on Climate Change and Green Growth (CIMV in Portuguese acronym) is also worth mentioning, established by Decree no. 10,845 of 2021, with the objective of defining guidelines, articulating, and coordinating the implementation of the country's public actions and policies related to climate change.

Table 10 - 4: Commitments made by Brazil at COP26

Announcements	Description	Source
Global Methane Pledge	• Initiative to reduce global methane emissions. • Joint effort to reduce methane emissions in 30% by 2030, against 2020 methane emissions.	Launch by US, EU and Partners of the Global Methane Pledge (europa.eu)
Glasgow Leaders Declaration on Forests and Land Use	• Initiative to preserve forests and stop deforestation and land degradation by 2030.	Glasgow Leaders' Declaration on Forests and Land Use - UN Climate Change Conference (COP26) at the SEC – Glasgow 2021 (ukcop26.org)

According to the Brazilian Energy Balance (EPE, 2021a), in 2020, the energy sector emitted around 398 million tCO_2eq. This figure was well below the limit established in Decree no. 9,578/2018 (868 million tCO_2eq)[8]. In addition, in the energy sector alone, there was a 4.6% reduction in emissions compared to 2019. The reduction was attributed to the decrease in emitting activities, such as transport and industrial production, especially in the first months of the COVID-19 pandemic.

Given this scenario and considering Brazilian potential for production of electricity and fuels from renewable sources, the sector's main strategy for mitigating GHG emissions continues to be precisely to maintain a high share of these sources in the matrix to ensure that emissions from energy production and use remain low. The trend presented in this Plan reflects the various governmental measures to maintain this characteristic of the Brazilian energy matrix.

[8] This absolute value appears in article 18 of the Decree and its calculation is based on the 3th National Inventory of GHG Emissions and Removals (MCTI, 2017).

Box 10 - 3: Outcomes of the 26th United Nations Conference on Climate Change (COP26)

COP26 was held in November 2021 in the city of Glasgow, Scotland. There was a lot of expectation around the developments regarding agreements and mechanisms to reduce GHG emissions. The final text of the Conference left gaps, such as the climate commitments delivered by the countries, considered insufficient to put the world on the 1.5°C path. Therefore, this task was left to COP27 in Egypt. But COP26 brought important advances, especially to create an international carbon market and to reduce the consumption of fossil fuels.

The "Glasgow Climate Pact" was the first COP document to link global warming to fossil fuels such as coal and oil. Although the final text was vague about deadlines and targets, it was the first time that the specific problem caused by emissions from fossil sources was recognized.

Although a parallel pact has not been signed, committing developed countries to a deadline to end production and consumption of fossil fuels, the agreement signed at COP26 highlights the need to speed up energy transition. And about 450 finance organizations, which control $130 trillion, or 40% of the world's assets, have agreed to direct part of the financing of carbon-intensive industries to fostering renewable sources.

The final text also calls for speeding up efforts to reduce inefficient subsidies to fossil fuels and coal that do not use emissions offset and capture technology. Toward that, a group of 40 countries, including the United Kingdom, Canada, as well as other large consumers, signed a parallel agreement to eliminate the use of coal from their energy matrix between 2030 and 2040. Among the countries that have not signed are Brazil, China and the United States.

The Glasgow Declaration on Zero Emission Cars and Buses is another document with the potential to reduce the consumption of fossil fuels that, according to the IPCC, accounts for approximately 25% of the world's total GHG emissions. This is a sector that requires innovative solutions and financing for public transport and low-carbon alternative fuels. The signed text provides for the end of sales of internal combustion engines in 2040 worldwide and by 2035 in the main markets. At least 13 nations have also committed to ending the sale of fossil fuel-powered heavy vehicles by 2040.

PROJECTIONS AND ANALYSIS OF GHG EMISSIONS

The total emissions over the ten-year timeframe is increasing, reflecting the outlook of economic growth in Brazil. In 2031, estimates for the baseline scenario indicate a total amount of 529 $MtCO_2eq$ (**Table 10 - 5** and **Chart 10 - 1**). The trend is towards an increase in emissions in all sectors and the expectation is that the distribution of emissions by sector will not change significantly over the timeframe.

Currently, the main sectors responsible for GHG emissions in energy production and consumption are the transport and industrial ones, which in 2021 accounted for 48% and 18% of total emissions, respectively (**Chart 10 - 1**). Over the timeframe, these sectors will collectively continue to account for most emissions from the energy sector, answering for almost 65% in 2031.

Table 10 - 5: GHG emission development in production, transformation, and use of energy

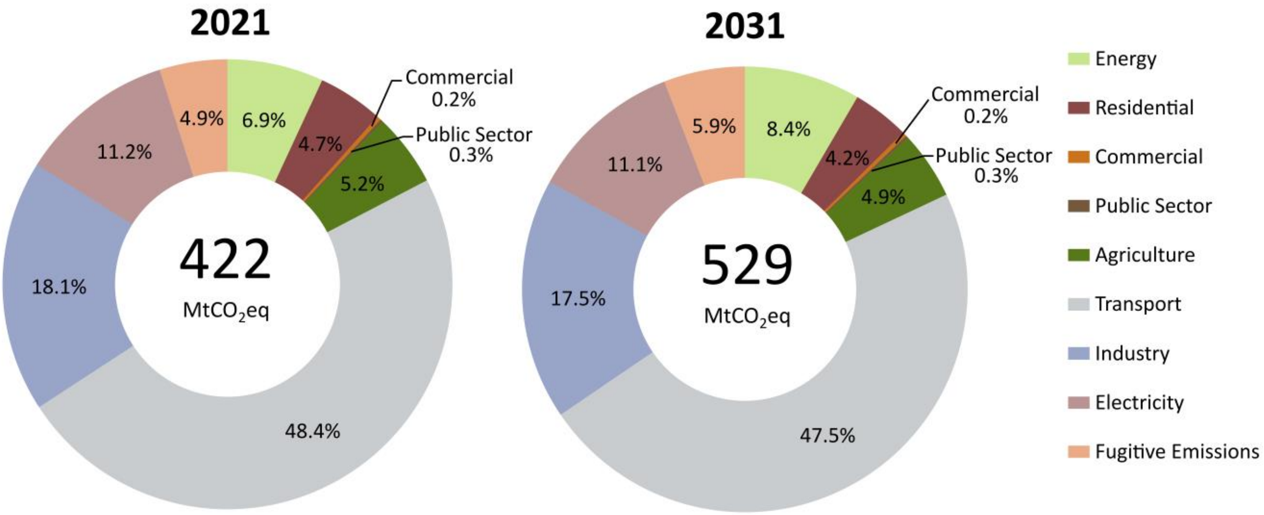
Sectors	2005	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	% Var 2021/31
	$Mt.CO_2eq$												
Electricity	27	47	33	32	32	33	37	43	48	53	58	59	24%
SIN	21	34	18	17	17	17	20	25	29	34	38	39	17%
Self-generation	6	14	14	15	15	16	16	17	18	19	19	19	42%
Energy	23	29	31	32	35	38	39	41	43	44	45	45	53%
Residential	26	20	20	20	20	21	21	21	21	22	22	22	11%
Commercial	2	1	1	1	1	1	1	1	2	2	2	2	24%
Public	2	1	1	1	1	1	1	1	1	1	1	1	22%
Agriculture	16	22	22	23	23	24	24	24	25	25	26	26	18%
Transport	141	204	211	214	217	219	222	227	232	238	244	251	23%
Industry	62	76	77	78	80	82	84	85	87	89	91	93	21%
Fugitive emissions	20	21	23	24	25	26	27	29	30	31	31	31	51%
TOTAL	**316**	**422**	**419**	**426**	**435**	**444**	**456**	**473**	**488**	**504**	**518**	**529**	25%

Notes: (1) The breakdown of sectors was made according to the Brazilian Energy Balance (BEN in Portuguese acronym).
(2) Fugitive emissions include transport and processing of natural gas and losses from E&P activities in addition to coal mining.
(3) The 2005 emissions were updated according to the 4th National Inventory of GHG Emissions and Removals (MCTI, 2021b). The CO_2 equivalence is given by the metric of the Global Warming Potential (GWP) for 100 years according to the Fifth Assessment Report of the IPCC - AR5 (CH_4=28 and N_2O=265) (IPCC, 2014).

It is worth noting that, in both sectors, actions to reduce GHG emissions are considered in the supply and demand projections. These actions are related to the replacement of fuels with higher emission factors for fuels that emit less GHG, such as natural gas or renewable fuels, and measures to increase energy efficiency of means of transport and industrial processes.

In terms of variation over the decade, the increase of around 50% in the "Energy Sector" stands out, which includes oil and natural gas exploration and production, mineral coal production, as well as activities of transformation of primary energy into secondary energy such as petroleum refining, ethanol distilleries and charcoal plants. As most of the emissions under this heading fall on the oil and gas sector, fugitive emissions have increased by the same order of magnitude (50%).

Chart 10 - 1: Development of sectoral participation in GHG emissions from energy production and use (MtCO2eq)

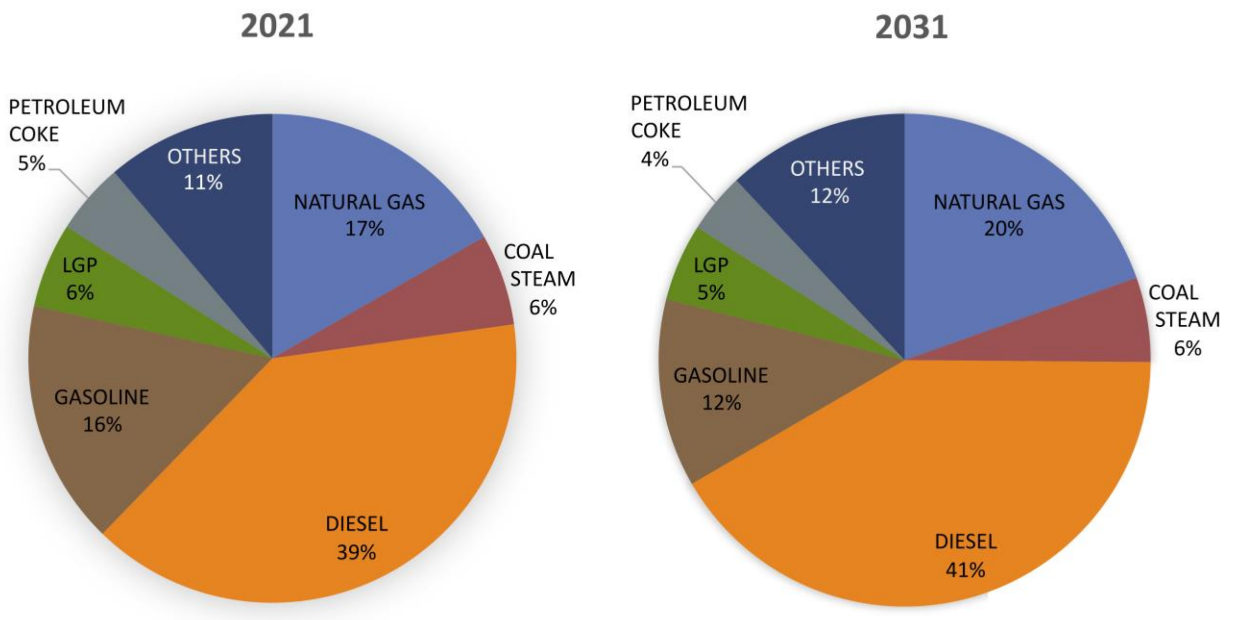


The expected growth in emissions from energy sector and respective fugitive emissions gives rise to the need for mitigation actions in oil and gas sector. There are already initiatives in this direction. Petrobras' Strategic Plan 2022-26 foresees the investment of R$1.8 billion in decarbonization initiatives, including actions to reduce fugitive emissions such as the implementation of closed flare and methane detection systems, among others. EPE has sought to improve its estimates of fugitive emissions through research, training, and interaction with institutions such as ANP and IBP, aiming at better modeling scenarios that include mitigation actions for these fugitive emissions.

As can be seen from

Chart 10 - 2, the most representative fuels in terms of GHG emissions at the end of the timeframe are diesel oil (41%), natural gas (20%) and gasoline (12%). Natural gas emissions are the ones that grow most intensely in the period, since the source plays an important role in guaranteeing the supply, especially considering the greater penetration of variable sources such as wind and solar, in addition to the start-up of new inflexible natural gas plants included by Law no. 14.182/2021. Diesel emissions also grow substantially, because of the concentration of road mode in the transport sector and a limit to the increase in the biodiesel blend. According to CNPE resolutions, the biodiesel content in diesel was reduced to 10% in 2021 (MME, 2021b) and is expected to reach 15% in 2023 (CNPE, 2018). From 2023 onwards, it remains stable until 2031. Gasoline emissions will only grow by 8% at the end of the period compared to 2021 and, as a result, lose share in relation to other sources. This low growth rate is due to the positive expectation of the impact of policies such as Renovabio in promoting biofuels. From this, it can be concluded that the greatest opportunities for reducing emissions in energy consumption will continue to be the substitution of fossil diesel and gasoline in the transport sector.

Chart 10 - 2: GHG emissions per fuel ($MtCO_{2eq}$)



Renewable fuels can fully or partially replace fossils. In the ten-year timeframe, a 48% increase in ethanol production is indicated, reaching about 46 billion liters in 2031, and a gradual increase in the mandatory addition of biodiesel to diesel oil[9], with an expansion of about 75%, reaching 11, 6 billion liters in 2031. This scenario is in line with the sector's expansion prospects from the adoption of the National Biofuels Policy, Renovabio.

In addition, the energy demand projections for the sector consider a scenario with gains in energy efficiency, achieved through technological evolution (new vehicles, with better energy efficiency, for example). The energy conservation resulting from these efficiency gains is 8% in the last year of the timeframe.

In relation to industries, which includes the energy sector, the same approach was taken regarding energy efficiency gains. In this case, technological trends that can increase the efficiency of equipment and processes and current policies are considered. The energy conservation resulting from these efficiency gains is nearly 5% for the last year on the timeframe.

In SIN, GHG emissions can vary substantially depending on hydrological conditions. Unfavorable hydrology situations lead to the need to start fossil fuel thermoelectric plants. In the ten-year timeframe, it is estimated that under average hydrological conditions, emissions in 2031 will be around 40 $MtCO_2eq$. It is worth noting that the new inflexible natural gas thermoelectric plants included by Law n. 14,182/2021 (8 GW, with 70% inflexibility) will impact emissions from the electricity sector. Even so, emissions from the electricity sector can be considered low in 2031, representing around 11% of all emissions from the Energy sector (in 2020, it represented 12.5%).

It is also worth mentioning that the expansion of gas pipeline infrastructure can mitigate, in their area of influence, emissions from hard-to-abate economic sectors, besides bringing systemic efficiency gains in fuel logistics, contributing to additional emission reductions. It also has the potential to be the basis for the

[9] CNPE Resolution no. 16/2018 established a gradual increase in the blending of biodiesel with mineral diesel, with B15 scheduled for 2023. In March 2020, B12 went into effect.

economic use of biogas/biomethane and low carbon hydrogen in Brazil.

Over ten-year timeframe, estimates for renewable electricity generation are maintained at a level of 84%, with growth in solar, wind and biomass energy. When the nuclear source is included, generation from non-GHG emitting sources adds up to 87% of total electricity generation in 2031.

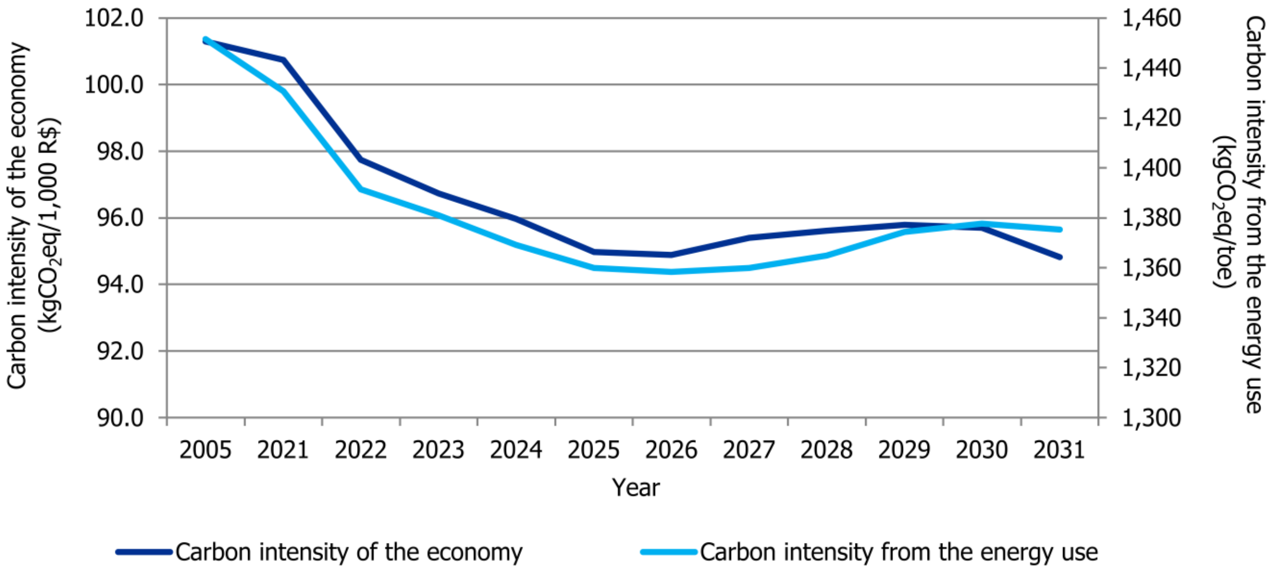
Thus, unlike what happens in most countries, in Brazil the electricity sector contributes little to total greenhouse gas emissions and the strategy provided for in this PDE 2031 seeks to maintain and expand this condition. Therefore, additional efforts to mitigate greenhouse gases should focus on sectors that present the most cost-effective opportunities and have the lowest marginal abatement cost of emissions.

Therefore, it is essential that Brazil should seek to increase knowledge about the abatement costs of emissions in the different sectors of the economy (abatement curves) to find and prioritize the most cost-effective measures.

Based on the 4th National Inventory of GHG emissions and removals (MCTI, 2021b), the growth in emissions due to energy production and consumption will be 67% between 2005 and 2031. However, this increase is lower than expected for gross domestic supply in the same period (73%), as shown in **Chart 10 - 3**. This means that, in the scenario of this PDE, the indicator of GHG emissions intensity in energy use in 2031 (kgCO2eq/toe) will be lower than that verified in 2005. The economy emission intensity indicator (kgCO_2eq/PIB) should also decrease along the ten-year timeframe, reaching 94.8 kgCO_2eq/BRL thousand [at 2010 prices] in 2031. With this trend, each equivalent ton of oil produced and each Brazilian real generated by the country's domestic product will have a lower carbon content, in line with the transition to a low carbon economy. The inflection in the intensity curves from 2026 onwards reflects the period of entry of natural gas thermoelectric plants. The tendency is for the curve of carbon intensity in energy use to fall again after the ten-year timeframe.

Considering this decreasing trend in the indicators, it can be said that the objective of PDE 2031 is in line with the PNMC and with the international commitments assumed by Brazil under the UNFCCC. The actions incorporated in this Plan, such as the expansion of renewable sources for the generation of electricity, the growth in the use of biofuels, the increase in energy efficiency measures, the expansion of the transmission network, among others, will allow Brazil to improve indicators performance of its energy matrix and remain among the countries that emit least greenhouse gases in energy production and consumption.

Chart 10 - 3: Development of carbon intensity



ADAPTATIONS TO CLIMATE CHANGE

Although cutting greenhouse gases is a priority for those countries and sectors that emit much, adaptation to climate change should be highlighted in the next climate negotiations, as it is already on the decision-making agenda of companies and governments to the planning of the infrastructures of the productive sectors, with emphasis on the energy sector. Several platforms around the planet, gathering data and studies, address the theme of adaptation, aiming to organize and disseminate strategies to face the challenges of overcoming the impacts resulting from climate change. In Brazil, we can mention the AdaptaClima[10] of the Ministry of the Environment (MMA in Portuguese acronym) and the AdaptaBrasil[11] of the Ministry of Science, Technology, and Innovation (MCTI in Portuguese acronym) as a reference.

An important issue related to adaptation, which national and international platforms and documents address, is that adaptation actions are foreseen in the face of gradual climate change, as well as extreme events, in the scope of energy production and distribution. Of course, publishers also warn of the potentially most serious combination of these threats. At this point, it should be noted that the energy system is related to several other sectors of society. So, even if, to protect its assets, the energy sector takes adaptation actions, there will be a need for plural and integrated innovative strategies.

Returning to the energy aspects, all sources, renewable or non-renewable, and their infrastructures, are subject to these climate phenomena and need to incorporate adaptation actions that are of a technical-scientific, administrative, operational, or constructive nature. Location and investment planning for decision-making on new projects, as well as for ensuring the safety of existing projects, will be progressively more attentive to the challenges of adaptation.

[10] AdaptaClima was launched in 2017, with the "objective of contributing to overcoming this knowledge gap and to achieving the 1st objective of the National Adaptation Plan, which includes among its goals an "online platform for managing knowledge in adaptation created and available to society", MMA (2021b).

[11] AdaptaBrasil MCTI was established in 2020, with the "objective of consolidating, integrating and disseminating information that makes it possible to advance the analysis of the impacts of climate change, observed and projected in the national territory, providing subsidies to the competent authorities for adaptation actions", MCTI (2021a).

The impacts to the energy system most reiterated by scholars in relation to gradual climate change are the increase in average temperature, the decrease in average precipitation, the increase in winds in arid and coastal areas and the rise in sea level. Individually or combined, these impacts amplify vulnerabilities and decrease efficiency, and can reduce or even interrupt the operation of energy facilities and infrastructure. Response adaptation measures can range from the use of equipment with better weather sealing, water reuse, dry cooling, etc. to the construction of protective works, relocation of projects or their construction in safer locations.

In relation to extreme weather events, whose incidence becomes more frequent, extreme heat, strong winds, storms, floods, landslides, aridity, lightning frequency, fires, among others, are mentioned. The impacts arising from these threats also accentuate the vulnerability of equipment and structures, in addition to reducing efficiency, with direct implications for energy generation. The required adaptation actions also range from physical measures of protection works to technical measures such as operational and constructive restrictions, adequacy of contingency plans, investment in improving short-term climate forecasts, increasing capacity and flexibility, and considering intermittence in the energy planning.

Regarding adaptation to climate change, it is assumed that a highly renewable energy matrix is also more sensitive to climate effects. Although there are still uncertainties and limitations of climate projection models, there is already a certain convergence in the projections regarding changes in the rainfall regime for some Brazilian regions, especially in the Northeast and North, which would directly impact hydroelectric generation.

With this perspective, EPE included in the PNE 2050 studies some simulations considering a reduction in hydroelectric generation (based on data available in the literature). The results show that the hydrological changes estimated by climate models could bring about significant changes in the sector's investment decisions, altering the participation of different sources in the electrical matrix, increasing the total cost of expansion and also GHG emissions. The objective of this type of simulation is that the sector can prepare in advance for eventual changes in the water regime that may reduce the availability of hydroelectric generation and, ultimately, guarantee the safety of the system. **Box 10.4** shows the line of action to address climate change adaptation that has been followed by energy planning.

The National Plan for Adaptation to Climate Change (PNA in Portuguese acronym) is the national reference for promoting the reduction of vulnerability to climate change and managing its risks. The Brazilian Ministry of Mines and Energy (MME in Portuguese acronym) is part of the technical group[12] responsible for reviewing the recently approved Final Monitoring and Evaluation Report of the National Plan for Adaptation to Climate Change - Cycle 2016-2020[13].

Integrated with the PNA and the Brazilian NDC, the “Improvement of climate services for investments in infrastructure” Project, CSI, is developed by MMA, in a partnership with GIZ (German Society for International Cooperation) and the Brazilian National Institute for Space Research (INPE in Portuguese acronym), and has MME and EPE as collaborators. The objective is to increase the use of national climate information in planning and assessing the climate risks of investments in infrastructure in the country (GIZ, 2020). CGT Eletrosul participated in one of the pilot studies of the CSI Program. In it, the major climatic threats that structurally impact transmission lines were evaluated. One of the results was the development of a tool for managing climate risks within the company (CGT Eletrosul, 2021).

[12] Temporary Technical Group for Adaptation to Climate Change (GTAdapta in Portuguese acronym) established by Resolution n. 3, of 08/17/2021.

[13] Approved by Resolution no. 6 of 10/20/2021, the Report brings the review of the first cycle and guidelines for the second cycle (2021-2025) of evaluation of the National Plan for Adaptation to Climate Change.

Box 10 - 4: Vulnerability of hydroelectricity to water availability

When looking at the current climate change scenario, the main issue faced by the Brazilian energy sector is related to uncertainties regarding future water availability. Although there are still inaccuracies and limitations of climate forecast models, there are concrete conclusions that there is a change in temperature patterns (IPCC, 2021), with probable reflections on precipitation and, consequently, on the profile of the flow series of watercourses. Added to this circumstance, there are two important variables regarding future water resource availability: the increase in the various uses of water with a forecast of growing demand (ANA, 2019), and changes in land use and cover, both complex to assess.

Water availability can affect several energy sources, however, given the configuration of the Brazilian system, it can be said that hydroelectricity will be the most impacted source. Considering the importance of this source participation, both with the current installed capacity and the planned modernization for the ten-year timeframe, and its wide geographic distribution, it is expected that changes in the rainfall regime in any Brazilian region should directly impact hydroelectric generation. In addition, the increasing use of water for other purposes ends up restricting the availability of water resources, and consequently, the operating conditions of the plants.

There are no tools to quantify the magnitude of the change in flows and to what extent it will occur in the next 10 years with reasonable confidence. However, while it is difficult to anticipate and measure these changes, it is essential for energy planning to analyze the possible repercussions to ensure system safety. For this, it is necessary to strategically discuss the issue and seek ways to improve the representation of the water issue in computer planning models.

Geared at that, energy planning has sought to discuss and implement actions referred to climate change adaptation, together with other institutions that deal with water resources and related topics: i) analyze existing operational restrictions; ii) improve methodology for reconstituting the flow series and generating scenarios; iii) invest in strengthening institutional relationships, seeking quality and predictability in water and data governance; iv) review strategies for modeling operational constraints in the medium and long term; v) improve parameters for risk perception; and vi) propose and prepare new sensitivity studies on climate change, land use and resilience.

CHALLENGES, INITIATIVES AND OPPORTUNITIES

International commitments and national policies aimed at reducing emissions reflect the importance of managing GHG emissions in energy production and generation. It is not by chance that this theme was recognized as a strategic socio-environmental challenge for expansion, as mentioned in item 10.2.

In addition to the emission reduction initiatives adopted and mentioned previously, such as the Renovabio program and advances in efficiency, the Brazilian energy sector is challenged to seek innovative solutions and technologies, considering the country's particularities and the cost-effectiveness of possible paths. In this scope, other specific challenges, initiatives, and possible associated opportunities deserve to be noted.

One of the greatest difficulties in controlling emissions in the energy sector, as well as in other sectors, is the lack of signaling the cost of GHG emissions for society. Valuation of emissions would allow the internalization of externalities produced by the energy sector. To this end, several instruments have been analyzed, and among them, carbon pricing has been indicated as the most cost-effective approach for countries to comply with their NDCs.

In this sense, as described in **Box 10.5**, the PMR Brazil Project stands out, which sought to evaluate carbon pricing alternatives to contribute to the implementation of the PNMC after 2020 (ME, 2021). In addition, for the electricity sector, mechanisms are being discussed for considering the environmental benefits of Law n. 14,120/2021, and, more broadly, on the creation of the Brazilian System of Registration and Trading of Greenhouse Gas Emissions (SBRC-GHG) with the Bill (PL in Portuguese acronym) no. 2,148, of 2015.

It should also be noted that carbon capture and storage (CCS) technologies or technologies that include their use (CCUS) could also play an important role in achieving low carbon goals. Currently, most projects focus on increasing oil recovery in reservoirs[14], and in Brazil, Petrobras reinjected 4.6 million tons of CO_2 (Petrobras, 2020) in 2019 alone. Other technologies can be made viable as the learning curve costs are reduced, incentive policies are implemented, among other stimuli.

Another path discussed is the use of carbon removals from the atmosphere through forests or other natural environments. In this case, conservation or restoration actions of natural environments and reforestation are encouraged to generate emission reduction credits. These credits can be particularly important for offsetting difficult or unavoidable emissions and must be used without prejudice to other actions to decarbonize energy matrix. In this sense, EPE has been working in cooperation with the Brazilian Development Bank (BNDES in Portuguese acronym) with the objective of evaluating and proposing mechanisms to connect the O&G sector's need for emission offsets and the environmental restoration activities to take advantage of the opportunities that these two sectors offer (EPE, 2021b).

[14] Enhanced oil recovery (EOR)

Box 10 - 5: Carbon pricing

Carbon pricing is an important instrument derived from the polluter pays principle that aims to reduce GHG emissions and has been adopted worldwide to support compliance with climate commitments. According to the World Bank, there are currently 61 pricing initiatives implemented, scheduled or under analysis (World Bank, 2021). The initiatives, with varied systems (emissions, taxes, and hybrid markets), have different scopes, goals, sectors involved, and revenue use strategy.

Progress in defining a global carbon market was hampered by lack of consensus on the rules of Article 6 of the Paris Agreement. Article 6 provides for voluntary cooperation between countries for the implementation of NDCs to enable greater ambition in climate policies, promote sustainable development, and ensure environmental integrity. The mechanisms enshrined in this Article form the legal framework to allow climate change mitigation based on market instruments and international cooperation.

The approval of the rules of Article 6 was one of the biggest victories of the Glasgow Pact and created great expectations for the creation of the international carbon market, especially for Brazil, which has the potential to be an exporter of carbon credits, mainly due to the energy and forest sectors.

Among the important points of the definitions of the rules, there are the corresponding adjustment, non-market initiatives and projects of Clean Development Mechanisms (CDM), baseline and certification of transactions, which will be in charge of a body under the Convention on Change UN Climate Change.

An important point for Brazil was the possibility of validating the carbon credits generated in the period from 2013 to 2020 from existing CDM projects. These credits can be used to reduce the NDC until 2030.

The implementation of the corresponding adjustment to avoid the possibility of a double counting in the deduction of carbon credits represents a relevant victory for the global mitigation of GHGs. Thus, in a carbon credits transaction, the selling country must add the credits sold in its NDC and the buying country must subtract them. Corresponding adjustments will apply to all units transferred in Article 6.2 and 6.4, for sectors and gases, policies, and measures within or outside the NDC. For use in the domestic voluntary market, however, corresponding adjustments do not apply. The guidance for the new credit mechanism established by Article 6.4 includes more ambitious requirements for setting baselines compared to the old CDM. In addition, it specifies that the mitigation results under Article 6.2 result from activities whose baselines have been conservatively established, below the emission projections of business-as-usual scenarios that consider existing policies.

Another favorable point was the decision that establishes a framework for non-market initiatives, from Article 6.8, with the creation of the Glasgow Committee on Non-Market Approaches. This Article aims to promote the ambition of mitigation and adaptation; expand the participation of the public and private sectors in the implementation of the NDCs and allow opportunities for coordination between the relevant instruments and institutional arrangements.

However, not all the points of Article 6 were resolved. There is still no consensus on the use of credits from Reducing Emissions from Deforestation and Degradation (REDD) projects. The consideration of REDD in Article 6.2 will be discussed at the next Subsidiary Body of Scientific and Technological Advice technical meeting and its inclusion in Article 6.4 depends on approval of a specific methodology.

Is Brazil ready to enter a global carbon market?

At the national level, there are debates and initiatives that can contribute to the implementation of a carbon pricing mechanism in Brazil. In addition to the experience with Renovabio, domestic decarbonization credits transaction (Cbios), the Partnership for Market Readiness (PMR) Project assessed the possibility of implementing pricing among the instruments for implementing the National Policy on Climate Change in the post-2020. PMR indicated the Emissions Trading System (SCE in Portuguese acronym) as the most appropriate instrument for the country, and suggested guiding principles for its implementation. Additionally, the topic has also been discussed within the scope of Law no. 14,120/2021, on the consideration of environmental benefits in the electricity sector, and the Bill (PL) no. 2,148/2015, on the creation of the Brazilian Emission Reduction Market (MBRE in Portuguese acronym).

Learn more about the work related to Carbon Pricing developed by EPE by accessing the contents of the cycle of

Box 10 - 5: Carbon pricing

debates on the effects of Law no. 14.120/2021 "Considering Environmental Benefits in the Electricity Sector - Is It Time for a Carbon Market?" (EPE, 2021c); and the Technical Note "Carbon Pricing: Risks and Opportunities for Brazil" (EPE, 2020).

Brazil has enormous potential and a series of competitive advantages in this segment. In addition, such solutions are versatile as they simultaneously contribute to GHG mitigation and adaptation to climate change. However, there are still obstacles to enabling mechanisms of this type.

Regarding the mitigation of international emissions from transport, there are also advances in the definition of GHG reduction measures. The International Maritime Organization (IMO) developed its initial strategy with a commitment to reduce emissions from international shipping by up to 50% in 2050 compared to 2008, and recently adopted mandatory energy efficiency measures (IMO, 2021). The International Civil Aviation Organization (ICAO) created the CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) program, based on the carbon credits market, with the objective of achieving neutrality in the growth of emissions from the international aviation sector (ICAO, 2021). In Brazil, the National Civil Aviation Agency (ANAC in Portuguese acronym) is the body responsible for the implementing and supervising CORSIA (ANAC, 2021).

Initiatives by companies to reduce or offset their GHG emissions, such as setting emission reduction targets, increasing efficiency, purchasing carbon credits in the voluntary market, and investing in forest conservation are also worth mentioning. The adoption of sustainable measures and practices related to climate change has been incorporated based on the consideration of environmental, social and governance (ESG) criteria in investments, associations with initiatives that aim at low carbon goals, among others.

It should be noted that some initiatives and campaigns have proved to be relevant to mobilize and promote the collaboration of companies and governments in the fight against climate change, such as: Oil and Gas Climate Initiative (OGCI); UN Global Compact – Business Ambition for 1.5ºC; We Mean Business Coalition; Science-based targets; Task Force on Climate-related Financial Disclosures (TCFD); Carbon Disclosure Project (CDP), among others. OCGI, for example, whose 12 members include companies such as Petrobras, Shell, TotalEnergies, among others operating in Brazil, announced the ambition to achieve the neutrality of operations under its control within a period compatible with the Paris Agreement (Petrobras, 2021 and OGCI, 2021).

As part of the United Nations High-Level Dialogue on Energy, Brazil was chosen as one of the leaders on the topic of the Energy Transition and presented two voluntary commitments in June 2021, called energy compacts, related to hydrogen, and Renovabio with the aim of accelerating the achievement of Sustainable Development Goal 7 (SDG 7) and its targets, (MME, 2021c). The hydrogen energy pact aims to strengthen research, development, and innovation, promote qualification and training of personnel and create a platform to collect, organize and disseminate information on hydrogen in Brazil. Renovabio's energy pact, on the other hand, aims to reduce the carbon intensity in the Brazilian transport matrix by 10% by 2030.

Initiatives and actions related to the challenges of adaptation to climate change are also being discussed and implemented in different spheres. Within the scope of the PNE 2050 studies, some simulations were included considering a reduction in hydroelectric generation, based on estimates from climate models, aiming at the security of the energy system. Together with this, **Box 10.4** brings a set of these actions aimed at improving energy planning. In a more plural and integrated scope, the National Plan for Adaptation to Climate Change is being reassessed with the aim of pointing out guidelines for its second cycle (2021-2025), including issues related to energy. In view of what has been commented, it is noted that there are important challenges to be addressed. At the same time, the energy sector has been striving to understand the scenario and develop mitigation and adaptation solutions. Eventually, some of these solutions can become interesting opportunities.

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▪ *Based on the expansion foreseen in PDE 2031, seven socio-environmental themes that seek to synthesize the most significant interferences of the planned set were pointed out: Biodiversity, Territorial Organization, Landscape, Indigenous Peoples and Lands, Air Quality, Water Resources and Residual Waste.* ▪ *For the Northeast region, the cumulative and synergistic effects of the combination of interference from wind, photovoltaic and transmission lines on the Biodiversity theme stand out. For Southeast, the Water Resource theme stands out, due to the large concentration of existing enterprises and conflicts, especially over the use of water.* In the South, the Biodiversity theme was also highlighted, because *of projects on native remnants and the fragmentation of rivers. In the North, sensitivity is due to the presence of Indigenous populations and lands, and the theme Indigenous peoples and lands stood out. In the Midwest, the Biodiversity theme once again stands out as a reflection of the fragmentation of rivers due to the large concentration of existing and planned hydroelectric plants.* ▪ *Given the pointed-out socio-environmental themes and the challenges posed to each energy source, three strategic socio-environmental challenges were identified for the expansion of PDE 2031: compatibility of energy generation and transmission with the conservation of biodiversity; making energy generation compatible with water use; and management of GHG emissions associated with production and use of energy.* ▪ *Regarding the "Compatibility of energy generation and transmission with biodiversity conservation" challenge, it is important to continue initiatives, articulations, and efforts between the energy and environment sectors in the search for joint solutions.* ▪ *As for the "Compatibility of energy generation with other uses of water" challenge, the scenario of water scarcity and the low levels of hydroelectric reservoirs that marked the year 2021 stands out. The management of multiple uses of water, especially in regions where there are conflicts over the use of this resource, and the development of water management tools and technologies that reduce its consumption remain important issues for the development of planned energy expansion.* ▪ *Regarding "Management of GHG emissions associated to energy production and use" it is indisputable that the sector must continue to contribute to the minimization of climate change, through investments and implementation of measures that reduce and offset emissions. The trend is to direct more and more efforts to the development of new decarbonization solutions and technologies, considering the desired energy transition process.* ▪ *Additionally, the following strategic socio-environmental opportunities were acknowledged: use of waste and residues for energy, resources, and infrastructure optimization, and sustainability mechanisms for energy projects.* ▪ *"Use of waste and residues for energy" is a chance to produce energy and improve waste and residues management based on sustainable business models and improving social, environmental, and economic*

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aspects for Brazilian society.

- *"Resources and infrastructure optimization" contributes to a better use of the energy resource and to the minimization of socio-environmental impacts, especially when the construction of new projects is avoided.*
- *"Sustainability mechanisms for energy projects" opportunity boosts the sector need to continue to identify mechanisms that promote sustainability while generating energy benefits and adding socio-environmental and economic value to projects.*
- *Climate policies and discussions are crucial for energy planning. Thus, PDE was established as the Sectorial Plan for Mitigation and Adaptation to Climate Change, becoming an instrument of the National Policy on Climate Change*
- *GHG emissions per unit of energy consumed in Brazil are small compared to other countries. However, per capita energy consumption is expected to increase considerably until 2031, so emissions from the sector will increase too.*
- *During COP26, in Glasgow, Brazil announced an update to its NDC target, proposing to reduce its emissions by 37% in 2025 and by 43% in 2030, based on 2005 emissions. The NDC text maintained the option of not allocating formal goals among the different sectors, so that the country can achieve the goals through different alternative paths. At the time, Brazilian government also agreed to the Global Methane Pledge, among others.*
- *Considering Brazilian potential of electricity and fuels production from renewable sources, the sector's main strategy for mitigating GHG emissions is precisely to maintain a high share of these sources in the matrix.*
- *The total emissions over the ten-year timeframe is increasing, reflecting the outlook of economic growth in Brazil. Major players responsible for GHG emissions in energy production and consumption are the transport and industry sectors that, along the timeframe, will continue to be responsible for energy sector emissions, adding up to 65% in 2031. The most representative fuels in terms of GHG emissions at the end of the timeframe are diesel oil (41%), natural gas (20%) and gasoline (12%).*
- *The actions incorporated in this Plan, such as the expansion of renewable sources for the generation of electricity, the growth in the use of biofuels, the increase in energy efficiency measures, the expansion of the transmission network, among others, will allow Brazil to maintain the indicators performance of its energy matrix among the countries that emit the least GHG in energy production and consumption.*
- *The scenario of energy supply and consumption expansion in the ten-year timeframe is in line with the trajectory presented in the Brazilian NDC. Thus, it can be said that the PDE scenario is in line with the PNMC and with the international commitments taken on by Brazil in the Paris Agreement.*
- *In this issue of the PDE, we tried to place greater emphasis on adapting to climate change. Discussions on the subject have expanded and should be an important agenda in the coming years. While renewable energy sources are a solution to mitigating GHG emissions, they are also more vulnerable to climate change. In this cycle, special attention was given to uncertainties regarding future water availability and impacts on hydroelectric generation from existing and planned plants.*
- *Finally, regarding emissions and climate change, the sector is challenged to seek innovative solutions and technologies in view of the country's particularities and the cost-effectiveness of the possible paths. In this context, challenges, initiatives and possible opportunities were presented, with emphasis on carbon pricing*

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and other financial mechanisms, carbon capture and storage technologies and restoration of natural environments to offset difficult-to-offset emissions.