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TEN-YEAR ENERGY EXPANSION PLAN

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Introduction

The Ten-Year Energy Expansion Plan (PDE in the Portuguese acronym) is a study prepared annually by EPE under the guidelines and support of teams from the Ministry of Mines and Energy, coordinated by the Secretariats of Planning and Energy Development (SPE/MME in the Portuguese acronym) and of Oil, Natural Gas and Biofuels (SPG/MME in the Portuguese acronym).

Its primary objective is to point out, and not exactly to determine, the outlooks for the expansion of the energy sector in the timeframe of ten years, from the perspective of the government, with an integrated vision for the different energy sources available. Such an outlook makes it possible to extract important elements for the planning of the energy sector, with benefits in terms of reliability and optimization of production costs and environmental impacts.

For this, the PDE is built based on the most important aspects associated with energy planning, namely: economic, strategic and socio environmental. In the economic aspect, PDE aims to present energy needs from the perspective of planning to meet the expected growth of the domestic economy. In the strategic aspect, PDE studies highlight the best use of domestic energy resources, within a medium- and long-term vision and encouraging regional integration. Finally, in the socio-environmental aspect, the expansion of energy supply must be done with access to the entire Brazilian population and considering socio environmental aspects.

It is important to reiterate that PDE should not be read as a static plan that determines what will happen in the next 10 years, precisely because of the uncertainty involved in any vision for the future, especially at the current time, when the impacts resulting from the COVID-19 pandemic are still a challenge. Thus, some issues of interest related to uncertainty about key variables are considered both through scenarios and sensitivity analyses, which we refer to as what-if alternatives.

By showing, through scenarios and sensitivity analyses, how the planning envisages the development of the Brazilian energy system under different conditions of its progress, PDE provides important signals to guide the actions and decisions of the players in order to reconcile the forecasts of economic growth of the country and the necessary expansion of supply, in order to guarantee to society the reliability of energy supply at adequate costs, on a technically and environmentally sustainable basis.

So, we rely on an always frank and direct dialogue with society, through their comments, criticisms and suggestions, especially in the Public Inquiry phase, and during the drafting of the plan, with the publication of the so-called "PDE Study Brochures". Therefore, over the last few years, PDE has consolidated itself as the main reference for the energy sector in the medium and long term. It is a source of data and information for decision-making in investments in various sectors, as well as, for academic research and development for society in general, exercising its role as a technical study that points out the paths for national energy development. Thus, its importance as a planning instrument for the national energy sector will be boosted, contributing to the design of Brazil's development strategies to be drawn up by the federal government.

The preparation of PDE 2031 started in the first quarter of 2021, and it was completed in January 2022. In addition to seeking to explore the uncertainties of the economic recovery as a result of COVID-19 pandemic, as well as its impact on planning, the plan also reflects lessons learned from the recent period of water scarcity, as well as greater emphasis on issues related to the energy transition process. Data from charts and tables, figures, explanatory texts, and methodological notes are available on the PDE 2031 page, on EPE website (www.epe.gov.br).

FOCUS OF THE STUDIES

A more significant recovery for the world economy is expected in the short term, reaching more moderate rates in the medium term. Expectation is that there will be an average growth of 3.3% p.y. on the ten-year timeframe. Among the assumptions adopted for the world scenario, there is a greater participation of developing countries in worldwide growth, to the detriment of developed economies, which should display more modest rates. In addition, it is worth mentioning the change in China's development model, leading to a slowdown in its growth, which could impact its main trading partners and world trade. It is important to emphasize that there are important risks for the international scenario, such as the evolution of the COVID-19 pandemic with the emergence of new variants and the possible need to adopt restrictive measures and those related to geopolitical issues.

As far as the Brazilian economy is concerned, it should show a dynamic recovery in the coming years, reaching an average annual growth of the Gross Domestic Product (GDP) of 2.9% in the ten-year timeframe, with similar rates in the macrosectors: agriculture (2.8% p.y.), industry (3.1% p.y.) and services (3% p.y.). In the medium term, an environment of greater stability is expected; this will allow an expansion of investments, above all in infrastructure, and the carrying out of reforms, even if partial, that will foster productivity and competitiveness gains, vital for medium- and long-term growth.

Thus, in a scenario in which economic growth occurs at a faster rate or where the resumption of some industrial sectors happens more sharply, energy demand may respond in a very diverse way. Initiatives within the federal government, such as “Novo Mercado de Gás” (New Gas Market), “Abastece Brasil” (Supplying Brazil) and “Renovabio” have the potential to promote the development of energy markets, changing supply requirements and estimated energy demand. In particular, the progress of demand for natural gas will be strongly conditioned by the competitiveness of this source against other substitute energy sources and the volume of supply available at competitive prices by the consumption sectors.

Energy consumption shows a trend towards electrification over the ten-year timeframe. Total electricity consumption is expected to grow above the pace of economic expansion, resulting in an income elasticity of 1.20, under the influence of both grid consumption and self-production and Micro and Mini Distributed Generation (MMDG).

In the benchmark scenario, the energy load on the National Interconnected System (SIN in the Portuguese acronym) is expected to grow at an average rate of 3.4% p.y. between 2021 and 2031. However, considering the great uncertainty for the ten-year period, two alternative scenarios were developed for the generation requirements, whose difference in the final year of the timeframe under study is 14.4 average GW (14%) between the upper and lower scenarios.

The Electric Energy Generation chapter presents studies for the expansion of the generating complex and the main interconnections between the subsystems in the ten-year timeframe, aiming to guarantee and optimize the adequate supply for the growth of the electric energy demand of the interconnected system in Brazil.

The expansion studies of centralized generation were carried out in the period when the Brazilian electrical system was facing the biggest water crisis in its history. So, one of the main objectives pursued was the incorporation of lessons learned, which point to structural planning solutions, and which are placed for broad debate with society by means of this report. Initially, it is important to highlight the diversification of the matrix based on investments in renewable sources in addition to hydroelectric plants, such as wind, biomass and photovoltaic, complemented by the expansion of dispatchable generation, such as natural gas thermoelectric plants. The water source, which at the beginning of the century accounted for 83% of installed capacity, should reduce its relative

share to 46% by the end of the timeframe (also considering the growth of distributed generation).

On the other hand, as the configuration of the generating park changes, new challenges arise to guarantee future supply. Among the lessons learned in the 2020/2021 two-year period, the situation of water scarcity showed how the different uses of water impact the management of reservoirs and brought to light that the way in which the operational restrictions of Hydroelectric Power Plants (UHE in the Portuguese acronym) are represented in the energy models can be perfected. In this sense, PDE 2031 proposes a new approach to the use of existing restrictions in the Newave model that can bring greater realism and predictability on the energy expenditure that occurs in the UHEs. This advance is a prompt response that PDE 2031 brings, in search of greater predictability for the sector and anticipation of its indications.

The generation chapter already includes the new supply criteria, thus considering explicit criteria for power supply and updating the energy supply criteria, in accordance with the new system situation. Based on these criteria, PDE 2031 presents an assessment of the SIN requirements, before addressing expansion scenarios. The use of the new approach for the representation of operational constraints in the models was reflected in the system requirements, both in the energy and power aspects.

The PDE 2031 report includes the expansion scenarios called "Free Round", which considers only the decisions of the mathematical model based on its input data, and the Reference Expansion, which incorporates energy policy guidelines, among them the provisions in Law no. 14,182/2021. The indicative expansion resulting from the Free Round maintained the trend that has been pointed out in previous cycles, with a predominance of renewable wind and solar photovoltaic sources to supply energy, complemented by thermoelectric plants without compulsory generation for the supply of power. In the Reference Expansion, part of this offer is replaced by thermoelectric plants with compulsory generation.

The two expansions presented meet the supply criteria, even considering more severe situations as a result of the new constraint modeling adopted.

Methodological advances in the construction process for expansion of the SIN generating complex in the ten-year timeframe are maintained in the PDE 2031, such as the use of the computational investment decision model (MDI in the Portuguese acronym), developed by EPE. As candidate technologies for the benchmark scenario, urban solid waste (USW), floating photovoltaic plants, demand response and the expansion and modernization of the existing hydroelectric complex were also taken into account.

Due to the great effort spent to incorporate the aforementioned advances, PDE 2031 will bring the what-ifs of the generation chapter in a future publication.

In the Electric Energy Transmission chapter, important issues are addressed that are currently under discussion in the electricity sector and that permeate the recommendations of network expansions that make up this PDE.

From this perspective, the various strategies that have been considered in the transmission expansion studies are described in order to enable the integration and flow of generation from the various energy sources, including wind and photovoltaic, which have been playing an increasingly important role in the Spot Market – ACL (Portuguese acronym).

Furthermore, it seeks to characterize the evolution of the transmission capacity of regional electrical interconnections within the ten-year period, recognizing the relevance of these facilities for the optimal use of SIN resources.

At the end of the chapter, important economic indications for the transmission sector are presented, including estimates of the

investments in transmission lines and substations in the coming years.

The Oil and Gas Production chapter presents forecasts for oil and natural gas production, highlighting the contribution of pre-salt on the timeframe and the sensitivity analysis performed for the increase in net natural gas production.

The chapter also presents the evolution of proved reserves, the R/P ratio (ratio between proved reserve and production), investments and the oil surplus in the next ten years, the forecast of investments in the sector and the demands for oil platforms of the Stationary Production Unit (UEP in the Portuguese acronym) type.

The process of preparing the oil and natural gas production forecasts of this PDE was based on July 31, 2021, the latest date when information on reserve, field production forecast, assessment area data and data from the Exploration and Production Database of the National Agency for Petroleum, Natural Gas and Biofuels (ANP) were included, among other information on exploratory grants.

Oil and natural gas production forecasts are prepared for Production Units (PU) with discovered resources, that is, resources with declared commerciality or under exploratory evaluation, and for PU with undiscovered resources, based on the geological knowledge of Brazilian sedimentary basins, both in areas already contracted with companies and in areas of the Federal Territory without a contract.

In the case of production of resources in the reserve category, the first years of the plan are baselined by information from the Annual Production Plan, which are production forecasts for five years, sent by the Concessionaires to ANP annually.

In the second half of the decade, production from reserves is strongly influenced by the excess volumes estimated for Assignment for Consideration grants. In the PDE 2031, surpluses from Assignments for Consideration correspond to the average volumes of the interval disclosed for these concessions, which were incorporated into the reserves, providing an increase in production flow.

Finally, reserve production forecast is also based on the indications of the operating companies on the entry of production modules and other information made available in their plans presented to the market.

Forecast for the production of resources in the category of contingents takes into account that such units, despite having confirmed oil potential, are still under assessment and do not have a commercial feasibility statement. A premise adopted for all units in this category is the application of a reducing factor related to the commerciality risk in each of the contingent resources, as they still have to obtain their commercial feasibility statement.

The production forecasts of undiscovered resources, both in areas already contracted with companies, and in areas of the Federal Territory without a contract, are based on assumptions related to discovery estimates, commercial feasibility statement and production start.

Discovery dates for contracted undiscovered resources are defined as midway through the expected exploratory period, generally based on grant contracts signed in the tenders. Thus, these resources' commercial feasibility statements are estimated in the remaining half of the exploratory period, that is, between the discovery date and the expiry of the exploratory period. The date for the production start of undiscovered resources is estimated according to the type of expected fluid (oil or non-associated gas), with the estimated final recoverable volume for the PU, in addition to the E&P environment in which it is located. Based on these parameters, a date to start production is estimated.

In the case of undiscovered resources without contracts, in the Federal Territory area, it is also expected that areas with extreme environmental complexity pointed out by licensing

and regulatory bodies, will have their corresponding volumes excluded from production forecasts.

In the chapter on Supply of Petroleum Derivatives, the conditions of service to the oil product domestic market in the next decade are analyzed. The development of international prices for oil and its products, the development of oil product supply in Brazil, the possibilities of importing and exporting oil products, and the planned investments in refining and associated logistics are assessed.

The chapter highlights that the high movement of volumes of oil and oil products may require greater care regarding operation of the country's logistics infrastructure, with a view to guaranteeing supply throughout Brazilian territory.

Based on government initiatives, development of a new framework for the domestic fuel market is expected, with an emphasis on encouraging the entry of new economic players, free competition and attracting investments in the sector, in an objective and transparent regulatory environment.

The country should consolidate its status as an oil exporter, remaining a net importer of the main derivatives throughout the study's timeframe, with emphasis on imports of naphtha, jet kerosene (QAV in the Portuguese acronym) and diesel oil.

Levels of imports of diesel oil and QAV should get above historical maximums and, in relation to the production of fuel oil, despite the downward trend in exported volumes over the ten-year timeframe, it is estimated that there will be surpluses throughout the entire period.

As for gasoline and liquefied petroleum gas (LPG) imports, the trend is for a decrease over the decade. At the end of the timeframe, Brazil will be able to reach self-sufficiency for these oil products. The influence of the lower growth in domestic demand and the increase in supply from natural gas processing units (UPGNs in the Portuguese acronym) with the processing of national natural gas stand out.

The projected import of considerable volumes of oil products may require investments in expanding refining capacity and/or in expanding and improving the operational efficiency of the country's logistics infrastructure.

Federal Government initiatives also seek to identify and encourage the expansion of port areas for the conveyance of fuel and to promote cabotage in the country. Investments in logistics infrastructure for oil products will be important in order to guarantee the supply of fuel throughout national territory.

In the Natural Gas chapter, the results of studies on the evolution of the demand and supply balance of natural gas and its structure in the period from 2021 to 2031 are presented. Initially, is discussed the existing infrastructure and those under construction. Next, the natural gas price projection section presents the most likely range of domestic prices, as well as bearish and bullish price projections. The chapter also provides an outlook on demand for natural gas (composed of thermoelectric and non-thermoelectric demand), the supply of natural gas (composed of domestic supply and imports), the balance between demand and supply of natural gas in the grid, and thermofluid-hydraulic simulation for the integrated network of transport gas pipelines. Finally, estimates of the investments forecast in the decade under study for projects to expand natural gas import, flow, processing and transport infrastructure in Brazil are presented.

As main highlights for the natural gas market, the enactment of Law 14,134 (New Gas Law) of April 8, 2021, followed by Decree 10,712 of June 2, 2021, should be highlighted. It is noteworthy that this PDE issue already incorporates the future developments of these new regulations.

Regarding existing and future infrastructure, approximately 94 km of new transport gas pipelines, a new pre-salt gas flow route (Route 3) and another new UPGN (UPGN Polo Gaslub) are expected to come into operation in the short term. In this chapter, an even more significant expansion

is considered when we take into account EPE studies related to indicative projects of transport gas pipelines, flow, liquefied natural gas (LNG) terminals and UPGNs.

For natural gas prices, it is noteworthy that the greater diversity of players and greater liquidity brought by the New Gas Market can make the Brazilian market migrate to a gas-gas pricing logic, benefiting it thanks to access to gas at competitive prices on the world market. Thus, it is expected that Henry Hub will have greater influence on domestic prices in the short term, enabling new contract models considering the indexation to this international price benchmark.

As for the natural gas balance, forecasts for the period from 2021 to 2031 in the integrated grid consider a smooth growth in non-thermoelectric demand of approximately 2% per year. On the other hand, thermoelectric demand shows more expressive growth, mainly from the second half of the period on, resulting in average growth rates of 6% per year. On the other hand, the potential supply of natural gas is higher than the demand over the entire timeframe, growing about 3% per year.

Finally, the analysis of the Brazilian natural gas transport infrastructure for the years 2022, 2027 and 2031 revealed that forecast natural gas demands would not be restricted due to logistical issues, since the 3 analyzed subsystems do not present restrictions. It is noteworthy, however, that additional constraints such as high production volumes in the Sergipe-Alagoas basin, as well as increased demand in Gasbol southern stretch, may result in the need to expand existing infrastructure.

The Biofuels Supply chapter presents the prospects for ethanol supply expansion to meet domestic demand and the share of the international market supplied by Brazil, as well as forecasts for sugarcane biomass for electrical energy generation, biogas and the supply of biodiesel, biojet fuel and the prospects for alternative fuels for maritime use and for the installation of biorefineries, on the PDE timeframe.

The estimates consider the positive signs arising from the establishment of the National Biofuels Policy (RenovaBio) (BRASIL, 2017a). This important public policy aims to acknowledge the strategic role of biofuels in the Brazilian energy matrix, focusing on the security of fuel supply and the mitigation of greenhouse gas (GHG) emissions. The developments of the Future Fuel Program (CNPE, 2021) and the results of the Working Group analysis on the insertion of biofuels for use in the Diesel cycle (CNPE, 2020) are also covered.

It should be noted that the forecasts for biofuels supply prepared in this study cycle encompass the developments resulting from the COVID-19 pandemic, whose impacts on the biofuels sector should be noticed more intensively in the short term.

It is expected that there will be an expansion in ethanol supply in the next decade, aiming to attend both the Brazilian and international markets. In the domestic market, the increase in ethanol demand is justified by the greater competitiveness of hydrous ethanol against gasoline, in part due to the positive signs coming from RenovaBio. In the international market, a marginal growth in Brazilian exports is estimated, mainly due to the maintenance of forecasting trends in the markets and the adoption of more efficient technologies.

In the ten-year timeframe, it is expected that the efforts directed by the sugar-energy sector with a view to improving production factors, added to the positive signs coming from public policies, will unfold in an increase in the competitiveness of ethanol against gasoline. In the industrial area, three factors should provide growth in the supply of ethanol: occupation of idle milling capacity and expansion of existing units, in addition to new production units, especially from corn ethanol. In this context, forecasts aimed at facilitating and reducing ethanol transport and storage costs are envisaged.

To anticipate possible threats to fuel national supply for light vehicles, a sensitivity analysis was carried out for ethanol supply, considering a less

favorable scenario for the sugar-energy sector. In this case, the indication that RenovaBio would not achieve full success in its objectives remained. As a result, hydrous would not gain competitiveness against C gasoline and the economic attractiveness of the sugar-energy sector would not be enough to induce relevant investments.

Sugar-energy industry residues stands out as a source of energy for the production process and for surplus electricity for trading. This study presents the assessment of the amount of energy already contracted by the electric sector, the analysis of its technical potential and bioelectricity supply forecast, based on the historical behavior of the generation from bagasse. It is evident that there is a significant amount to be exploited, pointing to a growing insertion of bioelectricity in the domestic electricity matrix. In addition, the study contemplates the energy use of sugarcane biomass to produce biogas/biomethane, biojet fuel and alternative fuels for maritime use. The greatest potential for biogas production is found in the use of residues from the sugar-energy sector, through the biodigestion of vinasse and filter cake. It can be consumed directly or purified to biomethane, with characteristics and applications similar to those of natural gas. For the timeframe of this study, its participation in the national matrix is envisaged to increase.

Prospections that contemplate the participation of biodiesel for the next 10 years consider compliance with the mandatory mixture, for which it will be necessary to produce increasing volumes of this biofuel. The percentages of blending with fossil diesel will vary until 2023 following the legislation in force, as established by the CNPE. To meet this demand, the availability of inputs was analyzed, as well as processing and production capacity. The green diesel regulation can bring opportunities for the insertion of paraffin hydrocarbons from renewable biomass in Diesel cycle.

PDE 2031 also includes the prospects for biojet fuel, which is presented as one of the alternatives for meeting international agreements to reduce GHG emissions by the aviation sector. Given the economic challenges for its insertion in the Brazilian matrix, a modest entry of biojet fuel is expected, at the end of the ten-year timeframe. The adoption of alternative fuels for maritime use in the medium and long term is estimated to be able to contribute to meeting the IMO (International Maritime Organization) pollutant emission targets.

In the Energy Efficiency and Distributed Energy Resources (RED) chapter, the results of conserved energy are presented. This indicator is obtained by the difference between consumption if the technological standards observed in the base year (2021) were maintained, and the final energy consumption forecast, considering energy efficiency gains. In this PDE, it is estimated that total energy conservation and RED will reach 9% in 2031, while electric energy conservation and RED will reach 21% in 2031. Regarding electrical efficiency, buildings (which include the service and residential sectors) are expected to contribute around 60% of total gains, while the industrial sector is expected to be responsible for more than 30% of these gains in 2031.

It is important to emphasize that REDs are important ways of meeting potential demand, strengthening themselves as relevant resources for medium and long-term energy planning for the energy sector in Brazil and the world.

As far as MMGD is concerned, installations in 2021 reached a record number. Almost 400 thousand new distributed generation systems were added, totaling 3.8 GW in the year. In early 2022, Law no. 14,300, that established the MMGD legal framework was enacted, bringing, among other issues, greater predictability on the incentive rules for this type of generation.

The new legal framework was considered in the PDE 2031 forecasts. Thus, strong interest in MMGD installations over the next decade is expected to continue. In the Benchmark scenario, PDE indicates an accumulated installed capacity in 2031 equal to 37 GW, distributed in just over four

million generation units. This capacity should contribute approximately 7% of the domestic load.

As in the previous plan, an analysis of the competitiveness of batteries behind the meter was carried out and showed that the cost of this equipment is still high in Brazil, making it difficult for them to enter the ten-year period. However, a drop in costs beyond what was foreseen could change the forecasts for this technology. And there may be insertion of this technology due to other non-economic factors, mainly for the replacement of diesel generation in stores.

The Socio-environmental Analysis chapter presents the analyzes that support the expansion definition of this PDE and the integrated analysis where the major socio-environmental issues of that expansion are discussed. Additionally, strategic socio-environmental challenges and opportunities were identified. The Energy and Climate Change section discusses climate agreements and policies, the profile of GHG emissions in the decade, adaptation to climate change, as well as challenges, initiatives and opportunities in the energy sector related to climate change.

The environmental variable contributed to the expansion presented in this PDE through a procedural assessment of hydroelectric plants, which estimates the year of entry into operation of the hydroelectric plants for the generation expansion model, and an analysis of the socio-environmental complexity of the oil and natural gas production units, in order to adjust production forecasts according to concerns reflected by environmental agencies. The procedural evaluation indicated eight UHEs with the possibility operating in the ten-year timeframe. The complexity analysis, on the other hand, indicated a discount of 8% and 9% of the expected volume of Federal Production Units (UPUs in the Portuguese acronym) for natural gas and oil, respectively, in addition to the application of an additional term for the environmental licensing of six Production Units (UPs in the Portuguese acronym).

In view of the expansion foreseen in PDE 2031, the integrated socio-environmental analysis indicated seven socio-environmental themes that seek to synthesize the most significant interferences of the planned set. From there, 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 the production and use of energy. For the three challenges, it is important that for the energy sector to seek innovative solutions, initiatives, and technologies to deal with these issues. Water scarcity and the 2021 hydro crisis were highlighted, and how the sector is dealing with the problem.

Additionally, the following were recognized as strategic socio-environmental opportunities: “energy use of waste”, as it is a chance to replace non-renewable fuels, contribute to the reduction of emissions and increase the efficiency of production processes; “optimization of resources and infrastructure” that contributes to a better use of energy resources and minimization of socio-environmental impacts; and “sustainability mechanisms for energy projects” that reinforce the sector's need to identify mechanisms that promote sustainability, generating energy benefits and adding socio-environmental and economic value to projects.

About greenhouse gas emissions and discussions on climate change, PDE itself is consolidated as an instrument of the Brazilian National Policy on Climate Change, since it is the Sector Plan for Mitigation and Adaptation to Climate Change.

In 2021, Brazil announced an update to its Nationally Determined Contribution (NDC) target, proposing to reduce its emissions by 37% in 2025 and by 50% 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.

Thus, it is noteworthy that the scenario of energy supply and consumption expansion in the ten-year timeframe is in line with the trajectory presented in the Brazilian NDC. This allows us to state that the PDE scenario is in line with the National Policy on Climate Change (PNMC in the Portuguese acronym) and with the international commitments taken on by Brazil in the Paris Agreement.

GHG emissions per unit of energy consumed in Brazil are small compared to other countries. However, as per capita energy consumption is expected to increase considerably until 2031, emissions from the sector will increase. As expected, the transport and industrial sectors remain over the timeframe as the main drivers of emissions in the energy sector.

Considering Brazilian potential for production of electricity and fuels 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, maintaining Brazil's prominence in the production of energy with low emissions.

As a novelty, the Energy and Climate Change section presents a sub-item dedicated to adaptation to climate change. It includes a discussion of the increasingly necessary actions for the energy sector to adapt to gradual climate change and extreme events. The major platforms, projects and national plans dedicated to the subject are also presented, in addition to ongoing and planned actions. Emphasis was given to the vulnerability of hydroelectricity to water availability.

At the end of the Social and Environmental Analysis chapter, the challenges, initiatives, and opportunities related to addressing emissions and climate change are presented, mentioning topics such as carbon pricing and other financial mechanisms and technologies for capturing and storing carbon.

By prioritizing the expansion of renewable energy sources, the PDE 2031 expansion scenario keeps Brazil on the path of the expected contribution of the energy sector to the Brazilian NDC.

In the final chapter of the plan, the main results of the PDE 2031 studies are consolidated for reference purposes, highlighting the development of the domestic energy supply and energy matrix and the set of forecast results, covering information on economy and energy, final energy consumption, and domestic energy supply.

NOVELTIES IN PDE 2031

In order to continually improve the analysis and bring more and more relevant information for discussion with society on the expansion of the energy sector in Brazil, the following advances incorporated in this PDE 2031 cycle stand out:

1. The Oil and Natural Gas Production chapter introduced two new items. The first dealt with the forecast of production in the onshore environment, with an emphasis on this environment considering the reference curve. The second presented a sensitivity analysis for the increase in onshore and offshore production, including the extension of life and the increase in the recovery factor of divested fields, and the contribution of Permanent Offer to the increase in reserves and production in the decade.

2. In the Socio-environmental Analysis chapter, greater emphasis was placed 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 greenhouse gas 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.

3. The Consolidation of Results chapter presents an approach to the major aspects considered in

the forecasts for the next 10 years within the energy transition context. This transversal vision of planning involves several aspects geared at broad transformations in socioeconomic systems and in their relations to the environment.

As hydrogen offers an alternative for sectors where it is hard to decrease carbon emissions, as well as being an energy vector, it is dealt with in an extraordinary chapter in this PDE 2031. As it can be used both for energy storage and connecting the energy sector to the industry and transport sectors, this resource has been receiving investments, especially in the low carbon hydrogen market. The various recent initiatives linked to the development of the global hydrogen market reflect these opportunities, with Brazil being a potential supplier for the domestic and international market, considering production through different technological routes. Given the magnitude of this potential market in the coming years, as well as its impact on different sectors, the insertion of hydrogen in energy planning becomes fundamental.